JOIFF AND FOAM:

Foam is one of the most important tools used by emergency responders across a range of incidents and is the key tool used to mitigate fire and non-fire incidents involving flammable liquids, expanding vapour clouds, controlling particles of man-made fibres in the event of an aircraft crash etc. Perhaps because of its importance to emergency response in Industry, for many years, Foam has been a very contentious subject, at times polarising the industry.

When the JOIFF Secretariat was appointed in 2001 and began to organise, develop and promote JOIFF, the importance of Foam and the fact that there were strongly held views on the subject was recognised and through the first editions of The Catalyst in 2001 and 2002, JOIFF provided the platform for members of JOIFF who were manufacturers and users of Foam to publically discuss different aspects of Foam. These editions are still available for free download from the Catalyst pages of the JOIFF website.

Continuing its policy of disseminating information on Foam, in 2010, JOIFF published the JOIFF Guideline on Foam which was made available for free download from the JOIFF website. In the years that followed, regulatory requirements and changes in the manufacture and use of foam were introduced which resulted in major changes in the Foam market and JOIFF revised the 2010 Guideline to reflect current Good Industry Practice and in October 2018 the JOIFF Guideline on Foam Concentrate was published and is available for free download from the JOIFF website.

Note from the Editorial Board of The Catalyst:

The word "catalyst" is defined as "a thing that precipitates change" and since its first edition in March 2001, the JOIFF quarterly publication The Catalyst, has worked to precipitate change for the better with regard to emergency response in Industry.

In continuation of this policy, JOIFF is pleased to publish this edition of The Catalyst as a special Foam edition, giving experts the opportunity to offer their opinions on serious current issues relating to Foam. The Editorial Board of The Catalyst hope that the opinions given by the authors of the articles in this edition will inform readers and give them further information to assist them in understanding some of the diverse opinions on this subject.

Neither JOIFF nor the JOIFF Secretariat Fulcrum Consultants endorses any article or opinion expressed, but they wanted to bring to the fore, different sides of the issues. The views and opinions expressed in the articles in this edition of The Catalyst are not necessarily the views of JOIFF or of its Secretariat, Fulcrum Consultants, neither of which are in any way responsible or legally liable for any statements, reports or technical anomalies made by authors in The Catalyst.

ENVIRONMENTAL IMPACT & MANAGEMENT OF FLUOROSURFACTANT-BASED FIREFIGHTING FOAMS

BY IAN ROSS PH.D., JONATHAN MILES PH.D., DANIELLE TOASE PH.D., JASON LAGOWSKI AND PETER STORCH

Fluorosurfactants have been used in firefighting foams since the 1960's, but in the last few years, many users have switched to fluorine free foams (F3) in response to the increased extinguishment performance of the new generation F3 foams and potential environmental liabilities, repuational risk and possible 3rd party litigation associated with use of flurosurfactants.

Fluorsurfactants used in fire fighting foams belong to a large group of several thousand emerging contaminants termed per- & polyfluoroalkyl substances (PFASs) which are increasingly being discovered in drinking water supplies, water bodies and in various species that form part of our food chain.

As a result of PFASs impacts to drinking water supplies, an increasing number of communities face the need to find alternative water supplies as a result of their presence above concentrations deemed safe, which tend to be exceptionally low per per trillion (ppt) (ng/L) levels. This has created rising pubic concern, press attention [*see references* 1-7 *at end of article*] and thus political focus on PFASs.

Protecting human health and safety through effective fire suppression is the foremost priority of every fire fighting foam system. However, a balance between minimising the environmental impact, liabilities and the long term harm caused by use of PFASs in firefighting foams needs to be considered to manage the overall risk of fire protection.

This artilce aims to provide an overview of the accelerating environmental regulations regarding PFASs, a brief smmary of recent foam testing activities and potential solutions to navigate risks associated with legacy and ongong use of PFASs in firefighting foams.

PFASs Risk to Human Health and the Environment

Historically, PFASs were used in firefighting foams designed to extiguish liquid hydrocarbon Class B fires, such as aqueous film fomiing foam (AFFF), film forming fluoroprotein foam (FFP) and fluoroprotein foam (FP) [*ref* 8]. Firefighting actvites represents one of the most environmnentally emissive uses of these chemicals, through both training exercieses and incident reponse.

