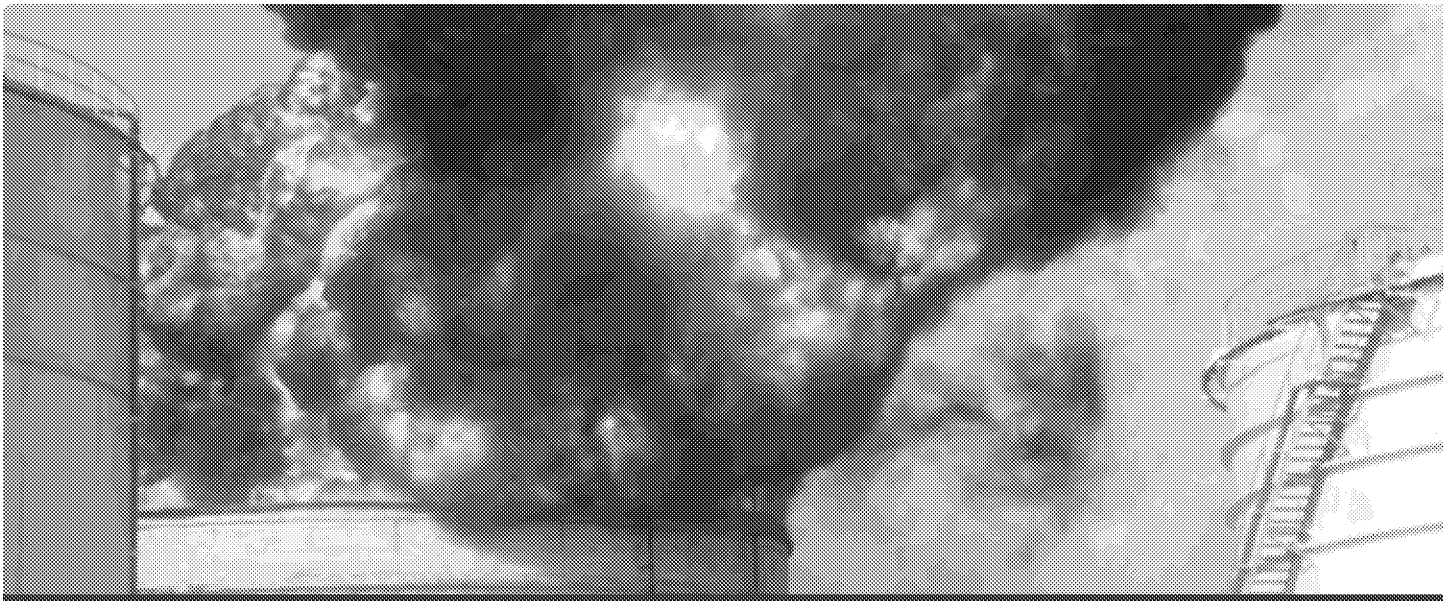

FLUORINE-FREE FIREFIGHTING FOAMS (3F)

VIABLE ALTERNATIVES TO FLUORINATED AQUEOUS FILM-FORMING FOAMS (AFFF)

Independent Expert Panel Convened by IPEN
Stockholm Convention POPRC-14
Rome

September 2018

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FLUORINE-FREE FIREFIGHTING FOAMS (3F) - VIABLE ALTERNATIVES TO FLUORINATED AQUEOUS FILM-FORMING FOAMS (AFFF)

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IPEN is a network of non-governmental organizations working in more than 100 countries to reduce and eliminate the harm to human health and the environment from toxic chemicals.

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INTRODUCTION

IPEN respectfully presents this paper, *Fluorine-Free Firefighting Foams—Viable Alternatives to Fluorinated Aqueous Film-Forming Foams (AFFF)*, prepared by eminent, independent experts for consideration by the Stockholm Convention Persistent Organic Pollutants Review Committee (POPRC), observers, and the public. We believe that it offers a fresh perspective from experts in the field who have direct experience and knowledge concerning the efficacy of fluorine-free firefighting foams as safer substitutes for AFFF. The paper concludes: "*The continued use of PFAS (per- and polyfluorinated substances) foams is not only unnecessary but would continue to add to the legacy and ongoing contamination that is responsible for the substantial, widespread and growing socio-economic and environmental costs being experienced globally.*" We hope that the evidence presented in the paper will contribute toward decisions that will prevent further harm to the global environment and human health caused by the dispersive contamination associated with continued production and use of fluorinated aqueous film-forming foams (AFFF) used in firefighting.

The POPRC has made crucial determinations about PFOA, including the conclusion in the Risk Profile (UNEP/POPS/POPRC.12/11/Add.2) that, "*based on the persistence, bioaccumulation, toxicity in mammals including humans and widespread occurrence in environmental compartments, it is concluded that PFOA, its isomers, salts and related compounds that degrade to PFOA, as a result of their long-range environmental transport, are likely to lead to significant adverse human health and environmental effects such that global action is warranted.*" In assessing the adverse human health effects of PFOA in the Risk Profile (UNEP/POPS/POPRC.12/11/Add.2), the Committee notes that the International Agency for Research on Cancer classifies PFOA as a Class 2B carcinogen with particular regard to testicular and kidney cancers. The Risk Profile also summarizes epidemiological evidence linking PFOA exposure with high cholesterol, inflammatory diseases, ulcerative colitis, thyroid disease, immune effects, pregnancy-induced hypertension, endocrine disruption and impaired neuro- as well as reproductive development. New insights about the adverse health effects of PFAS chemicals at exquisitely low exposure levels, including PFOA and PFHxS, are coming to light in the peer-reviewed scientific literature.

Patrick Breysse, director of the U.S. Centers for Disease Control's National Centre for Environmental Health, described the contamination of drinking water supplies by AFFF as "one of the most seminal public health challenges for the next decades." Millions of people around the world are now drinking water contaminated with PFOA and other per- and polyfluorinated substances that exceed thresholds known to cause harm to human health. In June 2018, the U.S. Agency for Toxic Substances and Disease Registry's Toxicological Profile concluded that health advisory levels for PFOA and other evaluated PFAS far exceed health protective standards based on sensitive health endpoints such as immune effects.

Based on the evidence presented in this paper concerning the availability, effectiveness, and certifications of fluorine-free firefighting foams, we affirm that no exemptions for continued production and use of PFOA and its precursors or PFOS in AFFF should be recommended and no exemption should permit continued use of existing AFFF stockpiles containing PFAS substances. We further caution that replacement of other per-and polyfluorinated substances in

AFFF including short-chain PFAS, would be regrettable substitutions that perpetuate harm to the environment and human health. Precaution is embedded in the Stockholm Convention and protective action is a moral imperative for implementing treaty objectives.

Pamela Miller
IPEN Co-Chair

September 9, 2018

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FLUORINE-FREE FIREFIGHTING FOAMS (3F) VIABLE ALTERNATIVES TO FLUORINATED AQUEOUS FILM-FORMING FOAMS (AFFF)

An Agreed Position Paper by an Expert Panel (the F3 Panel) assembled on behalf of IPEN www.ipen.org for presentation to the Stockholm Convention POPRC-14 meeting in Rome at the UN FAO Headquarters 17-21 September 2018. The Position Paper is structured to include verbatim statements as Appendices from individual Panel Members.

THE F3 PANEL

The panel consists of experts across the fire engineering industry covering firefighting foam end-users from airports, the aviation rescue and firefighting sector (ARFF), the oil, gas and petrochemical industries, including emergency disaster control, F3 foam formulators, trade associations involved in independent product testing and holistic assessment of risk, specialists in environmental chemistry, and national environmental regulatory bodies.

The panel was convened as the result of an initiative by the International POPs Elimination Network (IPEN) (Pamela Miller, co-chair of IPEN), a global network of approximately 500 NGOs worldwide). The panel were tasked to provide expert opinion and an agreed position for presentation to POPRC14 on the viability of non-persistent fluorine-free firefighting foams (F3) as alternatives to persistent fluorinated AFFF and related foams that are having widespread and considerable socio-economic and environmental impacts due to the extremely persistent, toxic, bio-accumulative, fluorochemical (PFAS) content. The expert panel consists of the following members together with their areas of expertise:

Michael ALLCORN	Alert Disaster Control Singapore. Decades of experience dealing with large oil industry fire, storage tanks, oil well-head fires, marine firefighting; using F3 foams operationally for some 15 years.
Dr. Thierry BLUTEAU	Leia Laboratories Ltd. France. PhD organic chemist and foam formulation chemist; formerly Croda Kerr and BioEx France, developer of ECOPOL (F3); currently developing solvent-free F3 foams.
John CORFIELD	Brisbane Airport Corporation Pty Ltd (BNE) Australia; environmental advisor. Extensive experience in the management of PFAS site contamination and remediation.
Martin CORNELSEN	Cornelsen Umwelttechnologie GmbH, Essen, Germany. Water treatment engineer; remediation and clean-up of PFAS contaminated soil and groundwater; developed absorption technology.
Graeme DAY	London Heathrow Airport (LHR): fire service compliance manager; formerly senior fire officer Kent and West Sussex Fire & Rescue Service. Extensive experience in use and effectiveness of firefighting foams.
Supt. Nigel HOLMES	Department of Environment and Science, Queensland Government, Australia; Principal Advisor Incident Management. Extensive experience across environmental and pollution management and regulation. Primary author of the Queensland Environmental Management of Firefighting Foam Operational Policy;
Dr. Roger A. KLEIN	Cambridge UK; panel coordinator; PhD chemist and medical doctor; extensive experience of advising the fire service; formerly Principal Scientific Adviser Cambridgeshire Fire & Rescue Service; affiliated research faculty Christian Regenhard Center for Emergency Response Studies (RACERS), John Jay College of Criminal Justice, City University New York (CUNY), NY USA;

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Gary McDOWALL	3FFF Corby Northants UK. Extensive experience in the foam industry; formerly Croda Kerr; F3 foams for hand-held and portable extinguishers; formerly founding director of IAFPA; currently chairman of the British Fire Consortium;
Kim T. OLSEN	Copenhagen Airports (CPH). Head of fire training academy; formerly fire officer; member of the Danish defence forces;
Dr. Niall RAMSDEN	Coordinator LASTFIRE. PhD physicist, fire engineering consultant; extensive experience of the effectiveness of firefighting foams for large-scale fires;
Dr. Ian ROSS	Arcadis; senior partner global remediation. Extensive experience in the analyses, behaviour, effects and remediation of fluorinated organic chemical contamination.
Ted SCHAEFER	Sydney Australia. Developed re-healing (RF) fluorine-free foam; formerly 3M and Solberg;
Roland WEBER	Germany; POPs Environmental Consulting;
Kevan WHITEHEAD	Fire Chief, Unity Fire & Safety Oman oil and gas fields. Previously serving senior fire officer Greater Manchester Fire & Rescue Service.

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EXECUTIVE SUMMARY

EN

- The operational capabilities of fluorine-free Class B firefighting foams (F3s) suitable for liquid hydrocarbon and polar-solvent fuel fires have continued to advance and expand in use dramatically since their initial development in the early 2000s by Ted Schaefer working for the 3M Company and are now well-established as high-performance firefighting agents.
- Current top-quality Class B fluorine-free firefighting foams are capable of meeting all the standard firefighting performance certifications applicable to AFFF and related foams. An unfortunate exception is US MIL-Spec which, due to a legacy-wording technicality dating from the early 1960s requires the inclusion of fluorochemicals and has not been updated significantly since. In contrast, other national defence forces have not been subject to such inertia and have adopted fluorine-free foams, as have many large and high-risk industries, based on demonstrated operational effectiveness including use on very large incidents such as spills and fires of refineries, bulk fuel storage tanks, oil and gas production, and shipping since 2003 [ECHA submission April 2016].
- Fluorine-free firefighting foams have considerable financial, socio-economic, public health and environmental advantages over persistent fluorochemical-based firefighting foams. They are non-persistent, biodegradable with only short-term, localized and self-remediating effects versus highly persistent PFAS in AFFF which are all toxic and bio-accumulative to varying degrees for the environment and human health, as well as exhibiting extreme long-range transport that has resulted in worldwide contamination.
- PFAS contamination often extends to agricultural land, waterways used for industry, recreation, fishing and aquaculture, as well as surface or groundwater used for drinking water. Treatment to remove PFAS (especially short-chain PFAS) is very difficult and expensive with crops, fisheries, industries, livestock and human health values potentially exposed. Fluorine-free foams do not have this disadvantage.
- PFAS pollution of sites resulting from foam incidents or training results in large, spreading down-gradient contamination plumes which may affect many kilometers off-site. Short chain PFAS (RC6) are more mobile and more difficult to remove from ground- or waste-water than longer chain (>C6) compounds such as PFOS or PFOA.
- Operational releases of fluorine-free foam runoff will degrade naturally in soils, waterways or groundwater. Discharges to sensitive hydrological or aquatic environments like enclosed waterways can cause limited, localise, short-term effects but will largely self-remediate. On the other hand, fluorinated foam releases have caused widespread, long-term pollution; runoff must be contained, collected and treated at significant cost as regulated industrial waste under many jurisdictions.
- PFAS contamination remediation and clean-up, if it is at all possible, is enormously expensive, time consuming with substantial socio-economic impacts such as loss of drinking water supplies, lost agricultural production, damage to river and offshore fisheries, depressed property values, economic and mental hardship for residents affected, as well as serious long-term public health consequences. Coupled with this is loss of public confidence in government, adverse public perception of the dangers to health, reputational damage and loss of brand image for industry, possible prosecution by the regulator, and lengthy, expensive legal class actions seeking compensation from the polluter. All the associated costs and losses will ultimately be felt by the community as a whole.
- Since the early to mid-2000s many foam users such as chemical industries, fire brigades, airports, bulk fuel storages, ports, oil and gas platforms and refineries have transitioned to fluorine-free foams and demonstrated their effectiveness in operational use. The fluorine-free foam market is now well-established and highly competitive and cannot be described as an untried or new technology. Regular advances in formulations are now being made for various specialised applications.
- A late-comer to change is the US Federal Aviation Authority (FAA) that currently requires that MIL-Spec fluorinated firefighting foams be used at civilian airports. In recognition of PFAS being a contributor to significant legacy and on-going pollution problems the recently passed US Federal Aviation Authorization Act 2018 removes the requirement for fluorinated foam use at US FAA airports.[1] Similarly, the US Department of the Navy, the custodian of MIL-Spec, has for some years been considering changing the MIL-Spec standard to be based around performance rather than referencing specific chemical content and properties.
- A key advantage of fluorine-free foams is that they have almost none of the large and growing socio-economic or potential health impacts of fluorinated foam with only limited, short-term, localise environmental impacts which mostly self-remediate through natural

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biodegradation or can be dealt with by simple remediation technologies.

- Fluorine-free foams do not need complex, expensive and time-consuming remediation; if limited environmental damage occurs it is rapidly ameliorated, and very importantly, vital assets and amenities such as societal infrastructure, livelihoods, food supply, drinking water, public health, agriculture and livestock production, industrial continuity, recreational activities, etc., will rarely be under threat and if they are at all impacted will become normalized far faster with a minimal risk of long-lasting infrastructural, political and reputational damage.

Fluorine-free foams are available, certified and effective for all firefighting applications, for the few specialised uses remaining to be fine-tuned developments to address these are well advanced. As such there is absolutely no need for any exemptions, whether conditional, i.e., derogations, or otherwise, allowing the continued use of existing or new stocks of fluorinated foams (including those containing free PFOA, its salts, or PFOA precursors) as the local regulatory legislation of almost all jurisdictions has more than adequate provisions to permit transition to best practice with controls, milestones and timelines appropriate to the particular circumstances.

The continued use of PFAS foams is not only unnecessary but would continue to add to the legacy and on-going contamination that is responsible for the substantial, widespread and growing socio-economic and environmental costs being experienced globally.

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- Les performances des émulseurs sans fluor de classe B (F3s) pour les feux d'hydrocarbures et de solvants polaires ont progressé continuellement depuis leur développement initié dans le début des années 2000 par Ted Schaefer, de la société 3M, et sont désormais reconnues comme des agents d'extinction efficaces.
- Les meilleurs émulseurs sans fluor actuels de classe B sont capables d'atteindre les mêmes niveaux de performance des normes en vigueur que les produits de type AFFF. Il existe une exception regrettable avec la norme US MIL-Spec qui, à cause d'un détail d'écriture technique datant des années 60', jamais mis à jour, exige de contenir du fluor. A l'opposé, d'autres Forces Armées nationales ont réagi et ont accepté les émulseurs sans fluor, tout comme de nombreuses industries importantes à risque, sur la base de l'efficacité constatée en particulier lors d'incidents importants survenus sur des réservoirs de stockage, sur des feux en raffinerie, en production et en transport maritime depuis 2003 [ECHA soumission Avril 2016].
- Les émulseurs sans fluor présentent des avantages environnementaux, financiers et socio-économiques considérables par rapport aux émulseurs fluorés persistants. Ils ne sont pas persistants et sont biodégradables avec seulement des effets limités à court terme, à l'inverse des PFAS des AFFF, très persistants, toxiques et bio accumulables - à des degrés divers – pour l'environnement et la santé humaine, et capables d'être disséminés sur de grandes distances et de contaminer la planète toute entière.
- La contamination due aux PFAS s'étend aux terres agricoles et à l'eau utilisée pour l'industrie, les loisirs, la pêche et l'aquaculture, et aussi aux eaux souterraines, c'est à dire à l'eau potable. Le traitement pour éliminer les PFAS (en particulier els chaines courtes) est très difficile et cher, et les récoltes, la pêche, l'industrie, l'élevage et la santé humaine sont des valeurs potentiellement exposées. Les émulseurs sans fluor n'ont pas cet inconvénient.
- La pollution par les PFAS de sites exposés pendant des extinctions d'incendie ou utilisés par les pompiers pour leurs opérations et entrainements résulte en une contamination généralisée et étalée sur plusieurs kilomètres. Les PFAS à chaine courte (=<C6) sont plus mobiles et plus difficiles à extraire dans les eaux – souterraine ou de surface – que les PFAS à chaine longue, tels que le PFOS ou le PFOA.
- Le rejet des effluents produits par les émulseurs sans fluor est acceptable car il se dégrade naturellement dans le sol, les rivières et les eaux souterraines. Les rejets dans des zones sensibles aquatiques et hydrologiques, tel qu'un plan d'eau fermé, peuvent entrainer des effets limités et localisés à court terme, qui seront rapidement éliminés. A l'inverse, les rejets d'émulseurs fluorés ont causé des pollutions largement diffusées et à long terme ; les effluents doivent être récupérés, et traités comme un déchet industriel, avec un cout important, en conformité avec de nombreuses réglementations.
- La remédiation et le nettoyage d'une contamination par les PFAS, quand c'est possible, est très onéreuse, demande beaucoup de temps et impacte de façon importante la socio-économie, comme par exemple la perte de réserve d'eau potable, la perte de production agricole, les dommages en pisciculture, la dévalorisation des biens, la dégradation des revenus des personnes concernées. De plus il en résulte une perte de confiance du public envers son gouvernement, une perception altérée des risques pour la santé, la détérioration de l'image de marque de l'industrie, et enfin la possibilité de procédures judicaires, longues et couteuses, engagées par les victimes pour obtenir réparation auprès du pollueur. En final, tous les couts et pertes affecteront la communauté dans son ensemble.
- Depuis le début des années 2000, de nombreux utilisateurs d'émulseurs, tels que la chimie, les pompiers civils, les aéroports, les stockages, les ports, les pétroliers, ont adopté les émulseurs sans fluor et ont vérifié leur efficacité dans des situations opérationnelles. Le marché des émulseurs sans fluor est un marché bien établi et très compétitif, et ne saurait être décrit comme une technologie nouvelle ou inconnue. Des améliorations de formulations apparaissent sans cesse pour des applications diverses et spéciales.
- Un des derniers à changer est L'Autorité Fédérale de l'Aviation Américaine US (FAA) qui exige des aéroports civils certifiés l'emploi d'émulseurs agréés MIL-Spec. Reconnaissant que les PFAS sont la source de graves problèmes de pollution, un Acte récent de 2018 émis par la US FAA élimine l'exigence d'emploi d'émulseur fluoré pour ses aéroports. De même, la Navy US, gardienne de la MIL-Spec, a étudié depuis quelques années l'introduction de modifications dans la MIL-Spec pour agréer les émulseurs sur la base de leur performance et non plus sur la présence de composés chimiques spécifiques.
- L'avantage décisif des émulseurs sans fluor, à l'inverse des émulseurs fluorés, est qu'ils n'ont pratiquement aucun impact sur les risques potentiels de santé ou sur

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le tissu socio-économique, avec un impact localisé et limité à court terme, grâce à la remédiation rapide par dégradation naturelle, ou avec un traitement simple.

- Les émulseurs sans fluor ne nécessitent pas de remédiation compliquée, longue et couteuse ; en cas de dommage environnemental limité, il est rapidement traité et plus important, les valeurs importantes comme les infrastructures sociétales, les biens, l'alimentation, l'eau potable, l'agriculture, l'élevage, l'industrie, les loisirs,... ne seront pas menacées et, si exposées, ces valeurs seront rapidement restaurées avec un risque minimal de dommage à l'image, au gouvernement ou aux infrastructures.

Les émulseurs sans fluor sont disponibles, certifiés et efficaces pour toutes les utilisations classiques anti incendie, et, pour les rares utilisations spécifiques restantes, les développements sont déjà très avancés. Il n'existe donc aucune raison de prévoir des dérogations de couverture pour continuer à utiliser les émulseurs fluorés, car la majorité des règlementations a déjà localement pris les mesures permettant la transition pour un meilleur emploi avec des contrôles, des objectifs et des délais ajustés aux circonstances particulières.

L'utilisation continue des émulseurs avec PFAS est non seulement inutile, mais contribuerait à ajouter à l'héritage et à la contamination déjà existante, responsable des coûts socio-économiques et environnementaux substantiels, répandus et croissants largement supportés à l'échelle mondiale.

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RESUMEN EJECUTIVO

ES

- Las capacidades operativas de los espumogenos sin flúor de clase B (F3) para incendios de hidrocarburos líquidos y solventes polares han continuado avanzando y expandiéndose en uso dramáticamente desde su desarrollo inicial a principios de la década de 2000 por Ted Schaefer trabajando para la compañía 3M. y ahora están bien establecidos como agentes de extinción de incendios de alta eficacia.
- Los espumogenos sin fluor de clase B actuales son capaces de cumplir con todas las certificaciones de eficacia de los estandares aplicables a los AFFF y espumas relacionadas. Una desafortunada excepción es la especificación estadounidense MIL-Spec que, debido a un tecnicismo de redacción heredada que data de los años sesenta, requiere la inclusión de fluoroquímicos y no se ha actualizado significativamente desde entonces. En contraste, otras fuerzas de defensa nacional no han estado sujetas a tal inercia y han adoptado espumas libres de flúor, como lo han hecho muchas industrias grandes y de alto riesgo, basadas en efectividad operacional demostrada que incluye el uso en incidentes muy grandes como derrames e incendios de refinerías , tanques de almacenamiento de combustible a granel, producción de petróleo y gas. desde 2003 [presentación de la ECHA en abril de 2016].
- Los espumogenos libres de flúor tienen considerables ventajas financieras, socioeconómicas y medioambientales frente a las espumas basadas en fluoroquímicos persistentes. No son persistentes, son biodegradables con solo efectos a corto plazo y localizados frente a PFAS altamente persistentes contenidos en los AFFF, que son todos tóxicos y bioacumulativos en diversos grados para el medio ambiente y la salud humana, y que muestran un transporte extremo a larga distancia que tiene como resultado la contaminación mundial.
- La contaminación con PFAS a menudo se extiende a tierras agrícolas, aguas utilizadas para la industria, recreación, pesca y acuacultura, así como en aguas superficiales o subterráneas utilizadas para el agua potable. El tratamiento para eliminar el PFAS (especialmente el PFAS de cadena corta) es muy difícil y costoso, con el valor de los cultivos, la pesca, las industrias, el ganado y los valores de la salud humana potencialmente expuestos. Las espumas libres de flúor no tienen esta desventaja.
- La contaminación por PFAS de los sitios resultando de la extincion con espuma o entrenamiento genera una grande contaminación, que puede afectar muchos kilómetros fuera del sitio. Los PFAS de cadena corta (RC6) son más móviles y más difíciles de eliminar del suelo o del agua residual que los compuestos de cadena más larga (> C6) como PFOS o PFOA.
- Los derrames operacionales de efluentes de espuma libre de flúor pueden tolerarse y se degradarán naturalmente en suelos, rios o aguas subterráneas. Las descargas a entornos hidrológicos o acuáticos sensibles, como un lago cerrado, pueden causar efectos limitados, localizados y de corto plazo, pero en gran parte se auto eliminan. Por otro lado, los efluentes de espuma fluorada han causado una contaminación generalizada a largo plazo; los efluentes deben contenerse, recolectarse y tratarse a un costo significativo como desechos industriales regulados en muchas jurisdicciones.
- La remediación y limpieza de la contaminación con PFAS, si es posible, es enormemente costosa, lleva mucho tiempo y tiene importantes impactos socioeconómicos como la pérdida de suministros de agua potable, pérdida de la producción agrícola, daños a las pesca en los rios y el mar, valores deprimidos de las propiedades, dificultades económicas y mentales para los residentes afectados. Junto con esto se pierde la confianza pública en el gobierno, la percepción pública adversa de los peligros para la salud, el daño reputacional y la pérdida de la imagen de marca para la industria, el posible enjuiciamiento por parte del regulador y las costosas y largas acciones legales que buscan la compensación del contaminador. Todos los costos y pérdidas asociados finalmente serán sentidos por la comunidad como un todo.
- Desde principios de los años 2000, muchos usuarios de espumas como industrias químicas, bomberos, aeropuertos, depósitos de combustible a granel, puertos, plataformas de petróleo y gas y refinerías han hecho la transición a espumas sin flúor y han demostrado su eficacia en el uso operacional. El mercado de espumas sin flúor está ahora bien establecido y es altamente competitivo, y no puede describirse como una tecnología nueva o desconocida. Se están realizando avances regulares en formulaciones para diversas aplicaciones especializadas.
- Uno que tarda en cambiar es la Autoridad Federal de Aviación de los EE. UU. (FAA) que actualmente requiere que se utilicen espumas contraincendios fluoradas MIL-Spec en aeropuertos civiles. En reconocimiento de que PFAS contribuye a importantes problemas de legado y contaminación en curso, el reciente borrador de la Ley Federal de Autorización de Aviación de los Estados Unidos 2018 elimina el requisito del uso de espuma fluorada en los aeropuertos de la FAA de los Estados Unidos. De manera similar, el Departamento

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de Marina de los EE. UU., El custodio de MIL-Spec, durante varios años ha estado considerando cambiar el estándar MIL-Spec para que se base en la eficacia en lugar de hacer referencia al contenido y las propiedades químicas específicas.