Regulation of long-chain "C8" PFAS ingredients of these foams, including perfluorooctane sulfonate (PFOS) and perfluorooctanoic acid (PFOA), in drinking water at ppt levels is driving focus on the whole class of PFASs. Shorter chain (C6) replacments for C8 are present in current PFAS-containing foams, and are also being increasingly regulated in many locations..

As environmental regulators globally accelerate their focus on PFASs, the continued use of long-chain PFASs in firefighting foams is perceived as posing a potential business risk to many sectors. If fires are extinguished using these products, there may be substantial consequential costs for environmental management and clean-up, in addition to reputational risks and possible litigation from affected 3rd parties. Many short-chain (C4-C7) PFASs, introduced as replacements for C8, have also captured the attention of some regulators and are also now becoming subject to rapidly evolving regulations, with short-chain PFASs regulated in Sweden, Denmark, Germany, Italy, Belgium, Switzerland, Canada, and 12 U.S. states.

There are many more proprietary PFASs present in firefighting foams than are regulated, such as in C6 fluorotelomer based AFFFs. These polyfluorinated varieties, have evaded detection by common analytical methods but in the environment will all eventualy transform to create the extremley persistet perfluorinated PFASs commonly subject to regulation, so are termed 'precursors'. A limited number of these fluorotelomer precursors are now themselves regulated, such as in Sweden, Germany, Denmark and Switzerland.

Firefighting foams comprise hundreds of individual PFASs which have not been accounted for until recent analytical advances have enabled the polyfluorinated PFASs to be measured indirectly, using a recently adopted technology termed the total oxidizable precursor (TOP) assay [9-11]. Regulators in Australia have recently applied this advanced analytical tool for sampling multiple environmental matrices, with the TOP assay now being used regularly in North America and Europe as a result of it's commercial availability.

None of the thousands of PFASs (C8 and C6 etc.) show any sign of being biodegradable and have been described as "forever chemicals". Whilst an understanding of the toxicity of C8 PFASs evolves, much less is known regarding the toxicity of the C6 fluorotelomer products. There have been reports of the increased toxicity of the bioactive transformation intermediates of fluorotelomers [12, 13]. The long-chain PFASs accumulate in humans through consumption of impacted drinking water. The short chain PFASs are more mobile in the environment than the long-chained variety so have greater potential to be detected in drinking water supplies, whilst the understanding of their toxicology and bioaccumulation potential is being actively researched. There is also some evidence that short-chained PFASs accumulate in the edible portion of crops, making them a potentially larger environenetal threat.

Numerous countries are now regulating an increasing number of PFASs, including precursors in addition to both long and short chain varieties, while the latter are still commonly used as commercial replacements (e.g. C6 in firefighting foams). Restrictions have been imposed on the use of all PFAS containing firefighting foams in South Australia and Washington State, and as of 2019, the European Union is also considering similar regulations.

Large scale remediation of a proprietary C6 fluorotelomer foam spill in Australia in 2017, with regulatory compliance requested measuring PFASs using TOP assay, seems to be an example of the future potential liabiities associated with holding and using C6 foams. Figure 1 shows the first use of an ozofractionation system to comprehnesively treat 15,000 m^3 of PFASs impacted wastewate, as determined using TOP assay.

Figure 1 Ozofractionation used to treat more than 15,000 m^3 of PFAS-impacted wastewater

Foam Evolution

Recent independent tests evaluating the performance of F3 foams by LASTFIRE to extinguish increasingly larger diameter fires have been very successful. In 2017 tests in Europe showed F3 foams performed well for extinguishment of spill fires and small tank fires with various techniques including monitor and pourer application in both compressed air foam (CAF) and conventional application equipment [14]. During 2018 successful demonstrations of extinguishment of 40m and 30m long fires was achieved using multiple application methods at Dallas Fort Worth Airport. The use of CAF processes allowed foam to travel 40m over a deep burning fuel surface to extinguish the fire in less than 3 ½ minutes at an application rate of just half that of the NFPA 11 standard rate used for conventional equipment. It's clear that the new generation of F3 foams and advanced foam distribution systems such as the

CAF process have evolved and can provide fast and effective fire extinguishment with negligible long term environmental consequences, as PFASs are no longer needed for the majority of fire extinguishment scenarios. LASTFIRE has emphasized that it is critical to use a proven combination of foam concentrate, application equipment and foam properties to provide optimum efficiency. Not all combinations are equal and there is still work to be done with different fuels and other fire scenarios.

Foam Transition

Successful foam transition takes a well-developed, site-specific strategy prepared by a qualified team of fire engineers, environmental engineers/ scientists, technology providers, equipment specialists and operations contractors [16]. Some of the consideriations associated with foam transition include:

1. Maintaining compliance with fire protection regulations and insurance accreditation;
2. Implement the transition while maintaining a functional fire suppression system to protect human health and assets.
3. A good understanding of the design basis of the fire protection system and operational knowledge of existing equipment;
4. Compatibility assessment of system components with new foam;
5. Effective decontamination of existing equipment in contact with foam to prevent cross-contamination of new foam;
6. Proper planning for containment and disposal of waste generated during transition;
7. Effective secondary containment, and inspection and maintenance procedures are required.

Residual contamination of historically used PFASs can create future liabilities if appropriate cleanout of equipment is not conducted. Biodegradable, non-toxic solvents have been developed and applied to prevent rebound and effectively extract PFASs from equipment, as shown in Figure 2.

There are ongoing challenges associated with managing PFASs including potential legacy management of C8 contamination of soil, groundwater and concrete surfaces, whilst C6 represent a source of future contamination. There is evidence that some fire training areas can remain a source of C8 PFASs for some 20 years following their last use and that the surface of concrete can continue leaching PFASs for decades.

There are many evolving solutions to manage PFASs releases to the environment, such as concrete surface treatments, soil stabilisation and technologies using ultrasound which can destroy PFASs, via a process termed sonolysis, creating innocuous fluoride [15]. Mobile sonolysis units to destoy PFASs in firefighting foam concentrates are currently being constructed for commercial use, which will significantly reduce the costs of foam disposal.

Conclusions

To conclude, the growing concerns regarding drinking water impacts from C8 PFASs, is driving a dramtically increased regulatory, media and political focus on the whole class of PFASs. At the same time the performance of F3 foams at extinguishing fires has markedly improved. So now the balance between potential harm caused and liabilities associated with continued use of PFAS based foams, given the comparable extinguishment performance of F3 foams, makes evaluation of how to move away from C8 and C6 PFAS based foams a wise commercial decision.

References

1. *Dennis, B. 'Not a problem you can run away from': Communities confront the threat of unregulated chemicals in their drinking water. 2019; Available from: https://www.washingtonpost.com/national/health-science/not-a-problem-you-can-run-away-from-communities-confront-the-threat-of-unregulated-chemicals-in-their-drinking-water/2019/01/01/a9be8f72-dd4b-11e8-b732-3c72cbf131f2_story.html?utm_term=.65f66107b810.*
2. *Rich, N. The Lawyer Who Became DuPont's Worst Nightmare. 2016; Available from: https://www.nytimes.com/2016/01/10/magazine/the-lawyer-who-became-duponts-worst-nightmare.html.*
3. *Walker, T. Six million Americans drinking water* containing unsafe levels of unregulated chemicals, study finds. 2016; Available from: https://www.independent.co.uk/news/world/americas/six-million-americans-drinking-water-pfass-unsafe-unregulated-chemicals-a7181716.html.
4. Allen, J.G. These toxic chemicals are everywhere — even in your body. And they won't ever go away. 2018; Available from: https://www.washingtonpost.com/opinions/these-toxic-chemicals-are-everywhere-and-they-wont-ever-go-away/2018/01/02/82e7e48a-e4ee-11e7-a65d-1ac0fd7f097e_story.html?noredirect=on&utm_term=.b16300a449cd.
5. Knaus, C. Toxic firefighting chemicals 'the most seminal public health challenge'. 2017; Available from: https://www.theguardian.com/australia-news/2017/oct/18/toxic-firefighting-chemicals-the-most-seminal-public-health-challenge.
6. Knaus, C. 'Children are being poisoned': fury at scandal of toxic firefighting chemicals. 2017; Available from: https://www.theguardian.com/australia-news/2017/jul/26/children-are-being-poisoned-fury-at-scandal-of-toxic-firefighting-chemicals.
7. Begley, C.F.a.P. Toxic Secrets: Where the sites with PFAS contamination are near you. 2018; Available from: https://www.smh.com.au/national/nsw/toxic-secrets-where-the-sites-with-pfas-contamination-are-near-you-20180616-p4zlxc.html.
8. Ross, I., Kalve E., McDonough, J., Hurst, J., Miles, J., Pancras, T., Per- and Polyfluoroalkyl Substances, in Emerging Contaminants Handbook, M.G. Caitlin Bell, Erica Kalve, Ian Ross, John Horst, Suthan Suthersan, Editor. 2019, CRC Press: Boca Raton, FL, USA. p. 85-257.
9. Ross, I., Houtz, E., Kalve, E., McDonough, J., Hurst, J. and Miles, JAL., PFASs and the TOP Assay. INDUSTRIAL FIRE JOURNAL, 2018. First Quarter: p. 26.