- Una ventaja clave de las espumas libres de flúor es que casi no tienen ninguno de los grandes y crecientes impactos socioeconómicos o potenciales de la espuma fluorada con solo impactos ambientales localizados limitados a corto plazo que en su mayoría se auto eliminan a través de la biodegradación natural o puede ser tratado con simples tecnologías de remediación.
- Los espumogenos libres de flúor no necesitan una solución compleja, costosa y que requiera mucho tiempo; si se produce un daño ambiental limitado, se mejora rápidamente y, lo que es muy importante, los bienes y servicios vitales como infraestructura social, medios de vida, suministro de alimentos, agua potable, producción agrícola y ganadera, continuidad industrial, actividades recreativas, etc., rara vez estarán amenazados y si se impactan, se normalizarán mucho más rápido con un riesgo mínimo de daño duradero de infraestructura, político y reputacional.

Las espumas libres de flúor están disponibles, certificadas y son efectivas para todas las aplicaciones de extinción de incendios, los pocos usos especializados que quedan por desarrollarse para hacer frente a estos están muy avanzados. Como tal, no hay absolutamente ninguna necesidad de derogaciones generales para el uso continuado de espumas fluoradas ya que la legislación regulatoria local de casi todas las jurisdicciones tiene disposiciones más que adecuadas para permitir la transición a las mejores prácticas con controles y plazos adecuados a las circunstancias particulares.

El uso continuado de espumas PFAS no solo es innecesario, sino que continuará aumentando la contaminación heredada y en curso que es responsable de los considerables, generalizados y crecientes costos socioeconómicos y ambientales que se están experimentando a nivel mundial.

i Ley de reautorización de la Autoridad Federal de Aviación 2018, HR 4, Sección 203.

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摘要

ZH

- 20世纪初，由3M公司旗下的Ted Schaefer首次开发使用液态烃和极性溶剂燃料燃烧的无氟B类灭火泡沫（F3s），其使用范围逐步扩展，现在已经成为广泛英语营养的高能消防灭火剂。
- 目前优质的B级无氟灭火泡沫满足适用于AFFF和相关泡沫的所有标准消防性能认证。然而美国的MIL-Spec，由于20世纪60年代在语言上曾要求包括氟化学品，此后并没有修改升级，从而成为例外。相比之下，其他的国防部队没有受到这种影响，而是采用了无氟泡沫；许多大型和高风险工业也是如此，例如，对自2003以来炼油厂泄漏，火灾、散装燃料，储罐、油气生产和运输等非常重大事故的有效的操作使用。[ECHA，2016年4月摘要]。
- 无氟灭火泡沫与持久性氟化学基灭火泡沫相比，具有更可观的财政、社会经济和环境优势。它们具有非持久性，可生物降解的具有短期和局部作用的特性；而AFFF中的PFAS，由于其高度持久性，对环境和人类健康均有不同程度的毒性和生物累积，并且由于其广泛的覆盖范围，这已导致全世界范围内的污染。
- PFAS污染通常会扩展到农业用地，和用于工业、娱乐、渔业和水产养殖的水道，以及用于饮用水的地表水或地下水。去除由PFAS，特别是短链PFAS造成的农作物、渔业、工业、牲畜和人类健康污染是非常困难和昂贵的。无氟泡沫剂不具有这种缺点。
- 由于泡沫事故或演习意外引起的PFAS场地污染会导致大量的深层度的扩散污染，可能影响许多公里以外的场地。短链PFAS(≤C6)比长链(>C6)化合物(如全氟辛烷磺酸(PFOS)或全氟辛烷磺酸(PFOA)移动的更快，并且更难从地下水或废水中除去。
- 无氟泡沫径流的操作释放，可以在土壤、水道或地下水中自然降解，因而是可以允许容忍的。敏感环境区域的排放，比如封闭水道，可以造成有限的，局部短期的影响，但基本上会进行自我调节。另一方面，氟化泡沫的释放造成的长期广泛的污染，在许多管辖区，必须作为受管制的工业废料加以控制、收集和处理。
- PFAS污染修复和清理，将会是非常耗财，耗时，并且会伴随大量的社会经济影响，例如饮用水供应的损失、农业生产的损失、河流和近海渔业的破坏、财产价值的降低、经济的损失。也会造成公众对政府丧失信心，担心公众健康，怀疑工业品牌形象，并且引起法律诉讼，要求赔偿。所有的这些都伴随着成本和损失，最终会影响到整个社会。
- 自20世纪初至2000年代中期以来，许多泡沫使用者，例如化学工业、消防队、机场、散装燃料储存库、港口、石油和天然气平台以及炼油厂，都已过渡到无氟泡沫，并显示出其在操作上的有效性。已经形成了良好的无氟泡沫市场，伴随着强大的竞争优势，并且向特殊行业制剂发展。
- 美国联邦航空局（FAA）是一个迟来的改革者，它目前要求MIL-Spec氟化灭火泡沫用于民用机场。由于认识到PFAS是重大遗留问题和持续污染问题的贡献者，美国联邦航空授权法案2018草案取消了美国联邦航空局机场使用氟化泡沫的要求。美国海军部，MIL-Spec的监管者，几年来也一直在考虑改变MIL-Spec标准以性能为基础，而不是参考特定的化学含量和性质。
- 无氟泡沫的一个主要优点是，它们几乎不具有氟化泡沫的耗财和损害健康。它们仅仅是对环境有着短期的局部影响，但是这些都影响都可以通过自然生物降解或者简单的修复技术就可以消除掉。
- 无氟泡沫不需要复杂、昂贵和耗时的补救措施，如果有局部的环境破坏，也会迅速的得到改善，从而不会影响到重要的资产和便利设施，比如社会基础设施、生计、粮食供应、饮用水、农业和牲畜锁的生产、工业的连续性、娱乐活动。即便是受到影响，也会很快地恢复正常。

易用，高效的无氟泡沫可用于所有消防应用。除了因为一些特殊行业的要求，需要做一些相对于的技术调整。几乎所有的区域都通过相应的法律法规定来协助氟化泡沫到过无氟泡沫的过渡。
继续使用PFAS泡沫的不仅是不必要的，而且会加大遗留的全球环境污染问题和经济成本。

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- Поверхностно-активные вещества (ПАВ) Класса Б, не содержащие фтора, используемые для тушения пожаров вызванных возгоранием жидких углеводородов и спиртосодержащего топлива и растворителей, завоевали прочную репутацию высокоэффективных средств пожаротушения. Их эксплуатационные свойства значительно улучшились с момента их разработки в начале 2000-х годов Тедом Шафером, который на тот момент наботал на компанию 3М.
- Современные не содержащие фтора высококачественные пены для пожаротушения Класса Б удовлетворяют всем сертификационным стандартам, предъявляемым к пленкообразующим пенам на водной основе (ППВО) и подобным веществам, за разве что досадным исключением военного стандарта США (Mil-Spec), которое из-за устаревшего запатентованного описания состава, унаследованного с 60-х годов, формально включает в свой состав фтор-содержащие химикаты. Между тем, вооруженные силы других стран, а также другие стратегические отрасли и отрасли высокого риска, не стояли на месте и перешли на применение безфторосодержащих пен для пожаротушения в силу на основании проверенной на практике высокой эффективности этих средств в чрезвычайных ситуациях, включая при разливе топлива и пожарах на нефтехранилищах и танкерах, транспортирующих нефть и газ, и при авариях на судах, с 2003 года (отчет приготовленный для Европейского Агенства по Химическим Веществам, апрель 2016).
- Пены для пожаротушения не содержащие фтора представляют значительную финансовую, социо-экономическую и экологическую выгоду по сравнению с фторосодержащими пенами для пожаротушения с длительным периодом распада. По сравлению с последними, их характиризует короткий период распада и способность к биодеградации, а последствия их применения носят локальный характер, в то время как высокостабильные фторосодержащие соединения ППВО все токсичны, имеют свойство накапливаться в живых организмах с различной степенью опасности для человеческого здоровья и окружающей среды, и отличаются исключительной мобильностью и масштабом распространения, что стало проблемой загрязнения по всему миру.
- Зона загрязнения фторосодержащими органическими веществами зачастую распростаняется на сельскоходяйственные угодья, водные пути, зоны отдыха, рыболовства и рыбоводства, а также на поверхностные и подземные источники питьевой воды. Процесс очистки от фторосодержащих органических веществ (особенно соединений с короткими углеродными цепями) чрезвычайно трудоемок и дорогостоящ и представляет потенциальную опасность для сельскохозяйственных культур, рыбного хозяйства, животноводства и человеческого здоровья. С пенами для пожаротушения не содержащими фтора таких проблем нет.
- Аварийные разливы фторосодержащиих пен или их применение в целях учебных мероприятий вызывают формирование значительных по площади шлейфов загрязняющих веществ, которые могут расстягиваться на километра от от места очага загрязнения. Фторосодержащие органичские вещества с короткими углеродными цепями распространяются быстрее и, как следствие, труднее удаляются из подземных или сточных вод по сравнению с фторосодержащие органические соединения с длинными углеродными цепями (>C6) такими как перфтороктановый сульфонат (ПФОС) или перфтороктанат (ПФОК).
- Последствия разливов и эксплуатационных мероприятий с применением пен не содержащих фтора не критичны поскольку эти соединение в почве и воде со временем разложатся сами. Эффект от их попадания их в экологически уязвимые водные экосистемы, например, закрытые водоемы, будет иметь локальный характер, а последствия будут кратковременныеми и незначительными и, со временем, эти экосистемы сами восстановятся. Для сравнения, существует масса примеров, когда загрязнение фтор-содержащими пенами приводило к широкомасштабным и длительным последствиям. В таких случаях, загрязненный участок среды нужно удалять и очищать в соотвествии со всеми требованиями предъявляемыми к промышленным отходам.

- Если полная очистка от фторосодержащих органических соединий вообще возможна, она требует значительных затрат средств и времени, а социо-экономические последствия огромны, включая потерю источников питья, ущерб рекам, вывод сельскохозяйственных угодий из оборота, вред причиняемый рыбному хозяйству, падение цен на землю и недвижимость, экономический и психический стресс для местного населения. Добавить к этому падение уровня доверия к государственным структурам, негативное общественное мнение и испорченную репутацию для промышленности, возможное привлечение виновника инцидента к ответственности и длительные и дорогостоящие судебные разбирательства по выплатам компенсаций. В конечном иноге, все затраты и ущерб ложатся на плечи общества.
- С начала до середины 2000-х годов многие потребители пен, например, химические предприятия, пожарные бригады, аэропорты, хранилища топлива, нефте- и газовые платформы и нефтеперерабатывающие заводы, перешли на применение пен не содержащих фтор и доказали их высокую эффективность на практике. В настоящее время пены не содержащие фтор прочно утвердились на рынке, так что эту технологию уже не назовешь ни пробной, ни новой. Состав соединений постоянно совершенствуется для применения в различных ситуациях.
- «Задержавшееся в прошлом» Федеральное Управление Авиации США все еще требует применение фторсодержащей пены MIL-Spec в аэропортах. Однако, в признание того факта, что фтор-содержащие пен были и остаются серьезным источником загрязнения окружающей среды, недавний проект закона по Федеральному Управлению Авиации США рассматривает исключение требования для использования фторсодержащей пены в аэропортах. Похожая ситуация в Департаментом Морского Флота США, отвечающим за формулировку стандарта MIL-Spec, на протяжении нескольких лет рассматривает предложение по изменению MIL-Spec стандарта, чтобы вместо ссылки на конкретный химический состав использовать формулировку указывающую на целевые свойства вещества.
- Ключевое преимущество пен не содержащих фтор заключается в том, что они почти не вызывают значительных или возрастающих социо-экономичкских последствий или потенциальных рисков для здоровья как фтор-содержащие пены; эффекты их воздействия на окружающую среду локальны, незначительны и кратковременны; и в силу их способности к биологическому само-разложению с ними нетрудно бороться.
- Не содержащие фтора пены не требуют сложных, затратных и трудоемких способов очистки и в случаях экологических инцидентов их последствия можно быстро ликвидировать без, что особенно важно, угрозы для жизненно-важных аспектов жизнедеятельности общества включая защиту источников еды, воды, доходов, социальных структур, предприятий промышленности и сельского хозяйства, объектов отдыха бесперебойного производства, и т.д. В худшем случае, ситуацию можно быстро нормализовать с минимальным риском долгосрочных экономических и политических последствий.

Не содержащие фтора пены доступные, сертифицированные и эффективные средства пожаротушения которые можно применять при пожарах любого рода, с оговоркой, что в ряде конкретных ситуаций их применение можно было бы улучшить путем дальнейшей разработки. На этом основании, больше нет необходимости в законодательных требованиях на дальнейшее использование фтор-содержащих пен поскольку почти все законодательные инструменты в различных странах содержат более чем достаточные механизмы чтобы установить сроки и разрешить переход на более эффективные методы контроля подходящие для конкретных ситуаций.

Дальнейшее использовании фтор-содержащих пен не только не обязательно, оно вредно, поскольку способствует дальнейшему загрязнению окружающей среды, которое вызывает значительные, широкомасштабные и возрастающие экологические и социо-экономические последствия, которые уже ощущаются по всему миру.

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ملخص تنفيذي

• استمرت القدرات التشغيلية لرغاوي مكافحة الحرائق من "الفئة ب " الخالية من الفلورين (F3s) والمناسبة لمكافحة حرائق الوقود الهيدروكربونية السائلة وذرات وقود المذيبات القطبية في التقدم والتوسع للاستخدام بشكل كبير منذ تطويرها الأول في أوائل عام 2000 من قبل تيد شيفر (Ted Schaefer) الذي يعمل لصالح شركة (3M) والآن يتم استخدامها كعوامل رئيسية عالية الأداء في مكافحة الحرائق.

• تستطيع رغاوي مكافحة حرائق "الفئة ب " الخالية من الفلورين عالية الجودة تلبية ومطابقة جميع اشتراطات اعتماد شهادات الأداء القياسية في مكافحة الحرائق المطبقة على جميع تشكيلات رغاوي الحرائق المائية (AFFF) والرغاوي ذات الصلة. الاستثناء المؤسف هو عدم استخدامها من قبل القوات الأمريكية الخاصة، والذي يرجع إلى تقنية متوارثة قديمة تعود إلى أوائل الستينيات من القرن الماضي، والتي تتطلب تضمين المواد الكيميائية الفلورية في رغاوي مكافاحات الحرائق ولم تتم المخاطرة في تحديثها منذ ذلك الحين. في المقابل، لم تخضع قوى دفاع وطنية أخرى لمثل هذا الجمود واعتمدت الرغاوى الخالية من الفلورين، كما فعلت العديد من الصناعات الكبيرة وذات المخاطر العالية، استناداً إلى فعاليتها التشغيلية المثبتة عمليا بما في ذلك استخدامها في حوادث كبيرة للغاية مثل الانسكابات وحرائق المصافي. صهاريج تخزين الوقود الضخمة، وإنتاج النفط والغاز والشحن منذ عام 2003. [ECHA submit April 2016].

• تتمتع رغاوي مكافحة الحرائق الخالية من الفلورين بمزايا مالية واجتماعية واقتصادية وبيئية كبيرة مقارنة مع رغاوي مكافحة الحرائق القائمة على الفلوروكيميائية. وهي غير ثابتة وقابلة للتحلل البيولوجي مع تأثيرات قصيرة المدى ومحددة فقط، مقابل مواد البلاتين المشبع بالفلور (PFAS) المستخدمة في تشكيلات رغاوي الحرائق المائية (AFFF) والتي تكون جميعها سامة وتراكمية البيولوجية بدرجات متفاوتة بالنسبة لصحة وسلامة الإنسان والبيئة، بالإضافة إلى عروض النقل بعيدة المدى والتي نتج عنها ظهور تلوثات في جميع أنحاء العالم.

• وغالبا ما يمتد تلوث هذه المادة (PFAS) إلى الأراضي الزراعية والممرات المائية المستخدمة في الصناعة والترفيه وصيد الأسماك وتربية الأحياء المائية، فضلا عن المياه السطحية أو الجوفية المستخدمة في الشرب. إن المعالجة اللازمة لإزالة مواد PFAS (خاصة PFAS قصيرة السلسلة) مكلفة وصعبة للغاية بالنسبة للمحاصيل، ومصايد الأسماك، والصناعات، والثروة الحيوانية، والأهمية الخاصة بالثروة الحيوانية وصحة الارواح البشرية المحتمل تعرضها لهذه المواد. الرغاوي الخالية من الفلورين ليس لديها هذا العيب.

• يتسبب تلوث المواقع الناتج من جراء حوادث الرغوة أو برامج التدريب في تلوثات كبيرة تنتشر تدريجيا قد تؤثر على العديد من الكيلومترات خارج الموقع. وتكون المركبات قصيرة السلسلة من السلفونات المشبعة بالفلور أوكتين (C6>) أكثر حركة وأكثر صعوبة في إزالتها من المياه الجوفية أو مياه الصرف الصحي من المركبات الأطول سلسلة (C6>) مثل سلفونات الأوكتين المشبعة بالفلور أو PFOA.

• النواتج والمخلفات للتشغيل والاستخدام العملياتي للرغوة الخالية من الفلورين يمكن تخفيفها وسوف تتحلل بشكل طبيعي في التربة أو المجاري المائية أو المياه الجوفية. ويمكن أن يتسبب تصريفها في البيئات الهيدرولوجية أو المائية الحساسة مثل الممرات المائية المغلقة في تأثيرات محدودة ومحددة قصيرة المدى ولكنها ستعالج نفسها بنفسها الى حد كبير. ومن ناحية أخرى، تسبب نواتج ومخلفات الرغاوى المفلورة في تلوث واسع النطاق وطويل الأجل، ويلزم احتواء الجريان السطحي لمخلفاتها وجمعه ومعالجته في تكبد تكلفة كبيرة جدا، كالنفايات الصناعية الخاضعة للرقابة في العديد من الولايات القضائية.

• إن معالجة التلوث والتخلص من سلفونات الأكتين المشبعة بالفلور والتطهير -إذا كان ذلك ممكنا على الإطلاق- باهظة التكلفة وتستغرق وقتا طويلا مع تأثيرات اجتماعية اقتصادية كبيرة مثل فقدان إمدادات مياه الشرب، وخسارة الإنتاج الزراعي، والأضرار التي تلحق بالمصايد النهرية والبحرية، وانخفاض قيمة الممتلكات، المعاناة الاقتصادية والنفسية للمقيمين المتضررين. إلى جانب فقدان الثقة العامة في الحكومة، وإدراك الجمهور للمخاطرالسلبية على الصحة، والأضرار التي تلحق بالسمعة العامة وفقدان صورة العلامة التجارية للصناعة، ومقاضاة محتملة من قبل المشرع، وإجراءات قانونية طويلة ومكلفة للحصول على تعويض من المتسبب بالتلوث. جميع التكاليف الباهظة والخسائر المرتبطة بها سيشعر بها المجتمع ككل في نهاية المطاف.

• منذ أوائل الى أواسط عام 2000، انتقل العديد من مستخدمي الرغاوى مثل المصانع الكيميائية، وأطقم الإطفاء، والمطارات، ومخازن الوقود

الضخمة، والموانئ، ومنصات النفط والغاز والمصافي إلى الرغاوى خالية من الفلورين والتي أثبتت فعاليتها في الاستخدام التشغيلي. إن سوق الرغاوى الخالية من الفلورين الآن راسخة وذات قدرة تنافسية عالية ولا يمكن وصفها بأنها تكنولوجيا غير مجربة أو جديدة. ويجري الآن التقدم المنتظم في تطوير التركيبات لمختلف التطبيقات والمتطلبات الخاصة.

• من التغييرات التي تأخر إجراؤها هي في هيئة الطيران الفيدرالية الأمريكية (FAA) التي تتطلب حاليًا استخدام رغاوي القوات الأمريكي الخاصة المفلورة في مكافحة الحرائق في المطارات المدنية. وبالاعتراف بأن PFAS كانت تساهم في مشاكل تلوث كبيرة قديما ومستمرة، فإن مشروع قانون هيئة الطيران الفيدرالي لعام 2018 الذي صدر مؤخراً يزيل متطلبات استخدام الرغوة المفلورة في مطارات هيئة الطيران الفدرالية الأمريكية. وبالمثل كانت إدارة البحرية الأمريكية، والقوات الأمريكي الخاصة، تدرسان منذ عدة سنوات تغيير معيار القوات الامريكي الخاصة ليتمحور حول الأداء بدلاً من الإشارة إلى محتوى وخصائص كيميائية محددة.

• إن الميزة الرئيسية للرغاوى الخالية من الفلورين هي أنه ليس لديها تقريبا أي من التأثيرات الاجتماعية والاقتصادية الكبيرة أو المتفاقمة، أو تأثيرات صحية خطرة للرغوة المفلورة مع تأثيرات بيئية محدودة ومحدودة قصيرة الأجل فقط والتي غالباً ما يتم إصلاحها ذاتيًا من خلال التحلل البيولوجي الطبيعي أو التعامل مع تقنيات العلاج البسيطة.

• لا تحتاج الرغاوى الخالية من الفلورين إلى معالجة معقدة ومكلفة ومضيعة للوقت، وإذا حدث ضرر بيئي محدود فإنه يتم تخفيفه بسرعة، والأهم من ذلك أن الموارد والمرافق الحيوية مثل البنية التحتية المجتمعية، وسبل المعيشة، والإمدادات الغذائية، ومياه الشرب، والزراعة والإنتاج الحيواني، والاستمرارية الصناعية، والأنشطة الترفيهية، وما إلى ذلك، نادرا ما تكون مهددة وإذا ما تأثرت على الإطلاق فسيتم تطبيعها بأسرع ما يمكن مع وجود خطورة ضئيلة من الإضرار بالبنية التحتية والسياسية والسمعة العامة على المدى البعيد.

الرغاوى الخالية من الفلورين متوافرة ومعتمدة وفعالة لجميع متطلبات مكافحة الحرائق، للاستخدامات الخاصة القليلة المتبقية والتي يتم تطويرها بشكل دقيق وبتقدم جيد للتعامل مع هذه التطبيقات. وعلى هذا النحو، لا توجد حاجة مطلقة إلى عدم التقيد الشامل لاستمرار استخدام الرغاوى المفلورة حيث أن التشريعات التنظيمية المحلية للسلطة القضائية لجميع الولايات تقريبًا لديها أكثر من أحكام كافية للسماح بالانتقال إلى أفضل الممارسات مع الضوابط والمعالم والجداول الزمنية المناسبة لظروف معينة.

إن الاستخدام المتواصل لرغاوي PFAS ليس فقط غير ضروري، ولكنه سيظل يضيف ملوثات وباستمرار الى حصيلة التلوث الإرثي والذي يعتبر المسئول عن التكاليف الاجتماعية والاقتصادية والبيئية الكبيرة والواسعة النطاق والمتنامية التي تتم تجربتها عالمياً.

قانون إعادة تفويض هيئة الطيران الفيدرالية 2018، HR 4، القسم 203.

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STAKEHOLDER END-USERS

There are a wide range of firefighting foam end users with overlapping interests in performance and risks.
The primary end users are:

- **Aviation Industry**
  - Aviation rescue and firefighting
  - Fuel storage
  - Hangars and maintenance
  - Terminal buildings
- **Petroleum and chemical industries Refineries**
  - Off shore oil and gas
  - Wharfing and refuelling terminals
  - Chemical process plant
  - Helipads
- **Ports, harbours and shipping Storage tanks**
  - Wharfing and transfer terminals
  - Bulk solid materials handlers
  - Onboard firefighting
  - Coastal waters and rivers facilities
- **Mining and exploration**
  - Heavy excavation machinery
  - Heavy haulage vehicles
  - Fuel storages
  - Utility vehicles
- **Fire Brigades**
  - Municipal fire and rescue services
  - Industrial fire responders
  - Rural fire services
- **Defence facilities**
  - Bulk fuel storages
  - Airforce bases
  - Naval combat and resupply vessels
  - Land and sea defence fire services
- **Extinguishers and Systems Manufacturing**
  - High-expansion systems – deluge systems
  - Sprinklers
  - Fixed installations – tank farms, fuelling facilities, buildings
  - Commercial properties
  - Hand-held and portable extinguishers

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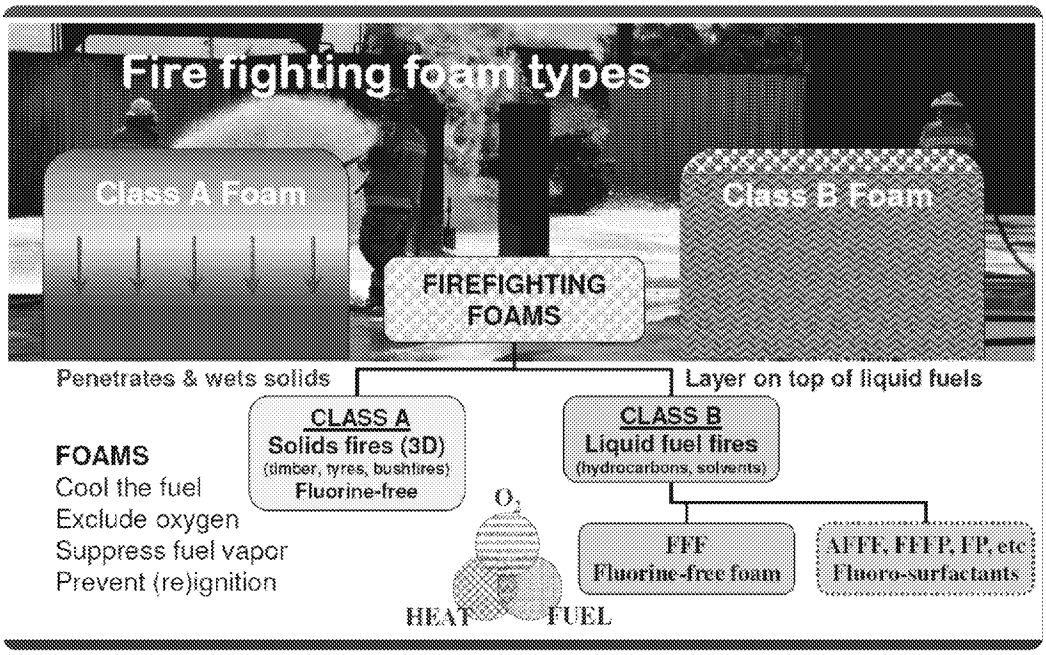
1. FIREFIGHTING FOAMS



From Holmes (2015) evidence to the Parliament of Victoria Fiskville Inquiry.

1.1. TYPES OF FIREFIGHTING FOAMS – CLASS A AND CLASS B

Class A firefighting foams are specifically formulated for the rapid extinction and control of fires involving carbonaceous fuels such as wildland fires, structural wood fires, burning paper and plastic. These foams are fluorine-free – they do not contain fluorosurfactants or fluoropolymers – and are composed of hydrocarbon surfactants designed to aid deep penetration of the carbonaceous fuel by water by lowering the contact surface tension. This results in rapid cooling of the fuel due to the latent heat of vaporisation of water.

Class B firefighting foams, on the other hand, are formulated to be most efficient at extinguishing liquid hydrocarbon fuel fires. Class B foams are also produced as 'alcohol-resistant' or AR variants, most typically by incorporating carbohydrate-derived materials or gums, e.g., xanthan gum, and suitable for liquid polar solvent fires, e.g., acetone or isopropanol (IPA).

Class B foams currently available are either (i) aqueous film-forming foams (AFFF), fluoroprotein foams (FP), or film-forming fluoroprotein foams (FFFP), all of which contain highly fluorinated fluorosurfactants or fluoropolymers; (ii) fluorine-free Class B foams (F3) using proprietary mixtures of hydrocarbon surfactants. Fluorine-free foams are also known as 'synthetic' foams. This is a misnomer as AFFFs are also synthetic, i.e., not made from naturally occurring substances. FP and FFFP although containing natural protein – for example, sourced from slaughterhouse horn-and-hoof waste – also contain synthetic ingredients.

Other types of extinguishing agents such as Classes C (flammable gases), D (metal fires), E (electrical fires), and F (fat fires), are of no concern here.

1.2. A BRIEF HISTORY OF THE DEVELOPMENT OF FLUORINE-FREE CLASS B FOAMS

The first successful development of a true synthetic fluorine-free Class B foam was achieved by Ted Schaefer a formulation chemist working for the 3M Company, and named RF or 're-healing foam'. Starting work immediately after the 3M Company's announcement 16 May 2000 that they were phasing out use of the Simons ECF (electrochemical fluorination) method for the production of PFOS and were withdrawing entirely from the firefighting foam market and the dispersive use of fluorosurfactants [3M announcement], he achieved a fully functional fluorine-free firefighting (F3) foam which met ICAO Level B and matched AFFF in performance including a US MIL-Spec product. This development is described in more detail in one of the Appendices. Thus, Ted Schaefer must be considered to be truly the father of Class B fluorine-free firefighting foams, as well as the inventor of an important Class A foam for wildland fire applications [FireBrake™].

Ted Schaefer.

Subsequently a number of other companies have been involved in further developing Class B fluorine-free foams (F3) to meet increasingly stringent specifications. The foremost amongst these is undoubtably Solberg Scandinavian, later Solberg Foams, who bought 3M's patent rights to re-healing foam (RF) in 2007 as well as employing Ted Schaefer. Thierry Bluteau working for Bio-Ex in France developed the highly effective Class B F3 product ECOPOL in the early and mid-2000s.

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Since then, many other companies have marketed their own fluorine-free F3 Class B formulations, including: Angus Fire (Syndura, JetFoam, Respondol); Sthamer (Moussol-FF); Orchidee (Bluefoam); Dafo Fomtec (Enviro); Auxquimia (Unipol); Chemguard (Ecoguard); 3FFF (Freedol-SF); and VS Focum (Silvara); responding to end-user demand for a firefighting foam without the environmental problems and lifetime costs associated with fluorochemical-based foams.

1.3. APPROVALS & CERTIFICATIONS - FLUORINE-FREE CLASS B FOAMS

Modern generation Class B fluorine-free foams are capable of meeting the same high-performance standards as almost all AFFF-type foams. Although the best F3 products on the market are able to match the performance of many MIL-Spec foams, they technically cannot achieve MIL-Spec approval *by definition* because they do not contain fluorine or have positive spreading coefficients necessary for film-formation, legacy out-of-date requirements of the specification [MIL-Spec or MIL-F-243385F]. For example, F3 foams outperform MIL-Spec AFFFs on low surface tension hydrocarbon liquid fires, such as n-pentane, n-hexane, or iso-octane, where film-formation with AFFF does not occur, i.e., the spreading coefficient becomes close to zero or negative.

All US Federal Aviation Authority (FAA) certified airports are mandated to use MIL-Spec approved firefighting foams. However, the recent draft of the US Federal Aviation Authorization Act 2018 [Federal Register] looks to removing the requirement for a specified fluorine content, as in MIL-Spec, thus potentially at least allowing fluorine-free foams to compete on the basis of performance criteria.

Similarly, the US Strategic Environmental Research and Development Program (SDERP) put out a Statement of Need for FY 2017 [WPSON-17-01] for the development of "a fluorine-free surfactant formulation for fire–suppression operations" that meet the performance requirements defined in MIL-F-24385F.

NFPA 403 list fluorine-free foams (F3) as acceptable alternatives to AFFF, FP and FFFP for use in the Aviation Rescue and Firefighting (ARFF) at airports.[2] As pointed out in NFPA403, the need for extinguishing a fire can occur either immediately following an aircraft accident/incident, or at any time during rescue operations, and must be assumed at all times. The most important factors bearing on effective rescue in a survivable aircraft accident are the training received, the effectiveness of the equipment, and the speed with which personnel and equipment designated for rescue and firefighting purposes can be put to use.

There is currently considerable resistance from vested interests and lobbying groups representing the US chemical industry to these changes, with many unfounded or untrue assertions and myths, downplaying the effectiveness and operational efficiency or safety of fluorine-free foams (F3). These are dealt with and rebutted in detail in a later section of this Position Paper.

Many fluorine-free F3 products on the market are capable of meeting the following performance specifications as do the better AFFF formulations:

- EN1568:2008 Parts 3 and 4 all fuels, fresh and saltwater, polar solvents (acetone and isopropanol, IPA) some quote 1A/1A; caution may be required as there is some indication that a 1A result on polar solvents points to siloxane surfactants being used which may have potential environmental persistence problems of their own depending on structure;
- ICAO Level B and Level C at 3% and 6% (Aviation);
- LASTFIRE batch approvals on both heptane and ethanol, fresh and saltwater;
- IMO – MSC.1/Circ.13.12. (International Maritime Organisation);
- UL162 with fresh and seawater;
- UL162 listed Type III and sprinklers on hydrocarbon fuels;
- FM 5130 approved;
- ULC 5564.

Foam concentrates are available for 1%, 3% and 6% induction rates, with alcohol-resistant (AR) variants for polar solvents (acetone and IPA), as well as freeze protection to as low as minus 25° C. Foam concentrates may be Newtonian or non-Newtonian in terms of flow properties during induction.

All the tests for these approvals or batch certifications must be carried out or witnessed by independent certified test houses to have any validity. Expressly, tests must not be done by the manufacturers themselves, nor for that matter should tests be by a manufacturer disingenuously imitating and manipulating tests using a competitor's foam in an attempt to discredit its performance.

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NON-PERSISTENT FOAM PERFORMANCE (FFF)

Industry Application	Australia/New Zealand	FFF meets required specifications
LAST Terminal Facilities & Refineries hydrocarbons, blends and polar solvents	LAST Fire Test & EN1568 (some UL/FM for fixed systems)	Yes
Aviation hydrocarbon fuels	ICAO & EN1568	Yes
Offshore hydrocarbon fuels, some methanol polar solvent	ICAO & EN1568	Yes
Fire Services hydrocarbons, blends and polar solvents	ICAO & EN1568	Yes
Defence (Army, Air Force, Navy)	DEF(Aust)5706 / ICAO Level B	Yes [Note 2]
Royal Australian Navy	US Mil Spec / UK Defence Spec	Yes [Note 2]
Ports, Tugs and Ships	ICAO & EN1568	Yes
Oil and Gas Industries		Yes
Mines	EN1568	Yes
General Industry	LAST Fire Test & EN1568 (some UL/FM for fixed systems)	Yes
Mining Heavy Vehicles	AS5062	Yes
Hand Held Extinguishers	AS1841	Provisional [Note 5]

Note 2 – Legacy US MilSpec specifics FOC content in addition to performance standards, changes being considered

Note 5 – Approved EU, under consideration in Australia

Examples in the above table for the regulatory environment in Australia and New Zealand are taken from Holmes (2015), evidence to the Victorian Parliamentary Inquiry into CFA Fiskville.

Thus, certain fluorine-free F3 foams can meet all the requirements and are comparable in performance to some of the better fluorine-containing AFFFs, without the environmental disadvantages inherent in extremely persistent perfluorinated end-products with known (such as PFOA or the longer chain PFCAs) or potential toxicity and bio-accumulative potential.

An article[3] by Ramsden describing the LASTFIRE tests done in 2017 shows that new generation foams such as C6-pure PFAS foams and F3 foams were shown to be effective for storage tank incidents up to a tank diameter of 11m using standard application rates and conventional application equipment; work on larger scale testing is ongoing. There is already wide scale application of F3 foams across multiple sectors such as aviation and oil & gas, with F3 foams being used by the military in Scandinavia for several years as demonstrated with tests described by the Danish Airforce Fire Chief. F3 foams have achieved certification under various firefighting foam certification programs (e.g., Underwriters Lab, LASTFIRE and International Organization for Standardization [ISO]) with some foams having passed the highest levels of International Civil Aviation Organization (ICAO) extinguishment tests. They are widely used at major airports worldwide, including major international hubs such as Dubai, Dortmund, Stuttgart, London Heathrow, Manchester, Copenhagen and Auckland. All of the 27 major airports in Australia have transitioned to F3 foams.

These approvals and certifications remain just that, somewhat artificial hurdles that manufacturers have to jump through before being able to sell their products on the market. In exercising due diligence during the procurement process end-users must do their own operational fire performance testing under the conditions they would normally operate in regardless of foam type (for example, ambient temperature or humidity), with the equipment they would normally use such as inductors, hose and branch nozzles, and with the test being carried out by their own firefighters. It should also be acknowledged that operational technique and training are vital in achieving the top performance from any product.

Although it is not possible to be generic, because there is a wide variation in product performance for both AFFF and F3 foams, both spill and tank fires were extinguished with some of the better F3 foams using application rates in full accordance with NFPA 11 application rates or less. NFPA 403 lists as acceptable fluorine-free foams to be used as alternatives to AFFF and other fluorine-containing foams in the aviation sector (ARFF).

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The key to the applicability of any small-scale test is its validation against real events and realistic large-scale testing representing real world design scenarios. LASTFIRE has just completed this type of exercise for its special small-scale test designed to simulate tank fire scenarios. Further large-scale comparative tests comparing AFFF and F3 foams will be conducted at Dallas Fort Worth Airport in October 2018 [Niall Ramsden, LASTFIRE coordinator].

ANY CLAIM THAT A FOAM CONCENTRATE IS FLUORINE-FREE (F3) SHOULD BE SUBSTANTIATED WITH A TOTAL ORGANIC FLUORINE (TOF) ANALYSIS <10 PPM "F" AND IN ADDITION A TOTAL OXIDIZABLE PRECURSOR (TOP) ASSAY. MOREOVER, A TOP ASSAY IS ALSO ESSENTIAL FOR ANY MODERN 'PURE C6' AFFF CONCENTRATE CLAIMING TO BE LONG-CHAIN PFAS AND PFOA-FREE AT <1 PPM PFOA OR PRECURSORS.

1.4. MYTH BUSTING, TRUTHS, UNTRUTHS AND MARKETING HYPE

Over the years since the serious introduction on the market of Class B fluorine-free F3 foams suitable for hydrocarbon and polar solvent fires: there have been many attempts by the fluorochemical side of the industry and their lobbyist trade associations to undermine and downplay the operational performance of Class B fluorine-free foams whilst minimizing the environmental issues associated with fluorinated products. This has included publishing in the technical trade literature spurious performance tests carried out by non-independent or certified bodies funded by competitors to F3 producing companies, as well as continually perpetrating unsupported myths. It is these myths in particular that must be controverted for what they are: marketing hype, misrepresentation of test conditions, frank untruths or only partial truths, criticism of a competitor's product, and an exhibition of vested interests.

MYTHS	REALITY
Fluorine-free foam endangers life safety for both fire fighters and members of the public.	There is absolutely no evidence, anecdotal or otherwise, for this statement. All foams are individually assessed against the same industry-agreed performance standards. This is clearly marketing hype and irresponsible scare mongering on behalf of the fluoro industry.
Fluorine-free foams are ten times more toxic, based on acute aquatic toxicity, than AFFFs.	Irrelevant hyperbole and misuse of data. ALL foams fall into the very low acute toxicity categories '*relatively harmless*' and '*practically non-toxic*' with overlap of current 3F and AFFF. Effectively ten times almost nothing is still almost nothing. Similarly, BOD values are extremely high for ALL foams with a potential "toxicity" to cause oxygen depletion and fish kills in enclosed waterways. Strictly speaking 3F foams have on average lower BOD and are therefore less "toxic". The real issue is the chronic long-term toxicity associated with permanent PFAS pollution by AFFF.
Up to three to four times more fluorine-free foam is required compared to a fluorinated foam.	False - examination of the single incident behind this claim finds that the concentrate application rates were almost identical. However, the amount of firewater generated per hour was significantly less (78%) for the F3 foam. The fluorine-free foam also avoids the long-term PFAS environmental impacts, huge remediation and clean-up costs, as well as legal and other financial liabilities.
Fluorine-free foams do not work at higher-than-normal ambient temperatures on hot fuel.	A leading brand of fluorine-free foam has been shown to work at elevated temperatures, with very high vapor pressure fuels at both high fuel and ambient temperature (28-29°C as well as 36°C) - most importantly the test application rates were significantly lower than the minimum use rates allowed by industry. For example, the ICAO test application rate was significantly lower than the ICAO application rate required for an ARFF vehicle, which is approximately 2.5 times higher than the application rate actually used for the tests (i.e., the product has a large built-in safety factor). AFFFs have difficulty in extinguishing hot fuel or fuels with low surface tension because the spreading coefficient becomes negative and aqueous film-formation does not occur. Fuel surface tension drops dramatically as temperature rises negating any possibility of film-formation. Large quantities of foam are needed at the beginning of any operational incident to cool the fuel surface sufficiently for film-formation to occur.
Fluorine-free foams cannot be used for vapor suppression of chemically reactive liquids/vapors such as ammonia.	A commercially available fluorine-free foam applied using CAFS technology as a low expansion foam is capable of providing efficient ammonia suppression when compared to other AFFF products on the market with negligible loss of ammonia from the aqueous sub-phase.

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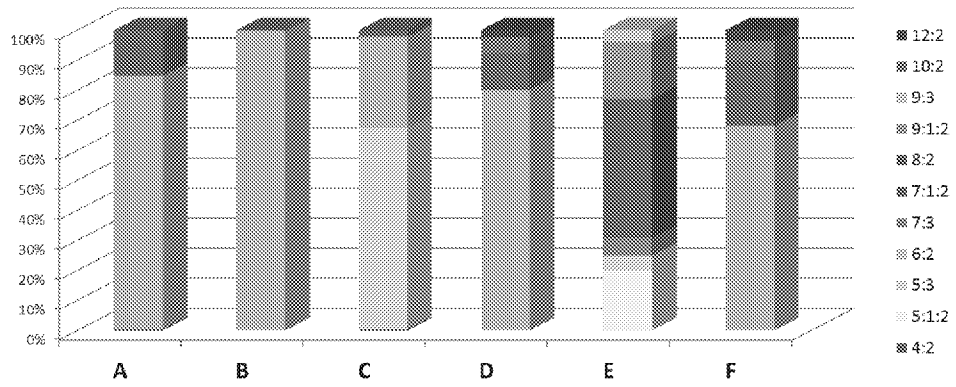
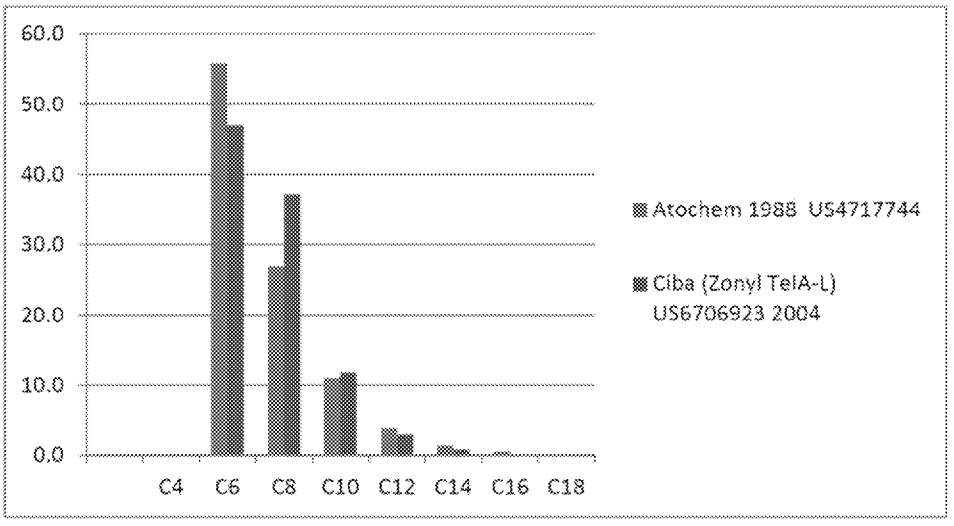
MYTHS	REALITY
Modern purer C6 fluorotelomer based foams are direct drop-in replacements for the older generation C6/C8 fluorotelomer foams.	C6 are not absolute "drop-in" replacements [see LASTFIRE study public report]. There are performance problems associated with reduced burn-back resistance related to the reduction or elimination of the C8 component, succinctly predicted by Thierry Bluteau at a Reebok foam conference some years ago. This reportedly necessitates an increase in the fluorosurfactant concentration mitigating any environmental advantage obtained by removing the C8; moreover, there is concern that some pure C6 products now on the market may have 'inherited' the approvals from the older C6/C8 versions rather than being completely re-tested as required for any formula change; in addition, currently there are no known approvals available for the newer C6 products to be used for sub-surface injection on large storage tanks as used in the petrochemical industry.
Modern fluorotelomer foams are "PFOS and PFOA free".	Largely irrelevant marketing claim - PFOS is a legacy compound; current fluorotelomer foams cannot contain PFOS as a consequence of the telomerization pathway used for chemical synthesis. Free PFOA has not been used in foams for decades, however, 200-600 PFOA precursors and related homologues are common in formulations or as later transformation products (e.g., 8:2 FtSAoS) and place the end-user at-risk by transforming to PFOA and related end-point compounds in plants, animals, people and the environment. Examples of the wide range of formulation variability are shown below (taken from Holmes (2015)).

Compositions of six foams



Holmes 2015 - Compositions of six foams ~2005-2010. Data from Backe, Day & Field 2013.

TELA Homologue Distributions



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Early fluorotelomer fluorosurfactant feedstocks used for foam formulations demonstrated an extremely disperse distribution of N:2 chain lengths as indicated by the patent information below.

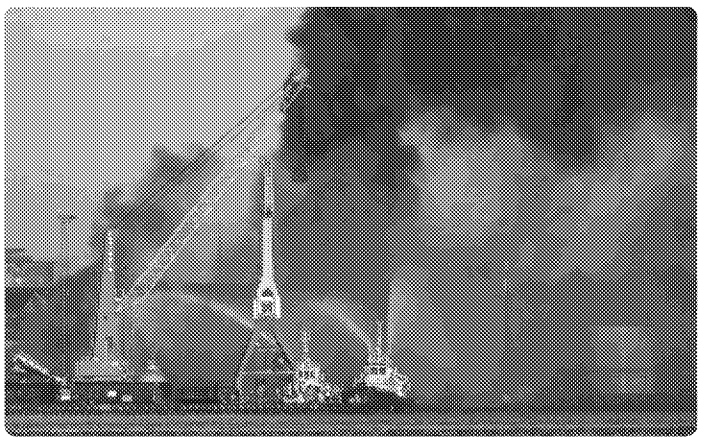
MYTH	REALITY
Fluorine-free foam cannot be used with non-aspirated or in sprinkler systems.	Certain F3 products have been approved under UL162 for Type III non-aspirated sprinkler applications at the same concentrations and flow rates as AFFF; Queensland Fire & Emergency Service (QFES) has routinely used F3 foam with a non-aspirating standard nozzle and 50mm hose since 2003.

The UL162 sprinkler test is very stringent involving non-aspirated sprinklers and relies on good burn-back resistance and long drainage times. Not many AFFFs manage to pass this test which requires the following conditions:

- 50 ft^2 n-heptane fire, 0.16 gpm/ft^2 application rate;
- sprinkler type Reliable F1, K-Factor 8.0;
- 15 sec pre-burn, 5 min foam application, 5 min water application, first torch test
- 15 min drain period;
- insert 1 ft^2 stovepipe, second torch test - ignite stovepipe internally;
- 1 min pre-burn; remove stovepipe, measure fire area; must be <20% of total fire area available after 5 min.

MYTHS	REALITY
Fluorine-free foams suffer from fuel-pick compared to AFFF with poor burn-back resistance.	No longer true - foams need to be selected for purpose; there are now products on the market comparable to high quality AFFFs that have an EN1568 1A/1A rating.
Necessary application rates are much higher for F3 foams.	No differences for EN1568, IMO, ICAO, LASTFIRE, AS5062 vehicles. Plus the potential for far LESS generation of firewater with F3.
F3 products do not throw as far and cannot be used on deep tank fires.	Can be solved by operational practice and modern delivery technology such as CAFS (compressed air foam systems).

An interesting recent example of fluorine-free foam use on a large tank fire occurred at Fredericia Port in Jutland, Denmark, in 2016. When a large storage tank containing palm-oil caught fire a lack of local foam supplies necessitated nearby aviation (ARFF) crash tenders attending and quickly and effectively extinguished the fire despite ARFF crash tenders not being ideal for this type of fire with the high energy density palm-oil having time to become heated and fully involved.



Fluorine-free foams were used to combat this storage tank fire in Jutland, Denmark, in 2016.

Key points illustrating the effectiveness of fluorine-free foams during the incident as well as for previous general operations observed and reported by the local Danish Defence Force fire chief after this incident include:

- **Three different commercially available fluorine-free foams** were applied with equal effectiveness.
- **A total of only 3800 liters** of foam concentrate was used.
- **Three different types of aviation crash tenders** (different equipment) were used.
- **Both freshwater and seawater sources** were used.
- **There were no differences in the extinguishing capability** between fluorine-free foams and AFFF-type foams
- **The fluorine-free products had similar throw characteristics** (distance) to fluorinated foams using their monitors.
- Crash tender proportioning systems were easily modified (previously) to cope with the viscosity of fluorine-free foam concentrates.
- **The fluorine-free foam blanket has the same durability** and burn-back time as AFFF.
- **The German Air Force, Billund airport and Esbjerg airport all agreed that fluorine-free foam performance was as good as AFFF.**

The Danish Defence Force fire chief commented: "*When it comes to the extinguishing capability of the fluorine-free foam, there are no differences compared to the old [AFFF]. It works exactly in the same way. The same goes for the reach of our monitors. We can cover objects from the same distance and the foam layer does have the same durability. The burn-back time appears to be comparable to the old foam.*"

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MYTHS	REALITY
Pure C6 firefighting foams have been around since the early 1980s.	*Pure* C6 foams have suffered significant performance problems. High-purity C6 fluorotelomer feedstocks were available as early as the early 1980s but pure C6 formulations have only made it to the market for Class B foams with the appropriate approvals in the last 5-6 years. So-called earlier "C6" foams were "C6-based" meaning they had C6 fluorotelomers as a significant component but depended on augmentation by significant amounts (as high as 35-40%) of C8 and higher chain lengths present to achieve the required performance.
F3 foams cannot be used for fires involving 3D-structures, running pool fires, vertical dripping fires.	Experience in the disaster control industry has shown that there are high quality F3 products available which are perfectly capable of being used for running pool fires as well as large three-dimensional structure fires, especially on vertical surfaces, for example in process plant where film formation is not useful.
Fluorine-free foams have poor burn-back resistance compared to AFFFs.	Even early published data with a first-generation 3M RF6 fluorine-free foam showed that burn-back resistance and extinction performance were completely comparable to PFOS-containing AFFF under the conditions of an ICAO Level B test protocol, both types of foam satisfying the requirements.[4]

TABLE IIIB - ICAO LEVEL B FIRE PERFORMANCE (4.5 M^2 FIRE TEST PAN) USING FIXED NOZZLE

	ICAO Level B	3M Foam RF6	3M Light Water AFFF FC 206CF	3M Light Water AFFF FC 3003
Witnessed by:		DNV (Norway)	SP (Sweden)	ASA (Australia)
Foam Technology		Fluorine Free	PFOS	PFOS
Solution Strength	6%	6%	6%	6%
90% Control		30 s	38 s	-
Extinguishment	<60 s	46 s	46 s	50 s
Burn Back Time	>5:00	>8:00	>8:00	7:06

From T.H. Schaefer (2002)

MYTH	REALITY
F3 foams do not have the same long drainage times as AFFFs.	False. Comparisons carried out by Williams et al (2011), working for the US Department of the Navy Naval Research Laboratory (NRL), compared a re-healing foam with two AFFFs and found that the drainage times for the fluorine-free product far exceeded those of the AFFFs.[5]

TABLE I - EXPANSION RATIOS AND 25% DRAINAGE TIMES OF FOAMS (MIXED AT NOMINAL STRENGTH IN FRESH WATER) AND TESTED ACCORDING TO MIL-F-24385F

Foam	Expansion Ratio	25% Drain Time (s)
National Foam 6-EM	9.0	262
Buckeye BFC-3MS	9.4	360
Solberg (3M) RF6	10.3	> 720 (no drainage observed)

From Williams et al (2011)

More recent measurements of burn-back times for later generation F3 products give drainage times far exceeding AFFF indicating a stable foam blanket. A proprietary current generation F3 gave far longer drainage times compared to AFFF and AFFF-AR under the conditions of the UL162 protocol on n-heptane:

- fluorine-free foam 3% rated induction, 30-75 min;
- fluorine-free foam 6% rated induction, 45-90 min;
- 3% AFFF, 3-4 min;
- 3x3 AFFF-AR, 6-16 min;
- 1x3 AFFF-AR, 11-14 min.