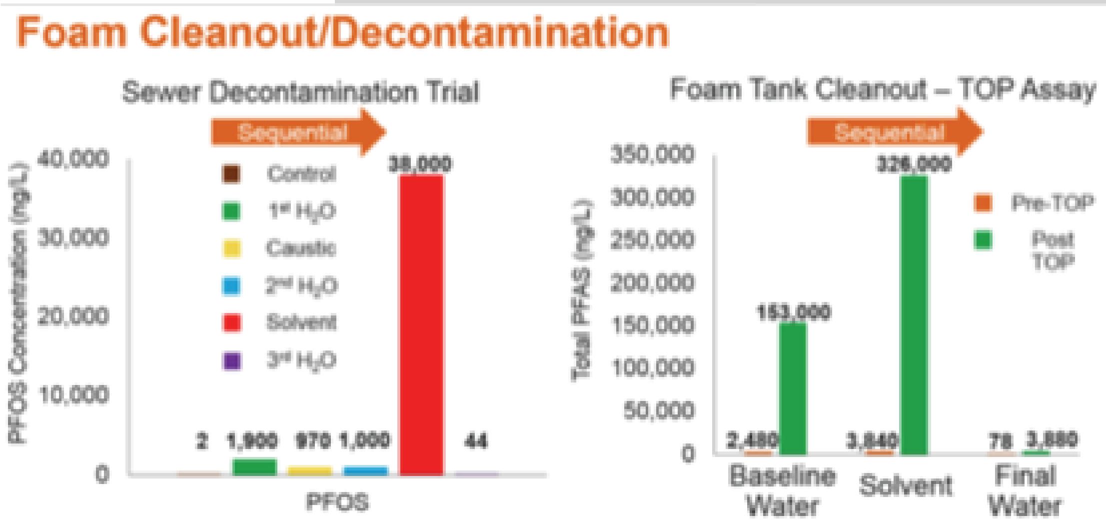

Figure 2 Data from a foam transition decontamination case study in Australia indicating the effectiveness of a biodegradable solvent for PFAS mass removal compared to water or caustic washes.

10. Houtz, E.F., et al., Persistence of perfluoroalkyl acid precursors in AFFF-impacted groundwater and soil. Environ Sci Technol, 2013. 47(15): p. 8187-95.
11. Houtz, E.F. and D.L. Sedlak, Oxidative conversion as a means of detecting precursors to perfluoroalkyl acids in urban runoff. Environ Sci Technol, 2012. 46(17): p. 9342-9.
12. Rand, A.A. and S.A. Mabury, Is there a human health risk associated with indirect exposure to perfluoroalkyl carboxylates (PFCAs)? Toxicology, 2017. 375: p. 28-36.
13. Phillips, M.M., et al., Chronic toxicity of fluorotelomer acids to Daphnia magna and Chironomus dilutus. Environmental Toxicology and Chemistry, 2010. 29(5): p. 1123-1131.
14. Ramsden, N., Foam Testing, in Pertroleum Review. 2018, Energy Institute. p. 32-33.
15. Ross, I., et al., A review of emerging technologies for remediation of PFASs. Remediation Journal, 2018. 28(2): p. 101-126.
16. Ross, I., Burdick, J., . Balancing Fire Safety and Environmental Liabilities: Transitioning Firefighting Foams. 2018; Available from: https://www.arcadis.com/media/5/0/4/%7B50476C6C-90AB-4B7C-A153-16F8B58D7ED3%7DBR_PFAS%20Foam%20Transition%20Perspective_web_ZP20181012.pdf.

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