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MYTH	REALITY
Fluorine-free foams have inferior vapor suppression performance under operational conditions.	A claim apparently seized upon from a single academic paper describing very small-scale flux chamber tests under artificial laboratory conditions.[6] Under more realistic conditions Williams et al (2011)v showed that the sample of re-healing foam (RF6 outlined below) was essentially indistinguishable from the two AFFFs tested across the three hydrocarbon fuels tested, i.e., iso-octane, heptane and methyl-cyclohexane. This exemplifies the importance of using realistically scaled test scenarios and not relying overly on laboratory scale testing.

TABLE V - STEADY STATE VAPOR CONCENTRATIONS AND FOAM BLOCKAGE FACTORS

Foam	Fuel					
	Iso-octane		Heptane		Methylcyclohexane	
	vapor conc.	blockage factor	vapor conc.	blockage factor	vapor conc.	blockage factor
None	20900		28800		14600	
National	950	22.0	2450	11.8	1400	10.5
Buckeye	1400	14.9	1750	16.5	2850	5.1
RF6	950	22.0	2700	10.7	1900	7.7

From Williams et al (2011)

MYTH	REALITY
Safety Data Sheets (SDSs) provide sufficient information for an end-user to carry out a suitable and sufficient assessment of environmental risk (SSAER) especially for fluorinated foams.	SDS are mostly inadequate to misleading. With a very few notable exceptions, manufacturers' SDS are inadequate as source material for the end-user to carry out an SSAER (Suitable and Sufficient Assessment of Environmental Risk) or for incident responders to assess and put in place appropriate measures.

Safety data sheets are assumed to be reliable by end users who rely heavily on them to assess risk and put in place appropriate day-to-day measures and incident contingency plans. Similarly, incident responders have the expectation that an SDS will provide essential information for environmental management considerations. For the assessment of potential adverse effects SDS are almost universally deficient in one or more of the following:

- **Isolated component's data only provided** (e.g., solvents) with no testing of the formulation as-sold to the end-user with synergistic effects that contribute to risk ignored.
- **Fluorosurfactants or fluoropolymers not mentioned** or glossed over in spite of the feedstock manufacturers clearly stating that the products must not be discharged to the environment and are environmentally persistent.
- **Over-use of the term "not available"** for data for even the most basic parameters.
- **BOD/COD data inaccurate or absent**, with complete biodegradability claimed for AFFF products despite persistent fluorosurfactants being present and common knowledge that the OECD approved chemical oxygen demand (COD) analytical method is incapable of oxidizing the C-F bonds.
- **Mislead users that PFAS can be discharged to sewer** for standard wastewater treatment. PFAS are not captured or degraded in wastewater treatment plants (WWTPs) and will ultimately pass through to contaminate effluent irrigated or released to waterways and bio-solids used for soil and crop application.
- **Referring users to "local EPA" for advice** on incident response and disposal for products with inadequate SDS information, especially AFFF/FP/FFFP foams with "proprietary" secret formulations including persistent fluorochemicals that the local EPA will have no knowledge of and would have the same expectations as the users and responders that the SDS is comprehensive and accurate.

MYTH	REALITY
Published approvals for some fluorine-free foams do not accurately reflect performance.	Marketing desperation. All foams are required to be independently tested and certified on the basis of product sampled from an unopened as-sold container. This applies to AFFF /FP/FFFP as much as to F3. End users should satisfy themselves as to the *bona fides* of the supplier and reliability of any composition and performance test results. "Test results" and claims by a supplier about a competitor's foam should be regarded with great suspicion.
F3 foams suffer from fuel pickup and reduced burn-back caused by the presence of hydrocarbon surfactants when used operationally.	In order to work all foams need to be appropriately applied in terms of the foam type, equipment used and the training of the firefighters. Fuel pickup for any foam is simply avoided by trained and competent firefighters as part of normal application methods by not using a "plunging jet" foam stream.

Although fuel pickup can be demonstrated under artificial laboratory conditions, firefighters are trained to avoid the use of a 'plunging jet' which disturbs the foam fuel interface and to use normal application methods in which the foam solution is allowed to flow over the burning liquid surface. Proper application is achieved by bouncing the foam off a vertical surface such as a wall or tank.

Recent video footage from comparative tests of an F3 and an AFFF MIL-Spec product on a pool fire at Dallas Fort Worth (DFW) Fire Training Academy shown at the recent LAST-FIRE conference in Budapest in October 2017 by the DFW Fire Chief Brian McKinney, showed no significant differences in performance between F3 and AFFF. Most notably the particular F3 foam used gave a stable foam blanket without re-ignition even after being disturbed and being exposed to a propane torch [McKinney LASTFIRE Budapest Meeting (October 2017)].

Flammable liquid fires in depth, such as occur with storage tanks, require the use of a technique referred to as 'top-pouring' in accordance with EN13565-2 (2009) or sub-phase injection to apply foam in a gentle manner without disturbing the fuel surface, in particular for water-miscible fuels - mainly polar solvents like alcohols, e.g., methanol, ethanol, isopropanol, and ketones such as acetone or methyl-ethyl ketone (MEK). Although gasoline (vehicle fuel) is itself not water-miscible, the high-ethanol blends such as E5, E10, E15 and E85 are in part. They contain, respectively, 5%, 10%, 15% and 85% denatured ethanol.

Disturbing a hot fuel surface covered by a foam blanket, whether by inappropriate application of a forceful foam or water jet, or by other means such as walking through it, would anyway in general be considered at best bad fire service practice, at worst extremely foolish.

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2. ACUTE AQUATIC TOXICITY VERSUS BIOCHEMICAL OXYGEN DEMAND (BOD) & CHEMICAL OXYGEN DEMAND (COD) FOR FIREFIGHTING FOAMS

Acute aquatic toxicity for firefighting foams has been much vaunted by the fluorochemical industry and trade associations to 'prove' that fluorine-free foams are some "ten times" more toxic that AFFFs. This is a completely disingenuous argument since all firefighting foams, whether F3 or AFFF, exhibit very low acute aquatic toxicities of >100 mg/ml and would therefore be classified under the USFWS system as practically non-toxic or relatively harmless – see table below.

Moreover, because acute aquatic toxicities are measured under the OECD Protocol [OECD 203, 1992] which requires a maintained oxygen saturation of at least 60% during the test, this makes the standard acute toxicity test fairly meaningless when assessing overall "toxicity" where the significant concurrent effect of biochemical oxygen demand (BOD) that kills by depleting dissolved oxygen levels is masked by the artificial aeration of the test and may not even become apparent over the short duration of the standard acute toxicity test.

In terms of the effects of firefighting foams minor differences in very low acute toxicities are not nearly as important as the largely unrecognized very high biochemical oxygen demand (BOD) and chemical oxygen demand (COD) of all firefighting foams, whether AFFF (on average ~440,000 mg/L) or F3 (on average ~330,000 mg/L).

US Fish and Wildlife Service toxicity scale. Aquatic EC50 or LC50 (freshwater).

	Effective concentration
Toxicity Category	**Range (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 –1,000
Relatively Harmless	> 1,000

High BOD is the most significant characteristic of foam that can cause an acute, short-term "toxic" effect in waterways. The high BOD potential of all firefighting foams arises from the high degradable organics content (~30%), such as solvents, detergents, carbohydrates, proteins and saccharides (excluding persistent, non-degradable, organic fluorochemicals of course). The rapid reduction in the concentration of dissolved oxygen in the receiving body of water by BOD is the primary effect that can produce immediate damage to all aerobic biota.

When there is a release of any organic material to a waterway the BOD effects are delayed as the microbes present take time to adapt to degrade the organic content. Consequently, there is a delay period of one to several days before BOD related oxygen depletion effects escalate. This delay means that there is the opportunity for flushing or flow in the waterway to disperse and dilute the foam before significant oxygen depletion occurs. Accordingly, enclosed or semi-enclosed waterways such as shallow streams, pools and ponds are at greatest risk from BOD-induced oxygen depletion due to limited water volume for dilution and low flow for flushing and turnover.

Keeping in mind the massive BOD potential of all firefighting foams, even when diluted for application (1%, 3%, 6%) and further diluted on entering a waterway to say 100s of ppm (sewage ~300-400 ppm) then normal dissolved oxygen levels of 6-9 ppm only need to be reduced by a few ppm for fish 'kills' and damage to other biota to be inevitable (see scale below).

SCALE

Additional toxic effects can also occur as a result of partial biodegradation, for example, foams containing protein, such as fluoroprotein (FP) or film-forming fluoroprotein (FFFP) products, can act as a nutrient source for toxic dinoflagellate blooms as well as generating highly toxic ammonia through the degradation of the protein.

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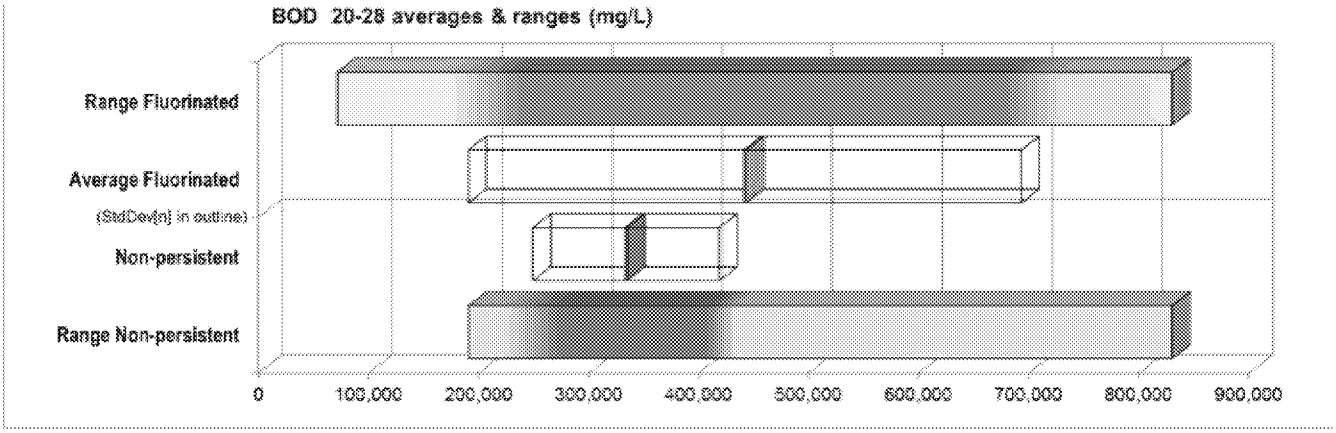
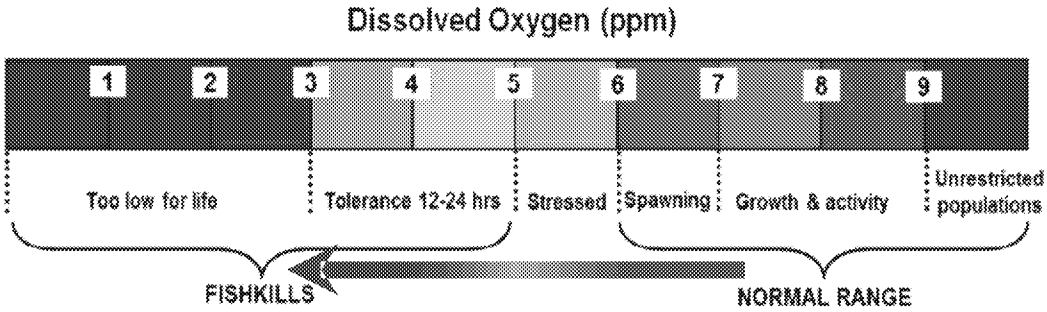
Klein & Holmes review of firefighting foam BOD (2016). Range, mean and standard deviations.



Dissolved oxygen effects on aquatic animals in natural water bodies (ppm ≈ mg/L). Adapted from Dissolved oxygen in water - Water Research Center, Dallas, Pennsylvania



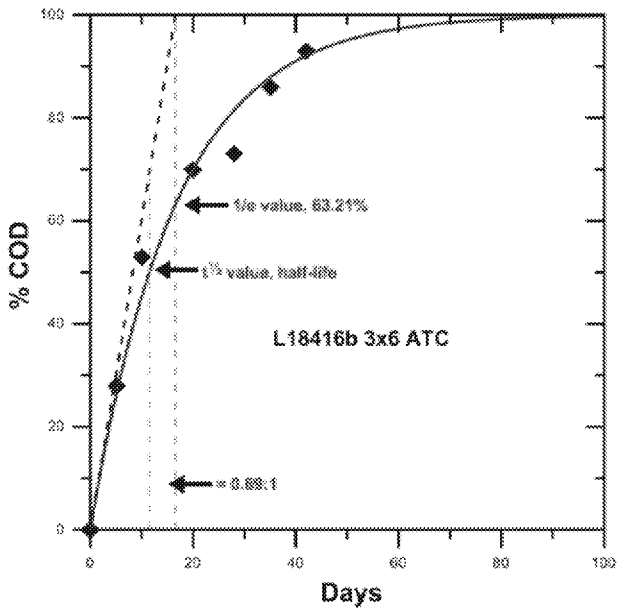
Effectively all firefighting foams share approximately the same extent of acute toxicity and BOD effects. The major distinction is that fully biodegradable fluorine-free foam effects are temporary and largely self-remediate while fluorinated AFFF/FP/FFFP foams will leave behind permanent, dispersive pollution by PFAS compounds.

Leaving aside the PFAS contamination aspect all foams suffer from the same logical dilemma for BOD effects in aquatic environments given their very high organic content.

- On the one hand rapid biodegradation in the environment is desirable to limit dispersal and allow early recovery and normalization.
- On the other hand, acute oxygen stress should be as low as possible through delayed degradation in order to limit immediate damage to biological organisms.

These two requirements are self-contradictory. In the case of all foams where the concentrate BOD potential is very high it will remain high even when diluted in use (1%-6%) and further on entering a water body. A delay period for degradation that would be sufficient to keep BOD below a few ppm would need to be considerable.

Rapid degradation results in high acute oxygen stress, whereas low acute oxygen stress means relatively slow degradation. This is illustrated in the figure shown below for foam degradation.



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Rapid degradation shifts the curve to the left with an increase in acute oxygen stress (determined by the slope of the curve at zero time – effectively the BOD5 value), whereas a low acute oxygen stress shifts the curve to the right but means that biodegradation is necessarily slower. There cannot be both low acute oxygen stress and rapid degradation at the same time unless the initial organic content is very low, far below any BOD/COD values seen for foams.

Examination of a database of BOD and COD values assembled for over 90 commercially available Class B firefighting foams [Holmes and Klein, 2016] shows that in many cases there is no effective difference in BOD or COD values for non-persistent fluorine-free (F3) or fluorine-containing (AFFF, FP, FFFP) firefighting foams.

Moreover, current developments in solvent-free F3 products [3FFF Corby, quoted by Weber *et al.* 2018 – see Appendices] reduce BOD and COD substantially by about 50% making any distinction between F3 and AFFF products even more striking. The development of solvent-free (SF) firefighting foams – see Appendices (Thierry Bluteau) - substantially reduces BOD and COD, and thus the potential for imposed oxygen stress on the receiving environment, by approximately 40%-60% compared to standard AFFF or F3 products.

A caution for end-users, responders and regulators, is that many SDS and product information publications make statements about the "high" degradability of their particular foam without mentioning highly stable end-point products; this is likely to be misinterpreted as being assurance that there are no persistent components that would leading to on-going pollution risks. Standards set for describing a product as "biodegradable" are not stringent (~60% of COD) and are irrelevant for fluorosurfactants.

All fluorochemical-containing foams cannot biodegrade completely because of the chemical stability of perfluorinated end-products, mainly perfluoroalkyl carboxylic acids (PFCAs) and sulfonic acids (PFSAs). The COD value used in statements of biodegradability for fluorinated foams is highly misleading in terms of indicating whether degradation approaches 100% or not as standard procedures using aqueous acid dichromate as the oxidant will fail to detect highly environmentally persistent fluorinated organic material which may be present in significant quantities.

As new technologies evolve to transition away from persistent fluorinated organics foam users should also be aware of the possibility that alternative persistent compounds such as silicon-containing surfactants (e.g., siloxanes) may have been substituted in a fluorine-free formulation especially where products claim exceptional performance on polar solvents, e.g., EN1568 1A/1A certification. By way of example of a such new risk emerging, some silicon surfactants and/or their degradation products, depending on structure but especially those that are cyclic, may be environmentally persistent and potentially endocrine disruptors, and thus undesirable alternatives to fluorosurfactants.

ON AVERAGE, THEREFORE, WITH SPECIFIC PRODUCT-DEPENDENT EXCEPTIONS, THERE APPEARS TO BE NO ENVIRONMENTALLY SIGNIFICANT DIFFERENCE IN SHORT-TERM EFFECTS TO DISTINGUISH FLUORINE-FREE (F3) FOAMS FROM AFFF-TYPE FOAMS (AFFF, FP, FFFP AND AR VARIANTS). THIS MAKES F3 NOT ONLY A VIABLE ALTERNATIVE TO AFFF BASED ON PERFORMANCE BUT HIGHLY DESIRABLE BASED ON THE GROUNDS OF ENVIRONMENTAL IMPACTS BEING LIMITED TO SHORT-TERM, LOCALISE EFFECTS WITH NO LONG-TERM EFFECTS.

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3. EXPOSURE, CHRONIC TOXICITY AND ENVIRONMENTAL PERSISTENCE

Chronic toxicity effects become increasingly more likely with chemically stable, environmentally persistent substances such as perfluorinated end-point compounds resulting from transformation of fluorochemical-containing foams.

Chronic exposure is usually defined as > 96 hours (4 days) which is very short compared to the indefinite environmental persistence of perfluorinated end-products. PFCAs and PFSAs have physical half-lives in environmental compartments such as soil and water certainly measured in at least decades to centuries based on their presence long after sites were last used, probably far longer.

The industry claim that fluorosurfactants readily "degrade". This is wholly misleading. While some components of the complex fluorotelomers used in the original formulation partially "degrade" they more correctly "transform" to ultimately yield extremely stable, perfluorinated end-point substances which are persistent and do not degrade further. It is worth noting that the transformation pathways are often complex with various intermediate fluorinated compounds such as fluorotelomer acids, aldehydes and ketones, that have potentially greater adverse effects than the initial or end-point compounds.

Exposure Types in General

- Acute: Short term (96 hours or less)
  - Severe effects
  - Rapid response to toxicant
  - Mortality endpoint (e.g. LC_{50})
- Chronic: Long-term exposure (> 96 hours)
  - Mild effect
  - Gradual response to toxicant
  - Sublethal endpoints (growth and reproduction are most common)
  - Examples: Early Life Stage (ELS), partial and complete Life Cycle, and Bioaccumulation Tests.

Types of acute and chronic exposure are listed in the table above [USFWS]. Chronic effects may be insidious with long latent periods. It is often difficult to establish direct cause-and-effect relationships between a suspected toxic material and an identifiable disease – for example, the now well-established direct relationship between exposure to blue asbestos fibres and pleural mesothelioma or more general effects such as diesel particulates and respiratory disease. Conventional toxicity testing does not generally account for sensitive low-dose endocrine and neuroendocrine effects.

Probable links between exposure and biological effects, which may include increased likelihood of a disease or other pathological condition developing, e.g., a predisposition, for example, to developing diabetes or immunologically related defects such as reduced vaccination response, are established based on epidemiological data. Interpretation may be complicated by confounding factors such as the presence of other toxic materials or pre-existing conditions, or by sampling bias. Establishment of a probable link means that a relationship between exposure to a particular substance and development of a specified condition are more probable than not, i.e., the probability of direct link is >50%that is "*more likely than not*" [3M medical director, Dr Carol Ley]. However, given the scientific uncertainty involved it is necessary, and a legal obligation under international convention, for regulators and enforcing authorities to apply the Precautionary Principle.

3.1. THE PRECAUTIONARY PRINCIPLE

The Precautionary Principle was established under the Rio Declaration on the Environment 1992 [Principle 15] and places particular obligations on users, manufacturers and regulators in terms of the product content, allowable uses, management considerations and decision making that are pertinent to any potential for adverse impacts, especially in the long term. The precautionary approach is affirmed in Article 1 of the Stockholm Convention.

Recent legal judgements have made clear the considerations necessary to meet the intent and obligations under ESD and the Precautionary Principle as required by legislation in many jurisdictions. Chief Justice Brian Preston (NSW Land and Environment Court) summarized the current legal precedents regarding application of the Precautionary Principle and how they specifically apply to the issue of PFAS in firefighting foam (White paper, CJ B. Preston, Queensland End User Firefighting Foam Seminar, 2017).

A current absence of evidence for an adverse effect by a product or activity is not proof that there will be no effect unless it is demonstrated by relevant, comprehensive and definitive studies. The burden of proof lies with the proponent of a new technology or activity to show that it will not cause significant harm. While this is a significant matter for

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regulators and policy setters, ultimately the end-user is the "proponent of the activity" and is also obliged to take this into account.

Where there is insufficient scientific evidence upon which to base a decision a conservative or precautionary approach must be taken, especially if there are suspicions, indications or reasonable scientific plausibility of possible adverse effects, especially if they are likely to be serious and irreversible in the long term.

There is ample emerging and significant evidence, well above that of suspicions and indications that PFAS have significant potential to cause short-term and long-term adverse socio-economic, environmental and health effects, especially where the use is highly dispersive and involves large quantities such as firefighting.

ASSESSMENT OF FIREFIGHTING FOAMS AGAINST THE PRECAUTIONARY PRINCIPLE ELEMENTS

Assessment element	Persistent toxic compounds	Non-persistent toxic compounds
Spatial scale of the threat	Local, regional, state-wide, national & global threat via dispersion and long-range transport. Wide dispersal over the long-term through air, soils, surface water & groundwater.	Immediately adjacent areas likely to be adversely affected. Wider dispersion & impacts limited by short half-life and rapid biodegradation.
Magnitude of possible impacts	Wider socio-economic, environment & human health impacts through high-level or enduring low-level exposure & increasing build-up over time including by bioaccumulation/ bioconcentration.	Local aquatic environment impacts & short-term direct exposure risks. Mitigation by rapid biodegradability.
Perceived value of the threatened environment	High perceived values for natural environment including food-chain, socio-economic values & long-term human health.	High perceived value for local natural environment. No significant lasting socio-economic or health implications.
Temporal scale of possible impacts	Long-term exposure - Effects lasting decades to inter-generational.	Short-term - Weeks to months.
Manageability of possible impacts	Very difficult to impossible to manage once chemicals have been released. Very high cost of remediation. Flow-on economic & social impacts at local & broader levels. Small spills contribute to build-up & wider exposure in the long-term.	Local relatively short-duration treatment or natural biodegradation & recovery processes. Low to moderate costs.
Public concern & scientific evidence	Worldwide established concerns & mounting scientific evidence of adverse social, economic, human health and environmental effects for PFAS. Uncertainty about the identity & safety of proposed alternative fluorinated & other persistent compounds with rapidly growing evidence of adverse effects.	Limited concern based on well-established evidence & knowledge of the behavior & effects of components.
Reversibility of possible impacts	Not reversible, very long-term or high cost for remediation where possible.	Reversible with basic remediation or natural recovery.

After Queensland Environmental Management of Firefighting Foam Policy Explanatory Notes (2016)

IPEN

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4. CONTAMINATED RUNOFF, WASTE DISPOSAL, REMEDIATION

In most jurisdictions that have a strongly developed environmental protection regime solid and liquid fluorochemical-contaminated wastes have to be disposed of and destroyed as regulated industrial waste by a licensed waste disposal operator. This continues to be an expensive process for PFAS as high temperature incineration or environmental immobilization have been and are currently the commonly used methods of waste management.

The use of firefighting foam is by its very nature highly dispersive. Moreover, firefighting foams account for ~32% of the annual global tonnage of fluorotelomer production (~26,500 tons) controverting previous public claims by the industry of less than 5% in support of their claim of minor environmental concern. This proportion of production used in firefighting foam has been stable for many years and is comparable to that used for the treatment of textiles. In addition, fluorotelomer production is predicted to continue to rise by ~12.5% per annum (MEA revenues in USD.)

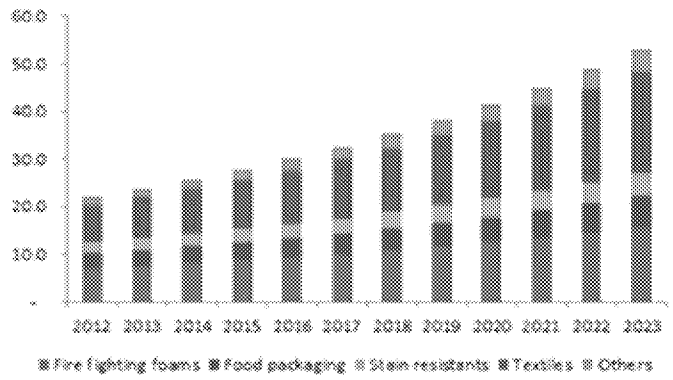
Fluorotelomer-based AFFF Class B firefighting foams have replaced older PFOS-based formulations. Additionally, older fluorotelomer technologies based on predominantly C6/C8 products are being replaced by purer C6 material, although significant firefighting performance issues remain. These include reduced burn-back resistance as well as, for example, an inability to achieve appropriate ratings for subphase injection, of importance for in-depth tank fires in the petrochemical industry.

During the operational use of firefighting foams, it may not be practicable to contain the very substantial quantities of firewater runoff that are produced, except at fixed sites with engineered impermeable bunding and drainage systems. Elsewhere potentially large quantities of runoff will enter the environment inevitably contaminating groundwater aquifers, rivers, streams, lakes and the marine environment. The quantity of contaminated runoff produced at a large incident may be enormous in the range of tens of millions of liters [Buncefield, 2005] and substantially uncontained.

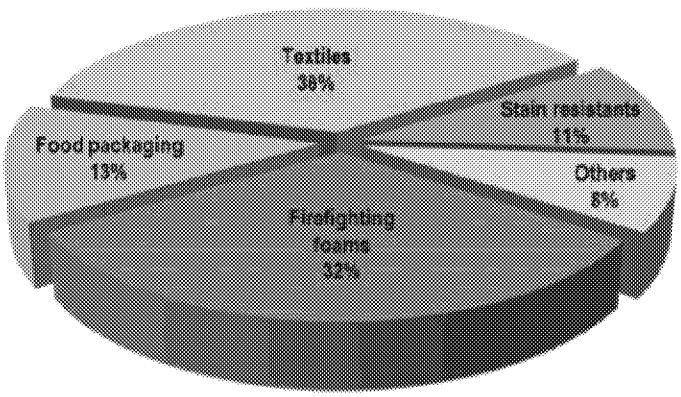
In order to appreciate the very considerable volume of foam solution and cooling water required to control or extinguish a *single* large tank fire it is necessary to be aware that an 80-meter diameter storage tank with a surface-area of 5000 m^2 would require:

- nearly 70,000 liters of foam applied per minute
- a total of at least 4,000,000 liters of foam
- use of ~250 tons (250,000 L) of a 6% foam concentrate
- large quantities of additional cooling water for the tank sides and pipework.
  [recommendations in accordance with EN135652 (2009)]

The use of 250 tons of a modern 6% fluorotelomer concentrate containing somewhere between 0.5% and 1% total fluorine, equates to the dispersive release of approximately 1250-2500 kilograms of fluorinated material into the environment unless completely contained. Stocks of older foam formulations that are still in use have higher fluorine content, especially those containing PFOS, and would result in even higher release of fluorinated material.



https://www.gminsights.com/industry-analysis/fluorotelomers-market



Fluorotelomer production: Global Market Insights 2016 (2015 total 26,500 t).

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The risk of release of persistent organic pollutants does not exist with the use of fluorine-free foams and release to the environment where firewater cannot be fully contained is tolerable in an emergency. With fluorine-free foams (F3) discharge to foul water sewers or the environment does not result in long term impacts; moreover, remediation costs are minimal or close to zero with little disruption of or impact on societal infrastructure.

4.1. EXAMPLES OF LARGE VOLUME PFAS-CONTAMINATION IMPACTS

4.1.1. Australia

Coode Island (Victoria)

In 1991 lightning caused a fire at the Terminals chemical storage facility at Port of Melbourne in Australia involving about 8.5 ML of hydrocarbons including acrylonitrile, phenol, methyl ethyl ketone and benzene. The firefighting response over several days used 200 tons of 3M LightWater™ PFOS-based foam with an estimated release of 1000 to 3000 kg of PFOS to the adjacent mostly enclosed Port Phillip Bay.

While this large-scale release of PFOS was in 1991, prior to the recognition of environmental and health problems with PFAS, the implications are that had fluorine-free foam been used any adverse effects would have been resolved within a few months versus concerns about the ongoing presence of PFOS and PFHxS in the aquatic environment that may have had an long-term effects on the quality of wild-caught commercial and recreational fish species as well as the long-established mussel farms.

Department of Defence Sites

The Australian Defence Forces army helicopter air base at Oakey in Queensland used 1.43 million liters of AFFF concentrate over a period of 25 years as part of intensive regular fire service training for the hot-refuelling of aircraft. Hot-refuelling takes place whilst the helicopter rotors are still running often with munitions hanging off the underside of the aircraft.

This is foam use equivalent to discharging approximately one 1000L IBC (Intermediate Bulk Container) of AFFF concentrate to the environment in an uncontrolled way every week for a quarter of a century! This means that, depending on the original fluorochemical concentration, somewhere in the region of between 10 and 100 kilograms of fluorinated material were released polluting the environment every week.

Firewater runoff was discharged directly to the surrounding ground and drains resulting in serious fluorochemical contamination, mainly PFOS and PFOA based on analyses, of the groundwater with an expanding down-gradient plume. This has affected both the urban township areas as well as agricultural land and groundwater bores used for drinking water, domestic purposes and irrigation. The impacts of the contamination are currently subject to a class action brought by affected residents against the Australian Department of Defence covering significant losses of resources, amenity, land value and human health impacts.

A number of other sites close to Australian DoD airbases have been similarly affected including Williamtown (NSW), Katherine (Qld), Townsville (Qld), Amberley (Qld) and Edinburgh (SA).

Groundwater beneath Perth International Airport in Australia has recently been reported to be heavily contaminated with PFAS from firefighting foams.

SIGNIFICANT PFAS CONTAMINATION AT AIRPORTS FROM FIREFIGHTER TRAINING AND CRASH TENDER MAINTENANCE PROCEDURES USING AFFF TYPE FOAMS OVER THE LAST 30-40 YEARS IS BECOMING A GENERALITY WORLDWIDE. WHEREVER MEASUREMENTS ARE TAKEN NEAR CRASH SITES OR FIRE TRAINING AREAS PFAS CONTAMINATION IS BEING FOUND. IN SOME INSTANCES GROUNDWATER CONCENTRATIONS FOR FLUOROCHEMICALS USED IN FOAM AND THEIR TRANSFORMATION PRODUCTS REMAINED EXTREMELY HIGH EVEN DECADES AFTER SITES WERE LAST USED, ESPECIALLY IF THE GROUNDWATER AQUIFER IS DEEP AND ANOXIC.

Maintenance and hangars - Qantas (Queensland)

In April 2017 a foam deluge system in Hangar 3 at Brisbane International Airport (BNE) discharged 22,000 liters of a fluorinated foam concentrate when a brass pressure gauge attached to galvanized steel pipework failed due to electrolytic corrosion. This accident was totally foreseeable and represented poor design and maintenance.

The foam discharge entered the storm drains and from there Myrtle Creek and the Brisbane River contaminating the inshore marine environment. As pointed out in one of the Appendices, remediation and clean-up costs are substantial whereas at a second incident on the same site twelve months later but involving fluorine-free foam (F3) remediation costs were minimal as the foam was contained. Had there been a need to deal with runoff contaminated by fluorine-free foam that could have been treated on-site and in the case of a release to the adjacent waterway, any adverse effects would likely have been minimal and short term with no need to restrict recreational and commercial fishing uses as happened with the previous spill.

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4.1.2. United Kingdom

Buncefield

The fire at the Buncefield Hertfordshire Oil Storage Terminal (HOST) on 11 December 2005 was a major incident caused by a number of explosions which eventually destroyed 20 large storage tanks. The site was the fifth largest petrochemical storage depot in the UK, with a total capacity of some 270 million liters of fuel. The initial explosion was caused by the detonation of a vapor cloud produced by leaking fuel thought to have been initiated by turbulence created by local vegetation, and registered 2.4 on the Richter scale rivalling the Flixborough explosion in 1974 and counting as one of the largest explosions in peacetime Europe.

The immediate economic effects of the Buncefield incident were because the terminal supplied ~30% of London Heathrow aviation fuel and this necessitated immediate rationing of aviation fuel causing some long-distance flights to stop-over at other airports before landing in order to re-fuel. Fuel shortages continued for months after the initial incident. There was considerable business disruption locally with commercial buildings having to be demolished because of the damage. At this stage the long-term socio-economic and environmental effects of the release of large volumes of PFAS to the soils, groundwater and waterways were not evident, although as mentioned elsewhere in this paper, the groundwater aquifer supplying the Greater London area remains unusable to this day.

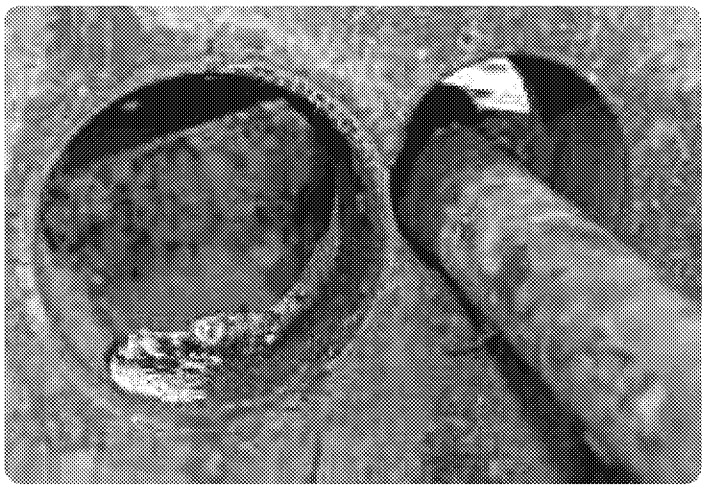
The incident had been brought under control by the afternoon of 13 December but in the meantime some 700-800 tons (700-800,000 liters) of foam concentrate had been used by the Fire Service. Initially some 32,000 liters of foam per minute were directed at the fire for about four hours (around 8,000,000 liters) after which the rate was reduced. Initially some legacy PFOS-based foams were used before being prohibited by the environmental regulator.

Ultimately there were some tens of millions of liters of foam and fuel contaminated firewater runoff, a substantial proportion of which breached containment bunding and contaminated the Greater London drinking water aquifer with PFAS resulting in continuing restrictions on its use now 13 years later and for some years to come. Primary containment bunding around the storage tanks failed because bund wall and pipework seals dissolved in hot hydrocarbon-contaminated runoff and failed catastrophically [see below].

4.1.3. Germany

Düsseldorf

Düsseldorf International Airport (DUS) located in a northern part of the city close to the River Rhine (subject to the Rhine Waters agreement between neighboring states) was found to have seriously contaminated the groundwater; remediation costs are estimated as possibly reaching 100 million Euros.



Catastrophic failure of primary containment bunding. © UK Health and Safety Executive

http://www.derwesten-recherche.org/2013/10/pft-alarm-am-flughafendusseldorf-verseuchung-noch-extremersanierung-konnte-100-millionen-kosten/

Remediation and control costs for a fire at which 43,000 liters of AFFF concentrate were used are assessed at 1-10 million Euros, whereas an ongoing case in Baden-Württemberg involving soil exchange are likely to be as high as 1-3 billion Euros.

http://www.faz.net/aktuell/wissen/badenwuerttemberg-chemische-abfaelle-aufdem-acker-14419295.html

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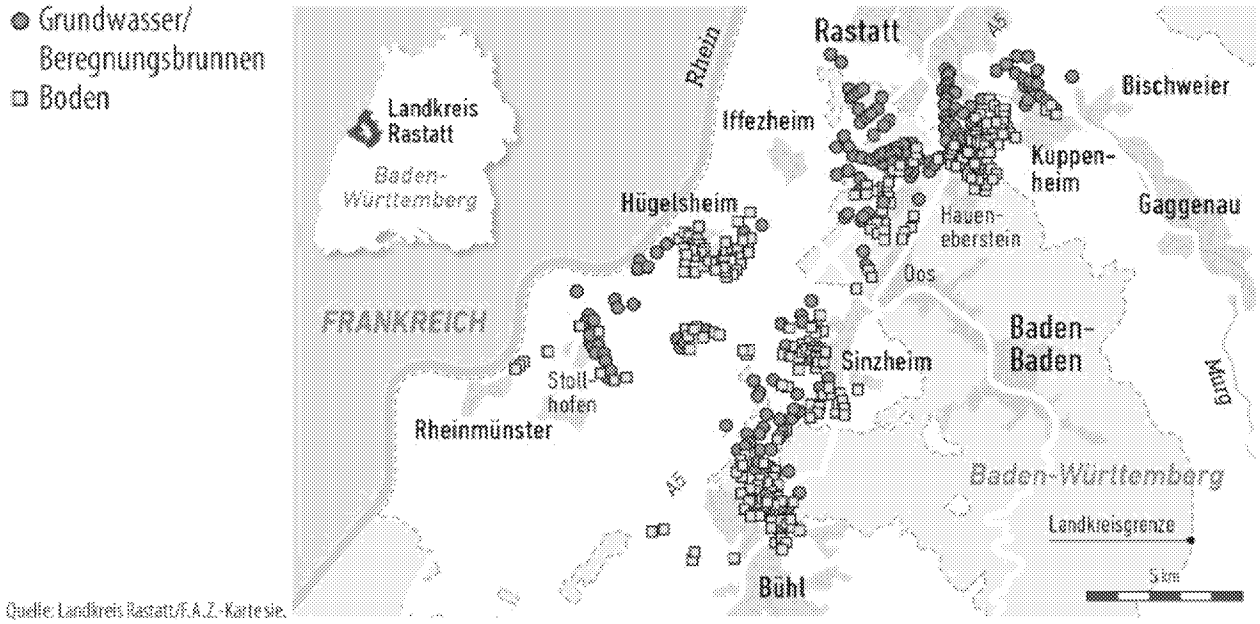
Messstellen mit PFC-Belastung



Quelle: Landkreis Rastatt/F.A.Z.-Karte sie.

Nürnberg

Contamination of former fire training and crash tender maintenance areas has resulted in serious pollution of the groundwater. Remediation costs are substantial and ongoing. Initial costs are estimated are around 10 million Euro and rising. Interestingly the airport fire service has solved the problem of being required to test crash tender foam monitors regularly under ICAO rules in a novel way by building an enclosed sloping pit with built-in drainage and storage tank usable in all weathers. The structure would be familiar to any farmer as very similar to a silage pit.

Möhnetal and Ruhrtal Water Catchment Area

In 2006 as a result of a single farmer at the head of the Möhne valley (Möhnetal), Hochsauerland Kreis (HSK) in Nord-Rhein Westfalen in Germany, using contaminated bio-sludge on a relatively small area of fields, the entire Ruhr valley water catchment area became contaminated affecting a large number of water treatment plants supplying a conurbation of some 5-6 million people. This resulted in a legal case in which a director of the company responsible for supplying the contaminated product was prosecuted. More importantly, remediation costs have been very high, are ongoing and the farmland remains out of use some twelve years after the contamination occurred. Interestingly, a similar situation has arisen in the years following the major incident at the Buncefield oil storage terminal in December 2005 in which, in this case, a major source of drinking water for Greater London remains unusable many years later due to PFAS contamination. As stated by Matt Gable of the UK Environment Agency in a recent article (International Fire Fighter pp.36-38 September 2017) "*...During the course of the fire, the containment bunds cracked and allowed fire water, contaminated with PFOS foam and fuel products to soak in to the underground water table. This Aquifer is an important public drinking water source for the Greater London area, but due to the contamination it is no longer available as a water supply and will remain unusable for several more years due to the bio-accumulative nature of PFOS type chemicals....*"

4.1.4. United States of America

There have been a very large number of PFAS contaminated sites identified across the US affecting soils, surface water and groundwater including manufacturing sites and Department of Defence bases. Apart from remediation costs there have been, and are ongoing, very expensive legal cases and class actions. Drinking water supplies have been contaminated with individual States, such as Minnesota, New Jersey, Vermont and Washington State, continuing to reduce the permissible levels of contamination for PFOS and PFOA significantly below the levels currently recommended as a lifetime health advisory by the US Federal EPA. In 2018, Washington State passed a state-wide ban or strict controls on products containing PFAS, including firefighting foams, effective after a two-year period of grace.

4.1.5. Hand-held and portable extinguishers

Hand-held, portable and vehicle-mounted foam extinguishers have not been regarded as a significant source of PFAS contamination due to their individual small sizes ranging from about 9 liters to 90 liters. However, there has been the realization that the very poor management practices relating to use and maintenance these extinguishers have

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resulted in overall large-scale, albeit diffuse releases of PFAS to the environment.

Following very poor product management advice from suppliers and manufacturers the extinguisher service agents and end-users have been dumping PFAS foam wastes directly to the ground (e.g., mining vehicle on-site test firing and wash-out) or to sewer (in the case of service agents refilling retail extinguishers) in the mistaken belief, based on supplier's advice, that the products will fully degrade or that wastewater treatment plants (WWTPs) will be able to capture and/or treat the PFAS wastes. Similarly, the retail end-user of hand-held extinguishers is not aware, and is not advised of the need to fully contain PFAS wastes and dispose of them as regulated waste. In all cases the release of PFAS is directly or ultimately to the environment, or to irrigation and biosolids with application to crops.

Recent developments in hand-held and vehicle extinguisher technology have meant that fluorine-free foams (F3) can now be used in both hand-held and portable extinguishing equipment with the ability to achieve the appropriate ratings (Appendices - Gary McDowall).

From a socio-economic point of view the very large numbers of hand-held and portable extinguishers in unregulated use by the public and being serviced by ignorant or unscrupulous agents represent significant releases of PFAS wastes and broad exposure of socio-economic values that are already being felt through increasing "orphan source" levels of PFAS in waterways affecting fisheries and aquaculture. Added to this is the increasing risk and cost now being experienced by government infrastructure service providers whose sewers, effluent and biosolids are being contaminated by PFAS to the extent of not only being unsuitable for beneficial reuse on crops but also representing considerable extra treatment and disposal costs that can only be passed on to the community.

With stricter and appropriate regulation of PFAS use and disposal the net economic and environmental cost benefits will strongly favour 3F hand-held and portable extinguishers over AFFF. This is already becoming a reality for the mining sector in Australia, and many operators have transitioned to fluorine-free foams to minimise the risks and their liabilities and to take advantage of the far simpler and much more economic, low risk and practical management practices associated with F3 use.

4.1.6. Disposal of firefighting foam wastes

There are very large differences between the costs and effort required to dispose of fluorinated organic foams versus non-persistent fluorine-free foams. Fluorinated organic compounds are very difficult to dispose of given that standard treatment methods are completely unable to destroy or capture them and their indefinite environmental persistence means they cannot be left in place to degrade or stored in situations where they may escape in the long term - by comparison, fluorine-free foams have numerous standard options available for the treatment and disposal of their biodegradable wastes that are likely to be compatible with treatment processes needed to deal with other contaminants from incidents such as fuels and combustion products. Fluorine-free foam being composed primarily of organic substances such as hydrocarbon detergents, carbohydrates, saccharides and organic solvents, any process capable of biodegrading these components is suitable. The disposal options for fluorine-free foams range across:

- on-site biodegradation in effluent holding ponds
- irrigation to open ground to soak in and biodegrade
- local wastewater treatment plants
- disposal to sewer as trade waste
- reuse as dust suppression solution, such as at mine sites
- using surplus or expired concentrate in training.

For example, roadside use of foam on tanker rollovers in Queensland (no fuel spilled and not immediately adjacent to a waterway) involving 250 to 500 liters of concentrate are usually left to soak in to the soil with no discernible impact on vegetation or wildlife and no cost for soil removal, no disruption of the road integrity by excavation and no remediation required. By contrast AFFF use in the same situation would require complete removal and destruction of wastewater and soils at considerable cost, diversion of resources from other more productive activities and disruption of services.

4.1.7. Remediation and clean-up

Examples of the very significant costs for site contamination assessment and remediation of PFAS contaminated sites are now common and many more examples continue to be reported almost daily in the press in many countries in the world. By comparison fluorine-free foams have been in use in various applications for over a decade with limited or no remediation costs provided that the use was not in or close to an enclosed waterway such as a shallow stream, waterhole or dry-season stream where it might cause oxygen depletion. Even in such cases simple remediation is generally only required to prevent entry to waterways such as hosing the foam residue into the soil to limit movement, short-term bunding, or irrigation of firewater to an adjacent dry area away from the stream to soak in to the soil. At the worst the wastewater can be recovered and disposed of to the sewer.

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5. SOCIO-ECONOMIC COSTS

The socio-economic costs of fluorinated foam use have been growing almost exponentially in the past five to ten years with the realization of the extent of large-scale legacy contamination now impacting a wide range of community, commercial and reputational values of widespread concern to the public, commercial interests, governments and industry through the adverse impacts on a variety of values including:

- Resource degradation (soils, waterways, drinking water...)
- Social values (amenity, recreation, fishing, tourism...)
- Economic values (fisheries, crops and pastures, bans on sales of livestock and agricultural produce, reduced property values...)
- Cost to business (clean-up, disruption of production, land use limitations...)
- Legacy sites (collateral impacts, leaching, clean-up costs...)
- Environmental values (waterways, wildlife...)
- End-user liability (law suits for damages...)
- Health (persistence, increasing exposure, toxicity, bio-accumulation...)
- Reputation (corporate, industry, government, political, locational, resource...)
- Public perception of risk, loss of confidence in local and national government

Ultimately the substantial costs of PFAS pollution impact the community through the increased costs on affected businesses and utilities that are passed on to consumers in the cost of products. Alternatively, there are significant costs to the taxpayer for remediation of the many orphan sites that the government is left to deal with.

Some cost reclamation from the original producers of the contaminants by class actions has and is still occurring, with settlements in the hundreds of millions of Euros/Dollars so far, but these actions are limited to those that have sufficient resources and support to follow through the lengthy and very expensive legal process. Similarly, a growing list of foam end-users are now facing law suits for damages to social and economic values, especially where they became aware of potential issues early on and failed to act promptly to warn of or mitigate the risks.

Given the dispersive characteristics of all PFAS through long-range transport, waterways, including the marine environment worldwide, and their associated socio-economic values are particularly at risk. A large-scale release of contaminated firewater from a large hydrocarbon storage facility incident, a hydrocarbon shipping tanker fire or even cumulative smaller releases to waterways and the marine environment can potentially impact those values not only by direct contamination of seafood resources and aquaculture stocks but also by generating the perception of contamination which is very likely to severely affect public opinion and depress local and overseas market purchases of local seafood produce.

For example, Queensland hosts commercial fisheries to the annual value about €280 million with aquaculture valued at €66 million and recreational fisheries valued at about €47 million. In Moreton Bay alone, adjacent to Brisbane, the value of commercial and recreational fisheries to Queensland's economy is between €28 million and €35 million per year (2012-14 values).

On land there are a growing list of PFAS contamination incidents that have resulted in socio-economic hardship ranging from property value loss to the point of being un-saleable, contamination of agricultural land, livestock and crops, contamination of commercial and recreational fisheries, and contamination of agricultural and drinking water resources with remediation impossible or prohibitively expensive.

There is now no excuse for not knowing that PFAS pose significant and unacceptable long-term risks making it vitally important to restrict and properly control the use and release of PFAS fluorinated organics given their exceptional persistence and the potential for ongoing and increasing exposure and the ready availability of proven effective and sustainable alternatives.

TABLE 5A. SUMMARY OF EFFECTS OF FLUORINATED VERSUS NON-PERSISTENT FOAMS.

PFAS persistent foams	Fluorine-free non-persistent foams
Specialised treatment and/or disposal for PFAS firewater required by high-temperature incineration as PFAS waste.	**Standard wastewater treatment** process, sewer disposal or on-site biodegradation in ponds or irrigation to soils.
PFAS contaminates all other incident materials such as fuels, combustion products and cooling water.	**Does not interfere** in the recovery of fuels or treatment of firewater and combustion products.
Bund overtopping by excessive firewater generation with release to the environment with permanent pollution of resources by PFAS.	**Firewater generation can be far less** with less risk of bund overtopping and only localise and temporary effects if released to the environment.

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Extremely high remediation costs for soils and groundwater if it is at all possible with no long-term degradation over time. PFAS dispersal, bioaccumulation and increasing exposure over time.	**Largely self-remediating** through biodegradation with only localise and temporary effects (~1-2 months). Waterways generally not impacted due to dilution and flushing.
Local, regional, national and global dispersion and contamination has been well demonstrated for PFAS as permanent pollutants.	**Local effects only** with temporary effects.
Potential for reputational damage for industry sectors with loss of public confidence and loss of confidence in governments that fail to act.	**Local impacts with rapid recovery** and restoration of values. Community can be reassured that risks are minimal and manageable.
Impacts on public health and important resources such as fisheries, aquaculture, livestock, crops, drinking water, etc. with long-term economic costs and loss of reputation for product quality.	**Temporary local effects** in the immediate vicinity only likely.

5.1. TRANSITIONING TO BEST PRACTICE

Transition to sustainable firefighting foam practices represents an opportunity for industry end-users to significantly reduce their potential costs and liabilities in terms of:

- Long-term social, economic and reputational damage to on-site and off-site resources due to incidents.
- Limiting or avoiding site remediation costs on decommissioning of the site.
- Reducing the costs for normal day-to-day management of foam by not needing to be subject to as rigorous containment and handling practices.
- Lower insurance premiums or lower risk of insurance not covering un-notified foreseeable damage.
- Lower incident and day-to-day waste disposal costs.
- Lower costs for production of goods and services.

In addition, the transition to best-practice can also enhance the user's corporate reputation within the community and trust relationship with the government regulators.

The cost of transition is not only worthwhile for the end-user in terms of reducing their liability for causing damage but also reduces risk of ongoing large-scale costs to the community of releases that damage public health and critical values such as fisheries or drinking water supplies.

5.2. THE QUEENSLAND FOAM POLICY TRANSITION EXPERIENCE

The Queensland Government (Australia) implemented the *Environmental Management of Firefighting Foam Operational Policy* in July 2016 that required:

- Immediate removal of PFOS/PFHxS foams from service.
- Transition from long-chain PFAS foams within three years to either:
  - fluorine-free foam with on-site waste containment or;
  - C6-pure foam with full and impervious containment of wastes.
- Implementation of interim containment measures during transition.
- Proper disposal of PFAS foam and associated wastes.

The great majority of foam end-users in Queensland have now opted for transition to fluorine-free foams well within the deadline on the basis of significantly reduced long-term costs and liability. This trend has also been seen across Australia and globally with the realization of the considerable risks associated with PFAS use.

A key element of the Queensland Foam Policy was that there was no need for new or special legislation and that the existing regulatory provisions, reflected in most jurisdictions globally, were sufficient to address the risks posed by the use, management and release of persistent organic pollutants, including PFAS, under the *Polluter Pays* liability principle and the Precautionary Principle.

Effectively the Queensland Foam Policy provided clarification as to the existing legal obligations under current environmental legislation that had already undergone comprehensive regulatory impact assessment and cost-benefit analysis with particular consideration of organohalogens. The foam Policy was also aimed at providing clear guidelines and a level-playing-field across firefighting foam end-users.

As the pollution regulator the Queensland Department of Environment and Heritage Protection (now Environment and Science) was, and is, legally obliged to undertake a balanced consideration of a range of factors when making decisions on regulation including:

- ESD, including the *precautionary principle*, intergenerational equity and conservation of biological diversity and ecological integrity.
- Character, resilience and values of the local and broader receiving environment (including human health).
- Best practice environmental management for the activities.

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- Financial implications of the requirements or regulation.
- The public interest, including socio-economic issues.
- The General Environmental Duty (GED) that requires the polluter to take all reasonable and practicable measures to prevent or minimise the harm having regard to the current state of technical knowledge for the activity.

It should be clearly understood that the predominant drivers and considerations in the development of the Queensland Foam Policy were the established, emerging and potential adverse socio-economic and human health impacts of PFAS pollution affecting both industry and the community. This is contrary to disingenuous claims by fluorochemical industry lobbyists who have sought to downplay the Policy and PFAS restrictions as a whole as only being grounded on environmental considerations.

The development of the Queensland Foam Policy involved a very extensive review of all foam types and their applications in terms of their day-to-day utility, safety and firefighting performance certification as well as the entire lifecycle cost including existing and emerging evidence for the potential for downstream acute and chronic effects of releases on social, economic, human health, amenity and connected environmental values. These effects have been, and continue to be demonstrated in various forms across Australia and globally.

A key element of the foam policy review (and its later application) was to ensure that proposed regulatory measures were necessary, practical and achievable, taking into account that every situation is different and that there needs to be an appropriate balance of considerations across:

- Firefighting performance for the various applications and circumstances, operational practicalities and compatibilities to protect life, property and the environment.
- Adjacent urban, amenity and economic values that could be impacted.
- Pathways for contaminants to affect adjacent values.
- Various foam formulations (every foam is unique in its composition or mixture).
- Practicalities of capture, containing and treating wastes and firewater.
- Workplace health and safety (day-to-day and during incidents).
- Variabilities in adjacent environmental values (e.g. wetlands, bodies of water, soils, groundwater, etc.).
- Compliance with other regulatory requirements and standards.
- Potential costs for clean-up and pollution caused on and off site.
- Appropriate insurance cover for potential costs.
- Costs and practicalities of waste treatment and disposal.
- Costs and practicalities for transition to best practice.
- Corporate reputation and liability.
- Value for money through a cost-benefit analysis.
- The constraints facing individual facilities in transitioning to best practice.

It was recognized early in the review for the Queensland Foam Policy that for certain aspects it is not appropriate to have blanket restrictions, or to have blanket exemptions as have been sought. For example, bulk fuel storage terminals face a range of technical, space, locational, time and economic challenges in changing over from older foam systems while a new green-field site can put in place best-practice foam application and firewater containment systems from the outset. Accordingly, a blanket exemption for even an industry group like "fuel terminals" in isolation, or any other industry sector, is clearly inappropriate and risk-prone, let alone to have an exemption for PFAS to be used in firefighting as a whole.

By way of an example of managing the different circumstances between and within industries the Queensland Foam Policy allows a generous three-year transition general grace period as well as making provision for facilities that have genuine difficulties to seek individual extensions to Policy requirements under existing licensing provisions that allow for agreed, enforceable deadlines and milestones appropriate to the circumstances.

Blanket exemptions and derogations for PFAS use, especially for firefighting foam, run the very real risk of failing to meet community expectations by unnecessarily and undesirably delaying risk reduction and risking further socio-economic costs. There is also the significant potential for undermining and delaying best-practice, driving industries to a lowest-common-denominator approach as well as providing an opportunity for an unfair economic advantage for some operators who unscrupulously take advantage of such loopholes.

TABLE 5B - REGULATORY BEST PRACTICE PRINCIPLES

Principle	Restriction relevance
Establishing a case for action before addressing a problem.	There is a well-established and overdue case for action world-wide to restrict PFAS due to short and long-term potential and demonstrated environmental and health impacts and related high legacy contamination costs of foam.
Considering a range of feasible policy options including self-regulatory, co-regulatory and non-regulatory approaches.	Default non- and self-regulation by most of industry has largely failed since 2005 (or earlier) when information on PFAS problems became clear. Co-regulation, informing and guiding industry to best practice is desirable with the need for compliance action by regulators only necessary where risks are not being adequately addressed.
Assessment of the benefits and costs.	An extensive cost-benefit assessment has been done for the EU with direct relevance to all other countries.
Ensuring legislation should not restrict competition.	There needs to be guidance and restrictions on PFAS that set a level playing field for all suppliers and end-users (equal competition) with clear standards and expectations for PFAS management to ensure that non-compliant firms will not be able to jeopardise the reputation of an entire industry.
Providing effective guidance in order to ensure that outcomes and expected compliance requirements are clear.	Clear guidance and transparent reasoning are needed for best-practice environmental management and compliance of PFAS to be fair and effective.
The benefits of the restrictions to the community as a whole outweigh the costs.	There are very high potential and demonstrated actual legacy costs for the community that are required to be managed under ESD. The costs of restrictions on the highly dispersive use of PFAS foams are far outweighed by the demonstrated and growing costs of legacy and ongoing pollution.
Ensuring that regulation remains relevant and effective over time.	Enhanced restrictions need to take a proactive and long-term view based on clear evidence available and that continues to emerge for adverse effects for all PFAS.
Consulting effectively with affected key stakeholders at all stages of the regulatory cycle.	The stakeholders at greatest risk from PFAS pollution are communities, foam end-users and governments. There are clear expectations that PFAS must be better managed, especially for highly dispersive uses such as firefighting operations involving foam.
Ensuring that government action is effective and proportional to the issue being addressed.	The case for PFAS restrictions is very soundly grounded in the current state-of-knowledge and international directions for management and best practice.

Queensland recognized blanket exemptions as an unacceptable and unnecessary risk and so adopted the overall expectation and requirement of transition to best-practice as soon as practicable with exemptions only considered where there was a clear justification in individual circumstances when enforceable timelines and milestones towards best practice were negotiated and agreed.

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6. EXAMPLES OF TRANSITION FROM AFFF TO F3

6.1. PETROCHEMICAL INDUSTRY

The experience from Australia is relevant. In July 2016, the state of Queensland issued its *Operational Policy for Environmental Management of Firefighting Foam*. This policy provided a 3-year timeframe to transition from long-chain firefighting foams to sustainable best practice using either non-persistent fluorine-free foams or C6 pure foams provided there was full containment of firewater and wastes in impervious bunds or sumps for disposal.

A core principle of the Queensland Foam Policy was that it recognised the challenges posed to some facilities in that they would need time to design, appropriate budgets, engineer, test and implement the necessary changes while maintaining normal operations. This was an important inclusion to positively engage industry and support an appropriate risk management approach not inconsistent with that required by Australian major hazard facility legislation (equivalent of COMAH or Seveso).

The other significant concession of the Queensland foam Policy was to allow the ongoing use of C6 pure PFAS foams, but only with clear justification for particular circumstances and under strict containment and disposal requirements. This was in response to industry submissions at the time that C6 pure foams may be the only viable option in the short to medium term for particular large-scale uses. Since then non-persistent fluorine-free foam performance has advanced considerably, plus the emerging evidence that short-chain PFAS are as problematic as other PFAS has prompted industry sectors to consider the likelihood that short-chain PFAS will also be severely restricted as has already started to happen in various jurisdictions.

This raises the prospect of "regret spend" for C6 foams, that is, having borne the cost of transition to C6 pure foam there is the distinct possibility of having to pay to transition again as the trend of tightening controls on remaining PFAS continues. For fluorine-free foams this is not a consideration as their characteristics and constituent parts are well known, not in doubt, and align with the same or similar substances that have long been in common use and dealt with on a daily basis. As such fluorine-free foams are not likely to be subject to any further regulatory controls beyond those long-established for the chemicals they contain.

For transitioning from PFAS foams according to best practice, in some cases pragmatic compromises have been reached with parts of sites that can transition immediately to fluorine-free foam having now done so, while extensions have been sought for transition for only those parts that cannot immediately make the changeover due to design, time and cost constraints, or that advances in foam technology are reasonably expected to occur soon that may avoid the spectre of a "regret spend".

At the time of Queensland Foam Policy implementation in July 2016 there remained significant unknowns that were of concern to industry. These included;

- **An emerging debate as to the medium to long term acceptability of C6** purity foam as an option (as allowed for in the Queensland policy, <10mg/kg PFOS and <50mg/kg C8-C14 PFCAs). Industry had a significant concern that in committing funds to transition from existing C8 foam stocks to C6 purity foams that they may well ultimately be required to transition again to a suitable performing F3 foam when that becomes available. For some operators transition costs were estimated at >$10m so this would represent a significant "regret spend".

  [This concern was highlighted when South Australia implemented amendments to existing environmental legislation specifically banning all PFAS foams (including C6 pure) within a two-year transition period.]

- **An absence of a suitable replacement non-persistent foam** for large atmospheric storage tank (LAST) flammable liquid tank fires. These require specialised foams capable of flowing across large burning liquid surfaces and sealing against hot metal surfaces to prevent re-ignition. Understanding of these matters and support from the policy regulator in undertaking research to ensure good risk outcomes has been important. [Progress on new technology for large fuel tank fires is advancing.]
- **An absence of supporting design standards for re-engineering foam systems** to cater for higher viscosity fluorine-free foams. This has placed greater emphasis on end-user operators conducting their own performance testing of shortlisted foams.
- **The absence of an approved waste facility for PFAS destruction** required to dispose of non-compliant foam stocks following transition. The economics of such destruction and associated waste transport costs remains un-tested at present.

Australian industries have largely recognized the requirement to transition to best practice and in recent years, even prior to policy restrictions, have proactively focussed on

overcoming the fire protection and engineering challenges rather than resisting emergent and inevitable policy changes. Policy provision to allow for transition timeframes/processes to permit these challenges to be overcome, without compromising operational risk, has been an important engagement strategy with industry.

The development and implementation of appropriate interim risk management by facility operators has been an important step in supporting this risk-based approach. Both industry and regulatory agencies have recognized that the levels of PFAS in the environment have arisen, not from actual application during real fire incidents, but largely from inherently controllable activities such as preventable accidental discharges, training, maintenance testing and end-of-life concentrate disposal.

By implementing robust interim risk management to prevent PFAS entering the environment via these controllable activities the industry has had a significant impact in reducing the total PFAS environmental load and risk to themselves. The importance of this in supporting overall performance outcomes of the policy should be appropriately recognized in all policy formulation. As a result, industry, with the cooperation of the regulator, has accumulated non-compliant foam concentrate & solutions held in temporary storages pending availability of a licenced and cost-effective waste disposal route, plus the ability to stage disposal in order to spread disposal costs across financial periods.

Industry has mobilized to plan, execute and report its own independent end-user acceptance testing of firefighting

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foam. Evidence to date of robust risk management for transition management includes the following key steps;

1. **Identification of suitable performing firefighting foam products** for industry application by reference to Standard certifications (e.g., EN, UL, LASTFIRE).
2. **Independent end user due diligence of shortlisted foam products** (e.g., supplier confirmation of non-biopersistence, eco-toxicity data, hazardous substance risk assessment).
3. **End user testing of the shortlisted foam** in facility specific equipment and as appropriate facility specific products and scenarios.
4. **Identification of engineering modifications required** to accommodate the new generation foam. This may include minor modifications to in-line proportioners to accommodate higher viscosity F3 foams.
5. **Confirmation of a suitable cleaning & decontamination process** for fixed foam equipment to be transitioned and identification/due diligence of an approved waste disposal route.

The above five steps provide a systematic process in support of well informed decision making. Ultimately, it addresses concern in the industry of being forced to transition to what is perceived in some cases, quite incorrectly, as a far less effective foam that may have life safety, environmental and critical infrastructure protection impacts. Ultimately the challenge is for foam producers to develop fit-for-purpose non-bio- or environmentally persistent foam products.

6.2. AVIATION RESCUE AND FIREFIGHTING (ARFF)

Fluorine-free firefighting foams are now in use at many airports worldwide including major ICAO category 10 hubs such as London Heathrow, London Gatwick, Copenhagen, Stuttgart and Dubai amongst others.

Graeme Day, fire service compliance manager and formerly a senior fire officer, responsible for the transition to F3 foams at London Heathrow Airport (Appendices – Graeme Day), makes clear in his comments that:

1. **Fluorine-free foam has no operational problems** and performs perfectly in an ARFF setting.
2. **Environmental impact and consequential remediation** and clean-up costs of using a fluorine-free foam compared to AFFF, FFFP, or FP are effectively zero and firewater runoff can be discharged directly to ground or drainage systems.
3. **Airport runways are back in service far more rapidly** for fluorine-free foam use compared to the disruption and clean-up costs when a fluorinated foam had been used previously.

Similarly, Kim Olsen, head of the CPH Fire Training Academy and formerly an Assistant Chief Fire Office at Copenhagen Airport in Denmark, describes the process of moving to fluorine-free firefighting foam (F3). In particular he highlights some of the legacy costs associated with having used fluorinated foams on the fire service training areas over many years and the need for remediation and clean-up which is an ongoing expense.

"*...Copenhagen Airport Environment department is still working on cleaning up from AFFF pollution in other areas of the airport where AFFF foam has been used. Just to maintain the sewer system around the fire training ground, the airport spends more than 1.5 million EUR every year and expects to be doing this at least the next 80 years (!)...*" (Appendices – Kim Olsen).

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7. CONCLUDING REMARKS

Current fluorine-free or non-persistent Class B firefighting (F3) foams are now viable operational alternatives to fluorinated AFFF. Quality for quality F3 and AFFF concentrates are comparably priced. Unlike fluorinated AFFFs, fluorine-free (F3) foams do not give rise to environmentally persistent, toxic or bio-accumulative chemically stable end-products; there is no permanent environmental pollution with perfluorinated POPs; any contamination is short term and rapidly self-remediates; clean-up and remediation costs are negligible or zero compared to the huge and ongoing costs associated with AFFF contamination; there are no significant legal and financial liabilities; socio-economic and public health values such as drinking water supplies are not compromised; and finally there is no erosion of public confidence in political institutions and government agencies, or damage to brand image.

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APPENDIX I

STATEMENT OF THE PROBLEM

Statement of the Problem:

"...The rapid extinguishment of hydrocarbon-based fuel fires is crucial to maximize incident survivability and firefighter safety in aviation related incidents. The current performance requirements for firefighting foams used by the United States (U.S.) military (MIL-PRF-24385F) Military Specification (MIL-SPEC) mandates the use of fluorosurfactants known as per- and polyfluoroalkyl substances (PFASs) as significant components of the concentrate mixture. These fluorosurfactant based foams are also used for asset protection in aircraft hangars and fuel tank farms. The widespread use of Class B firefighting foams such as AFFFs at incidents and during firefighter training and system testing has led to the contamination of both groundwater aquifers and surface waters; and consequently, the impact on numerous public and private drinking water supplies.

The requirement to use MIL-SPEC accredited firefightig foams currently extends to Certificated Part 139 civil airports, due to the Federal Aviation Adminstration (FAA) requirement that firefighting foams meet the military testing specification. However, in 2018, the FAA has begun to seek safety certification reforms which no longer require that civilian airports meet the MIL-SPEC requirements. Airports will instead be required to follow the latest version of National Fire Protection Association (NFPA) 403 Standard for Aircraft Rescue and Fire-Fighting Services at airports which allows use of F3 [1].

An increasing numbers of individual PFASs are being identified as posing a potential human health and environmental risk, with a focus in the US so far being on the perfluroalklyl acids (PFAAs), previously called perfluorinated compounds (PFCs), such as perfluorooctane sulfonate (PFOS) and perfluorooctanoic acid (PFOA). These have been termed "long chain" or C8 PFAAs; along with perfluorohexane sulphonate (PFHxS) and other long chain PFAAs, and in addition to being ultra-persistent and toxic, they also have the potential to exhibit long-range transport with high levels of bioaccumulation in the biosphere and humans.

PFASs are a large group of several thousand man-made chemicals [2] of accelerating global regulatory concern. The term PFASs has been adopted to describe this whole class of emerging contaminants. They all contain a perfluoroalkly group, within their molecular structure, with mutiple carbon to fluorine bonds, which imparts chemical stability, resistance to biodegaradtion and extreme environmental persistence often of the order of many decades rendering the problem a 'generational' one. PFASs which are analogous to PFOS and PFOA but have shorter perfluoroalkly chain lengths (i.e., C6 and C4) and are being used as replacements, are also of concern as environmental regulators are currently introducing environmental quality standards for these shorter-chain alternatives.

These replacement "short chain" PFASs are generally proprietary fluorotelomers, which dominate the composition of modern Class B firefighting foams, such as AFFF. The fluorotelomers are termed polyfluoroalky substances and they transform in the environment or can be metabolized in higher organisms to create short chain perfluorinated PFAAs which are also ultra-persistent [3]. Some fluorotelomer breakdown intermediates have been described to be more toxic than the end-point PFAAs that they form [4, 5], with exposure to these fluorotelomer derivatives being more complex than to the parent molecule; the various reactive transformation intermediates and the dead-end daughter PFAAs can all pose a concerted toxicological burden [6]. This is of current concern to the oil industry, as a result of potential occupational exposure risks to fluorotelomer based foams.

Environmental regulators in Europe and Australia have devloped environmnetal quality standards for fluorotelomers, such as 6:2 fluorotelomer sulfonate (6:2 FTS), associated with the C6-pure replacement firefighting foams. Many other jurisdictions, such as in Australia, Europe, Canada, Texas, Minnesota, North Carolina, Indiana, Oregon and Massachusetts are now also regulating short chain PFAAs. Regulators in Australia have begun to use the total oxidizeable precursor (TOP) assay for all analyses to enable the detection of polyfluorinated precursors, as previous assay methods left very substantial and significant portions of the precursors present undetected.

In May 2016, the United States Environmental Protection Agency (USEPA) announced a long-term health advisory of 70 nanograms per liter (ng/L) for a combination of PFOS and/or PFOA in drinking water. However, more recent toxicological assessments, by the Agency for Toxic Substances Disease Registry have suggested that even lower levels are more appropriate (7 ng/L for PFOS and 11 ng/L for PFOA). This corresponds with Maximum Contaminant Levels (MCL) being establised in the State of New Jersey in drinking water (14 ng/L for PFOA and 13 ng/L for PFOS), with the same levels proposed in California.

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There is significant ongoing uncertainty regarding the environmental risk posed by fluorotelomers and short chain PFAAs. Fluorotelomers transform in the environment to ultimately create the ultra-persistent PFAAs, via intermediates such as 6:2 FTS (6:2-fluorotelomer sulfonate) and lesser characterised intermediates, such as the 5:3 fluorotelomer carboxylic acd (5:3 FTCA or "5:3-acid"), which has recently been highlighted as potentially biopersistent (i.e., showing slow clearance from organizms, having potential for bioaccumulation). The short chain PFAAs have been identified as concentrating in the edible portion of crops [7-9]; they bind to serum and other proteins; have non-negligible half-lives in organisms; are potential endocrine disruptors with human toxicity still to be assessed [10]. Examples of crops, such as asparagus, being removed from the food chain as a result of their capacity to concentrate PFASs, are already being seen in Germany with significant impact on the agricultural industry.

The short-chain PFAAs have increased mobility in the environment as a result of greater solubility, forming more extensive groundwater plumes than their longer chain homologues, such as the 250 square kilometer mega plume described in Minnesota [11]. The increased solubility and decreased absorption by activated charcoal of the short-chain PFAAs, makes their removal from potable water supplies costly and challenging [12] as they are far more difficult to remove in WWTP (waste-water tteatmant plants) than their long chain (>C8) homologues. Regulators are concerned that they are subject to long range transport, with the potential for widespread contamination of drinking water [10]. The results of four studies in Europe reported widespread detection of short chain PFASs in tapwater, with between 18% - 86% of samples assessed containing short chan PFAAs [13-16].

To summarize, the general regulatory trend appears to be enforcement of more stringent standards and inclusion of additional PFASs beyond PFOS and PFOA. Environmental regulators at the Federal, State level, and more widely outside the U.S., for example in Australia and New Zealand s well as Germany and Scandinavia, are rapidly and increasingly focussing on PFASs as priority environmental contaminants. It appears that the short chain PFASs may become labelled "regrettable replacements", in terms of the perceived hazards they pose to the environment and subsequent future potential laibilities, as a result of current and futre reglatory attention. The U.S. Navy stated in February 2017 that "there is a definite need to eliminate the fluorocarbon surfactants from AFFF formulations to address their environmental impact while maintaining the high firefighting performance required by the MIL-SPEC" 17.

Several mature F3 foams products, which do not contain PFASs, are commercially available but none currently meet the full MIL-SPEC testing requirements. It is known that some F3 foams can meet the main MIL-SPEC fire performance tests but are not film-forming with a positive spreading coefficient as they by definition do not contain fluorosurfactants and cannot pass the complete specification, which includes at present an absolute requierement for a specified fluorine content. However, there is a question regarding whether the total package of tests in the MIL-SPEC specification is relevant to real world firefighting scenarios. As a result, this standard may not be fully appropriate to current operational conditions or suitable to assess many of the modern F3 foams currently commercially available. The modern F3 foams are being widely used outside of the U.S., as internationally there are a variety of standards used for aviation fire fighting (ARFF) and other applications. Some of these standards are performance-based rather than specific to a particular foam type. F3 foams have been certified as meeting appropriate criteria in many cases and are used at many airports for example. The potential environmental hazards of all F3 foam components have been comprehensivley assessed via a stringent chemicals testing program used in Europe by the oil industrry, such that they are deemed acceptable for use.

There is a need to review the scope of the specification of the MIL-SPEC to allow F3 foams to be assessed, without jeopardizing safety or firefighting performance, in order to identify if they can perform effectively at fire extinguishment by using tests that are objective and in line with the end user needs and without reduction in performance against AFFF in a military relevant environment.

The review needs to be independent and non-biased towards either F3 or AFFF and should take into account current operating conditions and requirements to reflect advancement in firefighting technologies. Over the last 52 years, since the MIL-SPEC was first conceived, multiple generations in the evolution and improvement of F3 foams and advanced engineering solutions for foam delivery have taken place. In addition, there is now the requirement to consider environmental criteria within the specification to allow the environmental consequences of using F3 and C6 foams to be directly compared, via an assessment of the potentially hazardous properties of their ingredients and their breakdown products both in the short and long term.

Technology Maturity.

The latest F3 foams are a fairly new technology to enter the commercial market by comparison to AFFF. However, the technology maturity has advanced such that F3 foams have achieved certification under various firefighting foam certification programs (e.g., Underwriters Lab UL162, EN1568, ICAO, IMO, LASTFIRE and International Organization for Standardization [ISO]). As is the case with AFFF, there is a wide range of formulations and associated differences in performance. As such, the technology continues to be improved upon through investments by interested stakeholders such as the international oil and civil aviation industry.

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Outside the U.S. the use of F3 foams in military and civil scenarios comparable to those required by MIL-SPEC has been demonstrated. For example, the International Civil Aviation Organization (ICAO) mandates tests of firefighting foam performance for civil aviation purposes which use firefighting tests appropriate to this extinguishment scenario. ***Several F3 foams have passed the highest levels of ICAO extinguishment tests and are now widely used at major airports worldwide, including major international hubs such as Dubai, Dortmund, Stuttgart, London Heathrow, Manchester, Copenhagen, and Auckland. All of the 27 major airports in Australia have transitioned to F3 foams, with airports in Europe such as Billund, Guernsey, Bristol, Blackpool, Koln Bonn also using F3 foams. Private sector companies using F3 foams include: BP, ExxonMobil, Total, Gazprom, Statoil, BHP Billiton, Bayern Oil, 3M, BASF, Chemours, AkzoNobel, Stena Line, Pfizer, Lilly, Weifa, JO Tankers, and ODFJEL. In the oil and gas sector F3 foams are being extensively, with Statoil in Norway having transitioned to F3 foams throughout all of it operations. Some military users including the Danish and Norwegian Armed forces have moved to F3 foams, with the Royal Danish Airforce transitioning to F3 foams several year ago.*** *A demonstration of the confidence the Danish military have in F3 foams was recently provided at an event in Skrydstrup, with various military establishments attending, as described in an article by their Fire Chief, Lars Anderson [17], with videos of these foams in action available online [18-20].*

CAFS has been used on fire trucks for over 20 years [21], mainly for municipal and wildfire applications. The International Aviation Fire Protection Association carried out some testing with an Aircraft Rescue and Firefighting (ARFF) truck with CAFS and stated after testing that "CAFS improved the performance by 30% or more". Kim Olsen the Fire Chief at Copenhagen published the results of trials, done in 2012, using F3 foams which were described just as effective as AFFF using CAFS and [22]. Copenhagen Airport now uses Rosenbauer ARFF (Panthers) all equipped with CAF capability. In the U.S. CAFS has been applied for: Railroad Bridge Monitor Systems, in NJ; Liquid Storage Protection in OK and PA; and Deluge Systems for various Industrial Purposes in VA, IA, MA., and CA. CAFS has also been applied for Helideck Protection and Multiple Power Plants in the Philippines, and Large Fuel oil storage in Oman and India. The LASTFIRE organization has carried out large scale testing with CAFS and found that it can provide more efficient performance than conventional techniques if engineered correctly ..."

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APPENDIX II

GENERAL COMMENTS ON PFAS AND FIREFIGHTING FOAM

"...Some general points on PFASs

- *Firefighting foams containing fluorosurfactants (PFASs) were developed in the 1960s when testing regimes were established using these products. In the last 50 years there have been significant advances in firefighting foams and application technologies, meaning that PFASs can now be eliminated.*
- *The most vocal support for the use the exclusive use of fluorinated foams still comes from the manufacturers of fluorinated foams and their lobbyists.*
- *Even if a non-fluorinated foam was twice as effective and half as expensive, it could not be used according to the MIL-Spec*
- *Fluorine-free foams reach the highest level of performance in ICAO (International Civil Aviation Organization) extinguishment tests, as well other protocols such as EN1568, UL162, UL162 sprinklers, and IMO.*
- *The ICAO and other standards that can be met without fluorinated foams mean that they are now used successfully at the majority of airports in Australia, Norway, Sweden, and also many dozens of other airports worldwide.*
- *The so-called "environmentally preferable" current fluorinated 'pure C6' foams are equally persistent in the environment, accumulate in human tissue and concentrate in the edible portion of plants, and are significantly more mobile, so form very large groundwater plumes and are very difficult and much more expensive to remove from drinking water than the previous generation of fluorinated foams.*
- *All of the 27 major Australian hub airports have transition to fluorine-free firefighting (F3) foams, as have the following major hub airports: Dubai, Dortmund, Stuttgart, London Heathrow, and Manchester, Copenhagen, and Auckland. Airports in Europe such as Billund, Guernsey, Bristol, Blackpool, Koln Bonn also using F3 foams. Private sector companies using F3 foams include: BP, ExxonMobil, Total, Gazprom, Statoil, BHP Billiton, Bayern Oil, 3M, BASF, Chemours, AkzoNobel, Stena Line, Pfizer, Lilly, Weifa, JO Tankers, and ODFJEL. In the oil and gas sector F3 foams are being extensively, with Statoil in Norway having transitioned to F3 foams throughout all of it operations. Some military users including the Danish and Norwegian Armed forces have moved to F3 foams, with the Royal Danish Airforce transitioning to F3 foams several year ago. A demonstration of the confidence the Danish military have in F3 foams was recently provided at an event in Skrydstrup, with various military establishments attending, as described in an article by their Fire Chief, Lars Anderson.* [1]
- *There is significant ongoing uncertainty regarding the environmental risk that the fluorotelomers and short chain PFAAs pose. Fluorotelomers transform in the environmnet to ultimately create the ultra-persistent PFAAs, via intermediates such as the 6:2 FTS and the lesser characterised intermediates, such as the 5:3 fluorotelomer carboxylic acd (5:3 FTCA or "5:3-acid"), which has recently been highlighted as potentially biopersistent (i.e. showing slow clearance from organsism, so having potential for bioaccumulation). The short chain PFAAs have been identified to concentrate in the edible portion of crops*[2-4]*, they bind to proteins, have non-negligible half-lives in organisms, are potential endocrine disruptors with human toxicity still to be assessed.*[5] *Examples of crops, such as asparagus, being removed from the food chain as a result of their capacity to concentrate PFASs, are already being seen in Germany.*
- *Environmental regulators in Denmark, Germany and Australia have defined maximum allowable concnetrations for common "meta-stable" fluorotelomers, such as 6:2 fluorotelomer sulfonate (6:2 FTS), associated with the C6-pure replacement firefighting foams. Many other jurisdictions are now also regulating short chain (C4, C6 etc.) PFAAs, sometimes in combination with long chain PFAAs to the same low regulatory threshold value (such as in Denmark and Sweden) or to µg/L levels such as in Minnesota, Bavaria, Australia and Canada. Short chain PFAAs are currently regulated in North Carolina, Texas, Minnesota, Indiana, Massachussets and Oregon with expectations that all States will eventually propose environmental regulations.*
- *The replacement "short chain" PFASs are generally proprietary fluorotelomers, which dominate the composition of modern Class B firefighting foams, such as*

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AFFF. The fluorotelomers are termed polyfluoroalky substances and they transform in the environment or can be metabolized in higher organisms to create short chain PFAAs which are also ultra-persistent.[6] *Some fluorotelomers have been described to be more toxic than the PFAAs they form*[7, 8], *with exposure to fluorotelomer breakdown products being more complex compared to the parent molecule; the various reactive transformation intermediates and the dead-end daughter PFAAs can all pose a concerted toxicological burden.*[9] *This is of current concern to the oil industry, as a result of potential occupational exposure risks to flurotelomer based foams.*

- *Environmental regulators in Europe and Australia have devloped environmnetal quality standards for fluorotelomers, such as 6:2 fluorotelomer sulfonate (6:2 FTS), associated with the C6-pure replacement firefighting foams. Many other jurisdictions, such as in Europe, Canada, Texas, Minnesota, Australia are now also regulating short chain PFAAs. Regulators in Australia have begun to use the total oxidiseable precursor (TOP) assay for all analysis to enable the detection of polyfluorinated precursors, as previous assay methods left significant portions of the precursors present undetected.*
- *The short-chain PFAAs have increased mobility in the environment as a result of greater solubility, so form long groundwater plumes, such as the 250 km² mega plume described in Minnesota.*[10] *The increased solubility of the short-chain PFAAs, makes their removal from potable water supplies costly and challenging.*[11] *Regulators are concerned that they are subject to long range transport, with the potential for widespread contamination of drinking water 5. The results of four studies in Europe reported widespread detection of short chain PFASs in tapwater, with between 18% - 86% of samples assessed containing short chan PFAAs.*[12-14, 15]
- *To summarize, the general regulatory trend appears to be enforcement of higher more stringent standards and inclusion of additional PFASs beyond PFOS and PFOA. Environmental regulators at the Federal, State level, and more widely outside the U.S. are rapidly increasing focus on PFASs as priority environmental contaminants. It appears that the short chain PFASs will become recognized as "regrettable replacements", in terms of the perceived hazards they pose to the environment and subsequent future potential laibilities, as a result of forthcoming reglatory attention.*
- *Firefighting foam is a foam used for fire suppression and is simply a stable mass of small air-filled bubbles, which have a lower density than oil, gasoline or water. Foam is generally made up of three key ingredients - water, foam concentrate and air. When mixed in the correct proportions, these three ingredients form a homogeneous foam blanket. Its role is to cool the fire and to cover the fuel, preventing its contact with oxygen, resulting in suppression of the combustion. The application of tighter, dense, bubble structures attacks all sides of the fire tetrahedron by smothering the fire with a "foam blanket", thus preventing oxygen from combining with fuel. It diminishes the heat by direct cooling and insulating (using the trapped air within the bubble structure) and reflecting (the bubbles actually reflect radiant heat, thus preventing excess heat from adding to the fire). It prevents additional fuel from reacting with the fire by providing a barrier. Innovation in firefighting foams has evolved next generation foams, many of which are classed as fluorine-free and devoid of fluorosurfactants or fluoropolymers. Ingenious engineering solutions have also evolved in the last 20 years for far more effective extinguishment of fires. Some such as compressed air foam system (CAFS) use compressed air to facilitate creation of more stable foams, which have the capacity to be propelled a much greater distance from point of delivery, to adhere to both horizontal and vertical surfaces, as well as using less foam whilst offering superior fire extinguishment performance.*
- *The foam blanket extinguishes fires by starving the hot fuel of oxygen and cooling both the fuel and surrounding structures. The concept that film-formation has is necessary for fire extinguishment has been described as just marketing, as how can a layer molecule-thick of a fluorosurfactant film, have any benefit in a fire which is burning at 1600°F (900-1000°C) as the water is boiling? In most cases does the film have any impact on extinguishment performance?*
- *Several mature fluorine-free firefighting (F3) foams products, which do not contain PFASs, are commercially available but none currently meet the full MIL-Spec test protocol. It is known that some F3 foams can meet the main MIL-Spec fire performance tests but are not film-forming and cannot pass the complete package of requirements. However, there is a question regarding whether the total package of tests in the MIL-SPEC specification is relevant to real world firefighting scenarios.*
- *There have been many advances in firefighting technologies, in the last 52 years, since the MIL-SPEC was originally conceived, such as multiple generations in the evolution and improvement of F3 foams and advanced engineering solutions for foam delivery, so fires can now be effectively extinguished without the use of fluorosurfacants,*[16] *which are a 1960's technology.*
- *CAFS has been used on fire trucks for over 20 years,*[17] *mainly for municipal and wildfire applications. The International Aviation Fire Protection Association (IAFPA) carried out some testing with an Aircraft Rescue and Firefighting (ARFF) truck with CAFS and stated that after testing that "CAFS improved the performance by 30% or more". Kim Olsen the Fire Chief at Copenhagen published the results of trials, done in 2012, using F3 foams which were described as just as*

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effective as AFFF using CAFS.[18] *Copenhagen Airport now uses Rosenbauer ARFF (Panthers) all equipped with CAFS capability. In the U.S. CAFS has been applied for: Railroad Bridge Monitor Systems, in NJ; Liquid Storage Protection in OK and PA; and Deluge Systems for various Industrial Purposes in VA, IA, MA. CA. CAFS has also been applied for Helideck Protection and Multiple Power Plants in the Philippines, and large fuel oil storage installations in Oman and India. (CAFS) in independent tests has shown that it can be used very effectively for spill fire application with F3 forms. CAFS generates a very homogenous bubble structure which results in excellent firefighting performance. In fact it has been clearly established that CAFS is a great "leveller" of foam performance.*[18] *The LASTFIRE organization has also carried out large scale testing with CAFS and found that it can provide more efficient performance than conventional techniques if engineered correctly.*[16]

GENERAL PROBLEM STATEMENT SUMMARY

What are PFAS?

Polyfluoroalkyl and perfluoroalkyl substances (PFASs) are a large group of emerging contaminants that have been used in a wide array of commercial goods and products since the 1940's. PFASs are thermally stable and repel oils and water with impressive surface tension levelling properties. For example, they have been used in some firefighting foams, for coating fabrics and textiles, in non-stick surfaces, and applied in hydraulic and lubricant oils. Some PFASs, also termed as fluorosurfactants, have been the key ingredient in "film-forming" Class B firefighting foams used to extinguish liquid hydrocarbon fires. Since the mid-1960s foams have been used at terminals and refineries for repeated fire training events and in fire supressant systems at tank farms.

Why Is there a Problem?

Globally, environmental regulations considering PFASs are rapidly being promulgated to very conservative (low) levels, and have generally focused on perfluorinated compounds and been evolving since 2009, when one particular "long chain" (C8) PFAS called perfluoro-octanesulfonic acid (PFOS) was added to the international Stockholm Convention on Persistent Organic Pollutants (POPs) schedule; this put in place restrictions regarding its production and use. PFASs show no sign of biodegradation at all and so have been described as "forever chemicals." PFASs are generally soluble and hence very mobile in the environment. Depending on the site setting, they can be transported with groundwater well beyond the original source area, and form large plumes.

The "long chain" PFASs (known as C8), including PFOS, accumulate in humans through consumption of impacted drinking water. Replacement PFASs are "short chain" (such as C6) and while the understanding of their toxicology and bioaccumulation potential is evolving, there is some evidence that short-chain PFASs accumulate in the edible portion of crops and are more mobile in the environment than the long-chained variety, making them a potentially larger threat.

Given growing evidence of human health risks and potential ecological harm, more and more countries are now regulating an increasing number of PFASs including both long and short chain varieties, while the latter are still commonly used as commercial replacements (e.g. C6 in firefighting foams r textile and fabric treatments).

There are many more proprietary PFASs present in commercial products than are regulated. These polyfluorinated varieties have evaded detection by common analytical methods but in the environment will be transformed to the increasingly regulated perfluorinated PFASs. Firefighting foams, for example, comprise hundreds of individual PFASs which have not been accounted for until recent analytical advances have enabled the total amount of PFASs to be measured using a novel technology termed the total oxidizable precursor (TOP) assay. In the environment, these polyfluorinated PFASs will all slowly transform the perfluorinated compounds, so regulators in Australia have recently adopted this advanced analytical tool for sampling environmental matrices and compliance.

GIVEN GROWING EVIDENCE OF HUMAN HEALTH RISKS AND POTENTIAL ECOLOGICAL HARM, MORE AND MORE COUNTRIES ARE NOW REGULATING AN INCREASING NUMBER OF PFASS INCLUDING BOTH LONG AND SHORT CHAIN VARIETIES

PFASs differ from hydrocarbons as they are much more mobile and ultra-persistent, so regulators perceive them as causing permanent damage to drinking water aquifers and natural resources. As PFASs can accumulate in the human blood or crops their environmental risk profile is somewhat distinct from hydrocarbons, but a further concern is rising pubic concern, press attention and thus political focus on PFASs.

PFASs are known to threaten drinking water supplies in many countries, with increased awareness and regulatory scrutiny being most evident in Scandinavia, Germany, Australia, Canada, and since early 2016 in the United States. Acceptable guidance concentrations for drinking water are very conservative (in the parts per trillion (ng/L) range), and the threat of third party litigation from communities affected by PFASs in their drinking water has created an increased need for environmental management services related to PFAS vulnerability, investigation, and restoration.

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In the US, PFASs have been made a campaign issue in the NY governors' race by Governor Cuomo, thereby bringing these chemicals some highly visible notoriety, which has now made them a core focus of the current US administrations environment policy. However, the greatest current financial and brand liabilities are associated with providing PFASs treatment to public water supplies or agricultural land, as well as settling third party litigation related to drinking water exposure or loss in property value.

For multinational companies, and particularly US traded companies, the initial conundrum is how to assess these potential risks and liabilities without triggering an increase in reserves that can affect the business value and bottom line.

CONTINUED FIRE EXTINGUISHMENT

As a result of the environmental liabilities associated with the continued use of PFASs in firefighting foams, an increasing number of stakeholders are swapping out the older C8 (actually C6/C8) foams for C6 or fluorine-free foams (F3), whilst evaluating the conversion of firefighting capabilities to the use of F3 for tank farm protection. The costs for changing foam delivery infrastructure and incinerating the C8/C6 foams may be substantial, but must be balanced with the potential environmental and legal liabilities associated with continued use of PFASs. The tradeoff between effective fire extinguishment and continued use of PFASs in firefighting foams is being addressed by a consortium of oil companies in conjunction with LASTFIRE, who are doing tests on F3 and C6-PFAS foams at progressively larger scales. The results so far show that some F3 foams exceed extinguishment performance of some C6 foams. However, their ability to extinguish very large tank farm fires is yet to be proven although F3 have been successfully used operationally by a global disaster control organisation since 2003 for large tank fires, marine firefighting and oil well head fires. Therefore, Arcadis is assisting LASTFIRE in organizing a Foam Summit Conference and a series of very large fire extinguishment demonstrations at the Dallas/Fort Worth Airport in October 2018.

THE COSTS FOR CHANGING FOAM DELIVERY INFRASTRUCTURE AND INCINERATING THE C8/C6 FOAMS MAY BE SUBSTANTIAL BUT MUST BE BALANCED WITH THE POTENTIAL ENVIRONMENTAL LIABILITIES ASSOCIATED WITH CONTINUED USE OF PFASS.

Remediation of PFAS contamination

The physicochemical properties of PFASs, conferred by their high degree of fluorination and the strength of the carbon-fluorine (C-F bond), leads to unique partitioning behaviour (i.e., both hydrophobic and oleophobic properties), chemical and thermal stability, and extreme recalcitrance. This provides challenges for many types of remediation technologies, including the conventional technologies currently being applied commercially, considering that many have been developed for other contaminant classes and not designed for PFASs.[11,19,20] Conversely, innovative remedial technologies, specifically designed or adapted to treat PFASs, can exploit these unique and distinct physicochemical properties resulting in the development of ingenious bespoke solutions. There are also significant opportunities for optimization and adaptation of conventional technologies for PFAS treatment.

One of the major challenges associated with PFASs is the relatively high mobility and persistence of these compounds in the subsurface. This creates the potential for large plumes in transmissive hydro-geological settings. Groundwater restoration efforts will necessarily involve managing large volumes of water and treating relatively low concentrations of PFASs to meet the exceptionally low drinking water standards (ppt) for regulated PFASs.[21,22] Given the extreme persistence of PFASs, designing remedies that will achieve these very low target levels in perpetuity will be challenging and likely involve long-term expenditure.[23] Furthermore, very few remedial technologies have been validated using analytical techniques that measure the entire PFAS mass, such as the total oxidisable precursor (TOP) assay,[24] and against PFASs with ultrashort (RC3) perfluoroalkyl chains.[25-27]

The shorter chain PFAAs generally have lower organic carbon partitioning coefficients than the longer chain compounds (such as PFOS and PFOA). Therefore, they are expected to be more mobile in aquifer systems and this may be a consideration when developing a CSM and planning remediation.[20] Short chain PFAAs are present in many articles of commerce[28] and Class B firefighting foams,

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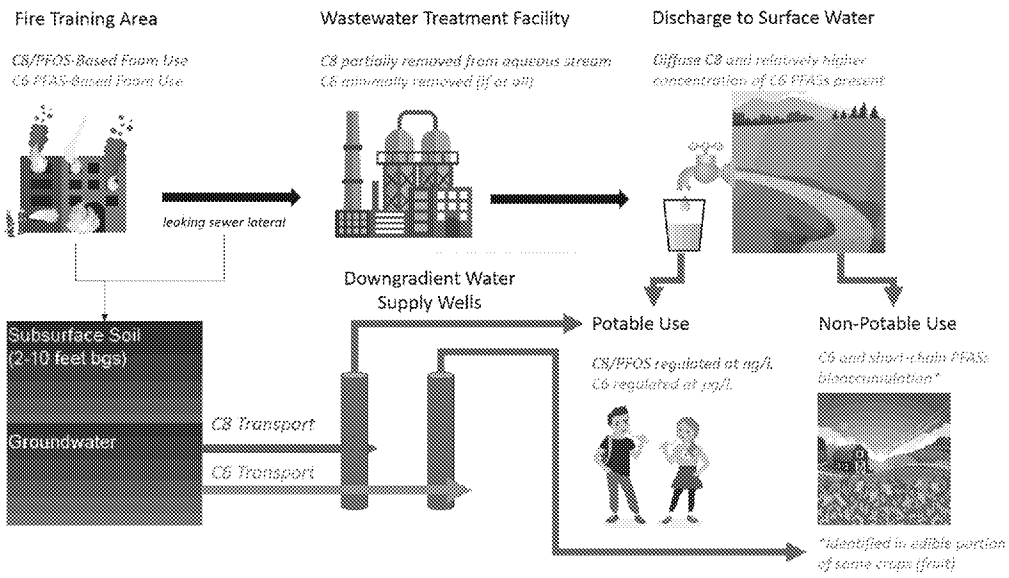
including ultrashort (i.e., <C3) PFAAs.[29] Further concerns when developing CSMs are reports of the shorter chain PFAAs bioconcentrating into the edible portion of crops, such as in grasses, fruit and vegetables,[2-4] whereas longer chains tend to be retained more in the shoots and roots of plants.

Fate and Transport Considerations.



The remediation of PFASs is technically challenging as many technologies which are applied to other contaminants are not effective on PFASs. For example, all biologically based remediation techniques, usually applied to conventional contaminants such as hydrocarbons and chlorinated solvents are completely ineffective for application against PFASs.

Most organic contaminants demonstrate some propensity for biodegradation, therefore remedial strategies can involve a series of approaches which also encompasses an element of monitored natural attenuation (MNA) where contaminant residuals can be demonstrated to be metabolized and thus detoxified. As PFASs are extraordinary in demonstrating extreme persistence, remedial costs will be exceptionally large as biodegradation of residuals cannot be relied upon to diminish concentrations following active phases of remediation.

The further complexity is that the compliance concentrations for PFASs are extremely low, often in the ng/L or sub ng/L range for long chain, whereas µg/L concentrations are applied for short chains they will still require a significant amount of remediation as these part per billion (ppb) concentrations are also very low.

Treatment technologies which rely on air stripping are also not appropriate as PFASs are not volatile. Remediation options for PFASs are very limited. The technologies currently applied for treatment of long chain PFASs, dissolved in water, generally include use of sorbent materials such as granular activated carbon (GAC) and ion exchange resins, but these just involve phase transition to concentrate PFASs, so a further stage of treatment which involves destruction is always required. Destruction is usually via a thermal process, so expensive as high temperatures (around 1100°C) are required. Remediation options for soils are lim-

Physicochemical properties for select PFASs.

Chemical Properties	PFOA	PFOS	PFHxS	PFBS	PFHxA	PFBA	6:2FTS	6:2FTOH
Molecular Weight	414	500	400	300	314	214	428	364
Solubility (@20-25°C), g/L	3.4-9.5	0.52-0.57	2.3	46.2 - 56.5	21.7*	Miscible	1.3*	0.02*
Log Koc [L/kg]	1.47-2.64	1.00	0.6-3.2	3.90*	1.91	1.88	-	2.43
Vapor Pressure (@25°C), mmHg	4-1300	0.0003	58.9*	631*	457	1307	0.11*	18.2
pKa	-0.16 to 3.8	-6 to -2.6	-6 to -5	-6 to -5	-6 to -5	-0.2 to 0.7	-0.13	-
Boiling point °C	188-192	>400	-	211	143	121	-	172

* estimated from published equations
From Pancras et al. 2016 https://www.concawe.eu/wp-content/uploads/2016/06/Rpt_16-8.pdf

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ited as thermal technologies are not proven and will need high temperatures to destroy PFASs, stabilization techniques are developing to encapsulate PFASs, soil washing is being trialed but there are concerns over the potential to remove polyfluorinated precursor compounds, then so far but destructive techniques are unproven.

These water treatment technologies, struggle with short chain PFASs as they are not retained on GAC and break though much more quickly, so GAC is not an appropriate for shorter chain PFAAs. Ion exchange resins can be applied for removal of long or short chain PFASs from water with some being regenerable, but these techniques are not yet widely deployed for treatment of PFASs in impacted waters. Emerging technologies for destruction of PFASs such as electrochemical oxidation is also far less effective on short chain PFASs and shows less effectiveness.[30]

Stabilisation of PFASs impacted soils is being optimized but struggling to retain the short chain PFASs, which as so soluble and thus easily mobilized, so short chain PFASs pose a significant challenge to many forms of soil remediation. Soil washing is usually applied using GAC to remove PFASs from the wash water, so alternative (more costly) options will be needed for short chain PFASs.

The costs of PFASs remediation are already very substantial as a burden on society, for example the military, where as a result of application of long chain PFASs in firefighting foams, costs for remediation of thousands of fire training areas have been estimated at trillions of US dollars. The cost for remediation of short chain PFASs will be significantly more expensive than for the long chain varieties as a result of the increased costs removing them from water and retaining them in stabilized soils. There are only a few technologies such as ion exchange resins, nano filtration and reverse osmosis that can remove short chain PFASs from water and they create a secondary waste, which then needs treating using an alternative technology to destroy the PFASs. The costs of PFASs management are astronomical compared to other contaminants.

Estimates for remediation of PFASs at Dusseldorf airport are €100M, with the costs of loss of 42 m^3 of AFFF being > €10M and a soil exchange in Germany has estimated costs of €1-3B. The costs of remediation of short chain PFASs are anticipated to be greater than for the long chains as a result of their increased mobility, which will contaminate significantly more groundwater and surface waters, vs long chain PFASs.

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APPENDIX III

STATEMENT BY GRAEME DAY, FIRE SERVICES COMPLIANCE MANAGER, LONDON HEATHROW AIRPORT, UK

"...We use Dr. Sthamer Moussol fluorine free foam concentrate at 3% at London Heathrow Airport (LHR ICAO Category 10). We took the decision to change products a few years ago for operational and environmental reasons and it also tied in with us changing our vehicle fleet. I was asked to lead the project and spent 15 months researching fluorine free foams that complied with ICAO Level B requirements and eventually shortlisted 2 products. (Dr. Sthamer and Solberg) I used an independent third-party test facility to further subject the 2 shortlisted products to operational effectiveness tests to assure myself that ***whilst they were ICAO Level B compliant, they actually worked.***

The concentrates were also sent away for independent chemical analysis (I had to sign non-disclosure agreements for this) to ensure that they were free from fluorine and organo-halogens. A decision to purchase was then made based on the customer support provided by each of the two companies and of course, cost. I took this approach as I wanted to ensure that we would have an effective working relationship with the company that we would eventually sign a contract with rather than just a relationship based on purchasing a product. I was lucky enough to work with the UK CAA on this project who ensured objectivity and operational compliance, along with Heathrow's environment and procurement teams. I did get some criticism along the way because some people in the foam industry felt that fluorine/organo-halogen free foams don't work but that isn't as common today, especially as there are now a lot more fluorine free foam concentrate manufacturers in the market.

Since purchasing our fluorine free foam, we have used it on 2 separate aircraft fires (an A321 and a 787) and it worked perfectly. Furthermore, the clean-up costs from these incidents were zero as following tests of the fire ground water runoff by the UK Environment Agency and local water company, we were given permission to wash the foam solution into Heathrow's surface water drainage system. This meant that the affected runways were available for use very quickly which had obvious financial benefits for Heathrow. We were not allowed to do this when we used AFFF and following the 2008 777 incident we spent thousands of pounds and many months disposing of the fire ground runoff. Another benefit of being able to wash fluorine free foam solution into the surface water drainage system is that our crews can train with foam concentrate instead of water or training foam.

We have just renewed our contract to supply Dr. Sthamer Moussol and are very pleased with the decision to use a fluorine/organo-halogen free foam concentrate. We've seen that neither fire fighter nor passenger safety has been compromised and that we have a product that not only meets our operational and environmental responsibilities but can also be used for training. We have also seen business continuity benefits in terms of a quick return of operational runaways and zero clean-up costs. We have also received a national environmental award for this project. Fluorine free foam concentrates are now widely used in the UK and in Europe and I would strongly recommend that any ARFF Chief gives consideration to looking at these products. I am now working on using our concentrate with CAFS and am again liaising with our CAA to write the relevant regulations (an EASA Alternative Means of Compliance) to make this happen...."

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APPENDIX IV

STATEMENT BY NIGEL HOLMES, PRINCIPAL ADVISOR INCIDENT MANAGEMENT, DEPARTMENT OF ENVIRONMENT AND SCIENCE, QUEENSLAND GOVERNMENT, AUSTRALIA

PFAS - THE REGULATOR'S PERSPECTIVE

It is no longer in dispute that all fluorinated organic chemicals (PFAS) and not just PFOS and PFOA are highly persistent, toxic, bioaccumulative and pose considerable threats to socio-economic, environmental and human health values globally.

Communities and governments are now experiencing the substantial collateral impacts on social and economic values by both long and short-chain PFAS pollution from a range of release sources considerably expanding the out-of-date view that PFOS, PFOA and PFHxS are the only chemicals of concern. The tally of closely related PFAS chemicals of similar or even greater concern is now several hundred to several thousand depending on the release sources.

The indefinite persistence of PFAS and their ability to pervade soils, waterways, groundwater, drinking water, livestock and crops has meant ever increasing exposure leading to growing impacts on social and economic values well beyond the impacts of other persistent organic pollutants in both scale and cost.

PFAS IMPACTS

The growing list of adverse impacts of PFAS pollution now spans large-scale degradation of social and economic values with spiralling remediation costs in addition to the initial concerns raised about human health and environmental effects. The spectrum of impacts from PFAS now encompasses:

- Resource degradation of water sources and soils negating or limiting beneficial uses.
- Social value degradation including loss of amenity, recreation and tourism for polluted areas.
- Fisheries resource contamination and loss of consumer confidence in seafood quality.
- Land value depreciation due to contamination or perception of contamination.
- Very high costs to businesses for cleanup, land use limitations and potential losses in business stock market value.
- Community and government costs for cleanup of orphan legacy sites.
- Reputational loss for corporations, industry sectors and governments.
- Loss of resources too polluted to be cleaned up including land and water resources.
- Agricultural production of livestock and crops value lost due to contamination.
- Additional costs to infrastructure providers to remove contaminants from water supplies.
- Loss of income and added disposal and treatment costs for contaminated materials such as WWTP effluent and biosolids.
- Human health adverse effects at low exposures.
- Environmental and wildlife resource degradation.
- Reduced public confidence in the government to regulate pollution and protect public health.

Significant costs for investigations, remediation, legal actions and compensation are already evident, growing rapidly and anticipated to be in the hundreds of millions of Euros for Defence and airport facilities alone and we are only just beginning to discover the extent of the problem.

PFAS SOURCES

Various diffuse sources of PFAS contribute to the releases to the environment including coatings for textiles, food packaging and stain resistance. However, the greatest threat across all social, economic, environmental and health values comes from the use of firefighting foam. Unlike the

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other PFAS uses, which at end-of-life can mostly be expected to be captured in landfills, firefighting foam is the most dispersive and uncontrollable use of PFAS. Some thirty two percent of current PFAS production (Global Markets Insights 2016) is for firefighting foam, this represents about 8,500 tonnes annually (@2015) of fluorotelomers with the potential for release directly to the environment during incidents or due to poor training and management practices.

The various myths that have been perpetuated about there being no alternatives to fluorinated foams (AFFF, FFFP, FP, etc.) are now being debunked with non-persistent foams not only being certified to be effective for all applications against industry performance standards with few exceptions but also growing in numbers are examples of their successful use in real-world incidents involving large-scale spills and fires and their adoption by high-risk, safety-critical sectors including military, airport, offshore oil industry, fire brigades, ports, refineries and bulk fuel storage.

No distinction is now made between short-chain and long-chain PFAS as there is already ample and rapidly growing evidence that short-chain PFAS, promoted as "safe" alternatives have characteristics and behaviour that make them of similar concern to long-chain PFAS with their use now beginning to face the same restrictions.

THE OBLIGATIONS OF THE PRECAUTIONARY PRINCIPLE

In terms of contrasting PFAS foams versus non-persistent foams the potential for adverse health, environmental, social and economic effects are vastly different. Fluorine-free, non-PFAS foams only have limited-scale, short-term effects and are largely self-remediating.

Comparison of PFAS and fluorine-free foams against the Precautionary Principle (ESD, Rio Convention reference, Preston reference) factors clearly summarise the drivers for transition from persistent organic chemicals to fully biodegradable and sustainable alternatives. The majority of countries have subscribed to ESD and the Precautionary Principle with legal precedents now established as to the obligations to apply it and the factors to be taken into account.

The legal obligation to apply the Precautionary Principle to decisions about the use of persistent chemicals applies to users in their choice and uses, manufacturers in the quality of the products they offer, and government regulators in setting appropriate controls in Policy and licence approval conditions. Users and manufacturers have generally failed to self-regulate so regulators globally have moved to implement appropriate controls in response to the overwhelming evidence of adverse effects and costs of legacy and ongoing PFAS pollution.

PRECAUTIONARY PRINCIPLE ASSESSMENT FACTORS

Assessment factors	PFAS foams	Non-persistent foams
1 Spatial scale of the threat	Local, regional, state-wide, national & global	Localise impacts only
2 Magnitude of possible impacts	Wider environment & human health Chronic as well as acute effects	Local aquatic environment Short-term acute effects only
3 Perceived value of the threatened environment	High perceived values for natural environment & long-term local & broader human health	High perceived value for natural environment considerations
4 Temporal scale of possible impacts	Long-term chronic effects Decades to inter-generational presence	Short-term - weeks to months.
5 Manageability of possible impacts	Very poor post release manageability Highly dispersive, very difficult to contain & treat	Treatable or by natural recovery processes
6 Public concern & scientific evidence	Established & growing concerns for all PFAS Rapidly mounting evidence	Limited concern about harm based on established sound evidence
7 Reversibility of possible impacts	Not reversible or extremely long-term reduction, increasing exposure if releases continue	Reversible with remediation or natural recovery/decay

TRANSITIONING TO BEST PRACTICE FOR FIREFIGHTING

Since the withdrawal of 3M from the PFAS firefighting foam market in 2000 there have been considerable advances in the development of fluorine-free, non-persistent firefighting foams. Fluorine-free foams are now certified and available for all applications with their effectiveness demonstrated in real-world large-scale incidents. This now provides the opportunity for industry sectors to transition to sustainable non-persistent alternatives.

For older, large facilities such as refineries and bulk fuel storage face a number of difficulties in transitioning to sustainable non-persistent foams. However, given that the practicalities and necessary timelines vary according to each facility's circumstances it is not appropriate to apply a broad derogation or exemption from deadlines for compliance with phase-out of PFAS foams.

For example, a new green-field facility would be able to comply immediately while an older facility may be able to transition immediately for some aspects but would need concessions to allow design and retrofitting to be staged for

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old PFAS systems. Provisions already exist in environmental legislation to allow regulators to consider and license the staged transition and interim measures due to special circumstances. This model of staged transition is already being broadly applied at various facilities in Australia with full cooperation form industry sectors.

PHASE-OUT OF PFAS

The uses of highly persistent, toxic, bioaccumulative PFAS chemicals in applications such as firefighting foam, where there is a very high likelihood of direct release to the environment with downstream social and economic effects, is highly undesirable and is no longer justified or acceptable given that there are low-impact, fully-effective alternatives now available.

Where transition needs to be staged to extend the phase out this is the sole jurisdiction of the relevant local regulatory agency to consider on a case-by-case, risk-assessed basis considering the particular facility's circumstances, necessary timelines and interim measures in the context of the adjacent **environment, social and commercial sensitivities.**

Broad derogations on PFAS use, even within the one industry sector, are not appropriate as there will not be a one-size-fits-all model and there is the risk that uninformed or unscrupulous suppliers and end-users will persist with high-risk management practices rather than undertake the necessary risk reduction measures.

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APPENDIX V

EDITED EXTRACT DERIVED FROM ROLAND WEBER, PETER FANTKE, BORHNE MAHJOUB, AND AMEL BEN HAMOUDA (2018)

"HOW TO PREVENT THE USE OF TOXIC CHEMICALS"

SECTION 12, PAGE 58.

This publication was developed by the Regional Activity Centre for Sustainable Consumption and Production (SCP/RAC) as part of the EU-funded SwitchMed Programme. SwitchMed benefits from collaborative coordination between the European Union, the United Nations Industrial Development Organization (UNIDO), the UN Environment and Action Plan for the Mediterranean and its Regional Activity Centre for Sustainable Consumption and Production (SCP/RAC) and the UN Environment Division.

12. PER- AND POLYFLUORINATED ALKYLATED SUBSTANCES (PFASS) IN FIREFIGHTING FOAM

Background, identity and use

The use of firefighting foam containing perfluorooctane sulfonic acid (PFOS) and other per- and polyfluorinated alkylated substances (PFASs) can result in the contamination of groundwater, drinking water and surface water, including the Mediterranean Sea. PFASs or their degradation products are highly persistent. Longer chain PFASs are increasingly bio-accumulative and toxic. Shorter chain PFASs accumulate in plants, including vegetables and fruits, and are much more difficult if not impossible to remove from waste water. There is no known degradation for perfluorinated substances in ground water or soil and therefore the contamination is long-term. PFASs are an issue of concern under the Strategic Approach International Chemical Management (SAICM).

For most firefighting foam applications, fluorine-free foams (F3) are available today. They degrade in the environment and are not a long-term concern for ground and drinking water. A few of these foams are even solvent free.

Tests from big waste disposal companies in Germany have shown much better results with F3 in a one- to-one test against fluorinated AFFF, for example on compressed plastics and other materials, where the water-film is not responsible for extinguishing the fires. F3 are effective due to their better foam quality, foam density and penetration of solid fuels. Therefore, they have a better cooling effect paired with oxygen cut-off, which is more important for those kinds of materials.

The lack of fluorinated molecules in F3 results in minor fuel pickup upon initial contact with the hydrocarbon fuel. As of today, AFFF still have a slightly better performance on 2-dimensional fires such as tank fires with crude oil or other hydrocarbons. The poorer performance of F3 in this case can be overcome with a higher application rate.

Within the German Fire Brigade Association there is a working group for foams that already recommends the use of fluorinated foams only as a last resort for big tank storages and refineries, due to their risk of large 2-dimensional fires. For all other uses, such as at airport in sprinklers, in other foam-based systems, in fire-extinguishers and for all other kinds of fire brigades and users, the recommendation is to restrict the use of AFFF in the foreseeable future, as the existing alternatives already have proven high performance levels for most situations.

At low application rates (approximately 4 l/min/m^2), a "gentle" F3 application is recommended due the known "fuel pickup" effect. Firemen are already trained in the gentle application method for all kinds of alcohol-resistant (AR) foams, therefore no additional training is needed. At high application rates (> 4.5 l/min/m^2), this effect becomes irrelevant.

Economic feasibility

Generally, the price of F3 doesn't differ significantly compared to other foams like AFFF used in Western Europe. However, Mediterranean countries generally buy very cheap and thus old technology-based foams, such as protein foams not considered best available techniques (BAT).

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This history of price sensitivity makes it very difficult to introduce more rigorously produced and tested foams in these markets or to argue for environmental protection. Currently, South Mediterranean countries are unaware of the costs of removing PFASs from drinking water or remediation of contaminated groundwater. Considering the price competitiveness of BAT for fluorinated and non-fluorinate foams, F3 have the economic benefit of avoiding the high cost of groundwater and drinking water clean-up and other external costs related to negative human health, environmental and ecological impacts.

Hazards, risk and life cycle considerations

The chemicals in F3 readily degrade in the environment and do not contaminate the groundwater and drinking water. In a BAT F3 product, no PBT substances should be found.

Depending on the formulation, F3 application might result in a higher biological oxygen demand (BOD) and chemical oxygen demand (COD) – [but see comment in main text]. However, the most advanced F3 from 3FFF uses solvent free ("SF") technology, which reduces COD and BOD to a minimum [comment: by about 50%].

The foam can be used safely without changing or compromising the operator's protection protocols, including heat radiation and distance protocols for fighting fires.

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APPENDIX VI

STATEMENT BY DR NIALL RAMSDEN, COORDINATOR LASTFIRE (LARGE-SCALE ATMOSPHERIC TANK FIRE) ORGANISATION

INTRODUCTION

As part of their ongoing determination to develop future policies for firefighting foam selection and application taking into account environmental issues as well as fire performance, the LASTFIRE Group has carried out the most extensive series of independent end-user managed large scale tank fire foam performance testing for more than 35 years.

The results have undoubtedly provided a major step forwards to this goal and identified where future work should be focussed to answer any remaining issues.

BACKGROUND

The LASTFIRE Group, the international forum of oil companies developing best practices in storage tank Fire Hazard Management, is working with their members to provide a strong foundation of knowledge and test data from which they can develop long term sustainable policies for firefighting foam selection and application.

It is very well known and accepted that the international pressure to minimise the environmental effects of firefighting foam has been increasing over a period of years. A recent example of this is the new legislation in South Australia that will prohibit the use of fluorosurfactant containing foams, although there is a possibility for a transition time provided it is shown that genuine efforts are being made to assess and prove alternatives. LASTFIRE is going through this process using an extensive research programme including testing and development of best practice guidance in foam management.

Manufacturers have developed "new generation" foams, some with "high purity C6" fluorosurfactant base and some with Fluorine Free formulations. Although C6 fluorosurfactants have been used for many years by some manufacturers in their formulations it must be accepted that all formulations on the market today are new to some extent and therefore unproven. With large scale testing being extremely expensive, and the industry generally being very good at preventing tank fires, it will be many years before extensive experience is gained from large diameter tank fires.

With this background, LASTFIRE embarked on a programme incorporating both small scale and "real life" situations testing using both Fluorine Free and high purity C6 formulations of new generation foams with different application techniques.

TEST OBJECTIVES

The following critical objectives were established for the work, recognising the need to maximise returns on the investment being made. (It is considered that the total real cost of this test series was, conservatively, in the order of 800,000 Euros when taking into account the time of all the parties involved and the real equipment/foam costs, most of which was provided free of charge.):

- Developing a snapshot of current capability of a representative selection of the new generation foams, particularly to assess if they can be considered absolute "drop in" replacements with equivalent performance capability and without the need for system or application equipment modifications.
- Forming an overall view on whether or not modifications to current practices of foam application are required with new foam formulations to achieve acceptable performance, or if more efficient usage of resources can be gained with different application techniques.
- Revalidation of the LASTFIRE test protocol against "real life" performance of new generation foams. (As part of the original LASTFIRE study in 1993-7 a critical foam performance test was developed to simulate tank fire application. This was validated against proven foams that had performed well in real incidents at typical standard application rates.)
- Validating the industry accepted strategy for large bund fires using a "section by section" approach. (Although a recognised practice described in standards such as NFPA 11, the principle of applying foam to large bund

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areas is relatively unproven in real incidents, although it has been used in some cases.)

- Assessing the accuracy of typical foam concentrate proportioning devices with the new generation foams. (Carried out as part of the overall goal to determine if new generation foams are true drop in replacements for existing systems.)
- Developing a LASTFIRE Group preferred vendor list for those companies which recognise LASTFIRE requirements and commit to working with the group to gain knowledge and improve tank firefighting efficiency.

SUPPLIER INVOLVEMENT

LASTFIRE research is funded from the annual subscriptions of members. Due to the high cost and the need to work with suppliers, in this case suppliers were requested to take part in the test series and help fund the work through a contribution towards the fuel costs. Many suppliers were approached but only 5 agreed to submit foam samples for testing and to make a contribution to fuel costs. The following suppliers joined the programme:

- Angus International
- Auxquimia
- Bio-Ex
- Dr. Sthamer
- Tyco

A total of 6 Fluorine Fee foams and 2 C6 based products were tested.

TEST RESULTS AND OVERALL CONCLUSIONS

The full report and test results are currently only available to LASTFIRE members and the participating providers of equipment, concentrates and services but the following are the main conclusions drawn from the work. It should be emphasised that this should be considered as one part of the ongoing work being carried out by LASTFIRE.

- The LASTFIRE test still continues to be relevant to all foam types for assessing the performance of foams using different application devices. However, some modifications and clarifications will be made to a new issue of the protocol.
- None of the new generation foams should be considered as a straightforward "drop in" replacement for any current foam concentrate being used. Even if appropriate fire performance can be shown for the specific hazard it is still necessary to check that the concentrate is compatible with the proportioning systems and other system components.
- From the samples tested, some concentrates of both C6 and FF formulations demonstrated adequate levels of fire performance for bund spill fires and small tank fires using standard NFPA application rates although generic conclusions cannot be drawn from this. The performance capability is very specific to the particular formulation and also to the type of application equipment used.
- There are different levels of performance within each generic type of foam. It is not possible to state, for example, that all C6 foams demonstrate better performance than all FF foams or vice versa. This emphasises the need for batch testing.
- There is no reason to doubt that adequate performance can be achieved for larger tanks than those tested but the flow capability over longer distances still needs to be checked.
- Strictly speaking this statement applies to all new generation foams but it is recognised that fluorosurfactant based foams are less likely to have an issue with this than FF types.
- The sectional application approach to bund fires can be effective but responders should be made aware of potential edge/hot object sealing issues and the need for constant monitoring and top up of any areas controlled when the main application is moved to other areas.
- It is important to note that full environmental data for foam types is required prior to developing strategies for application, containment, remediation and disposal. It must be recognised that all foams have some environmental effect. With the current state of development of FF foams in particular it is not possible to be generic in drawing conclusions about what environmental effects a foam has. LASTFIRE is working with the industry group PERF (www.perf.org) on this subject.
- It is considered that current standards do not give sufficient emphasis to the importance of the combination of foam type and the application device performance and consequent foam quality. It is important to get this combination right to optimise overall performance. There is great scope for developing more efficient systems achieving similar performance to those designed in accordance with current standard. Note: NFPA 11 has set up a Task Force to look at the issues of Fluorine Free foam. LASTFIRE consider this to be a great opportunity to develop Performance Based standards for the long-term future.
- CAF application, if engineered correctly, can be very forgiving of foam concentrate quality. (Note that the application rates used with CAF were in the order of 30-40% of those used with conventional equipment.)
- Detailed performance-based specifications are critical to achieving appropriate long- term performance and to managing foam stocks correctly. Such specifications

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need to request environmental data and materials compatibility data as well as fire performance standards appropriate to the hazards.

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APPENDIX VII

EXTRACTS FROM A STATEMENT BY TED H. SCHAEFER, BSC, MCHEMTECH, ME CCHEM, FORMERLY THE 3M COMPANY AND SOLBERG ASIA-PACIFIC

A BRIEF HISTORY OF THE DEVELOPMENT OF FLUORINE-FREE CLASS B FOAMS (F3S)

"...I have been involved with the technical aspects of firefighting foam technology as a practising chemist since 1980. Straight out of university, I was given the responsibility for firefighting foam chemistry at 3M Canada Inc., for manufacturing, sales & customer interface, plus for product development. Key customers for us were the Ministry of Transport and the Canadian Defence Forces. During 1981, I looked at the technical opportunities for product modification to better service the Canadian Market and look for growth opportunities. My initial project was to determine the function of each chemical used in the 3M Light Water AFFF products to understand their role in product performance, then to examine what alternative chemicals could be used to enhance product performance in the future, and this is when I truly started to understand firefighting foams.

In 1981, while learning about the AFFF film formation by measuring surface tensions and interfacial tensions on hydrocarbon liquids and how they worked. The 3M fluorosurfactants were considered key components that were required to be in the AFFF formulations to be able to have the product form an "aqueous film" and the hydrocarbon surfactants played a role also. I quickly found out that AFFF foams don't always form films, especially with simpler small chain hydrocarbon fuels, which have low surface tensions critically below that of an AFFF. This was confirmed by the Spreading Coefficient calculation of an AFFF on n-pentane and n-hexane, where the surface tension of the foam solution was higher than the surface tension of the fuel, which mathematically solves that the Spreading Coefficient is negative. In discussion with our US laboratories that my calculations were correct and that AFFF did not necessarily form a film all of the time, especially with the smaller chain hydrocarbon fuels. I was assured that the AFFF could still put out the fire with added effort and volumes.

I had also asked the 3M scientists about how fluorosurfactants biodegraded, because they were so environmentally stable. I was told that the fluorosurfactants are inert and they should be thought of like "chemical rocks" that were stable and non-reactive. They did nothing when they got into the environment and would just sit there doing nothing. There is nothing to fear and they don't go anywhere. What that meant by not going anywhere was that they would always be around. So, their concentration would grow.

In 1982 I was given a project to look at a problem that one of our customers was having. The Royal Canadian Air Force had an Aircraft Rescue Fire Fighting (ARFF) training facility that had an efficiency issue. They would go out for training fires with ARFF vehicles and could only have two training fires in one day as it took several hours to burn back the foam to allow a second training fire in a day. There was so much fluorosurfactant on the kerosene fuel from a training exercise that it took hours to burn off, or it would collect in the training ground water and fire pits. The RCAF wanted a Training Foam that would put out the fire and not stay around residually, allowing more training sessions in one day, giving trainee fire fighters more experience ... which meant eliminating fluorosurfactants to solve this problem.

I utilized my laboratory investigations to formulate and test a non-fluorosurfactant containing firefighting foam that had the ability to put out an aviation fuel fire securely and be capable of a controlled burning back that would allow the training scenario to be repeated more than twice a day. I remember being instructed to "not make the product too good!". I recall that we became a supplier to the RCAF of Training Foam for Defence Contracts. What I learned from this experience in 1982 is that military aviation fires could be controlled and extinguished by fluorosurfactant free (FFree) firefighting training foam. Effort was made to ***not*** *be close to the performance of an AFFF, so we purposely held back on performance.*

During the time period of 1981-1985, I became engaged at looking into a new market for firefighting foams. At that time there were no firefighting foams or water additives

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being used to assist the penetration of water into the fuels (Class A) in forest fires by ground attack fire fighters. Most of the chemicals associated with forest fire control were used from aircraft. While working from the basic research investigation of existing and new chemicals that could be used potentially in AFFF products, I started to look into formulating a new technology for forest fires. They goal was to design a product that had no or low environmental impact, no fluorosurfactants (to control cost, and release of environmentally inert chemistry), highly concentrated, and durable. What was meant by durable was that the resulting foam would last longer than an AFFF, so the water draining from the foam could be slowly absorbed by the trees and leaf litter on the forest floor. The new forest fire oriented technology would have significantly longer visible duration. The resulting foam technology (now called Class A foam) made water reside in forest fuels about 5-10 longer than plain water.

In 2000, when 3M announced the withdrawal from the AFFF market, I was assigned to determine if AFFF type fire performance could be achieved without fluorosurfactants. I immediately started to formulate a fluorosurfactant free foam by removing the PFOS based surfactants used by 3M. The first aspect I noticed was that once the PFOS was removed, the remaining surfactants as they alone did not put out a flammable liquids fire. However, when we looked at other hydrocarbon surfactants, we started to make progress and putting out aviation fuels. In about 300 experimental formulations later, we had met ICAO Level B performance, and matched AFFF performance on that same spec, which included a US Mil Spec product. Therefore, making an FFree foam that performed the same as AFFF was possible! With an invitation from the US Naval Research Laboratories, we were involved with a collaborative research project to investigate the potential of a fluorine free foam technology meeting the fire performance of a US Military Specification AFFF. Over several fire tests, we were within 5 seconds of the US Mil Spec performance specification and test fire. Therefore, meeting premium performance AFFF specifications is within reach. Only minor modification would achieve the goal of eliminating fluorosurfactants from high performance specification firefighting foams. In fact, recent developments have produced higher performance FFree foams that meet specifications in ICAO that were reserved for high performance US Mil Spec AFFF products.

What I have learned from the petrochemical industry is that n-pentane (and even n-hexane) are in a refinery product called "light tops" and are collected during Natural Gas chilling and stored in large storage tanks. If ignited, AFFF cannot extinguish this kind of fire and it becomes a controlled burn. This is also true for iso-octane. In fact, n-pentane, n-hexane and iso-octane has been proven to better extinguish by a high-performance synthetic fluorine free foam. This includes vapor suppression of hydrocarbon fuel spills. High performance FFree foam successfully out performed AFFF, AFFF/AR, and fluoroprotein foams on a large-scale test fire. At a major multi-tank fire resulting from an earth quake used high performance FFree foam to suppress several tanks and their bunded area from ignition during a vapor suppression operation by a major disaster control organization in Asia successfully for many days. Once the fuel was recovered, the firefighting water FFree foam used in the operation was the only firefighting water that was allowed by the Japanese EPA to be released to the ocean and not held back for extensive processing and fluorosurfactant capture.

Having read the recently published health related issues to the chemicals involved that are plaguing people in communities in the US from the major producers of fluorosurfactants used in AFFF firefighting foams, I can state that the Socio-Economic issues relating to the use of fluorosurfactants, which are used in AFFF products, are extremely costly to those who are suffering medically and those who have lost their lives due to the associated cancer that has emerged from the release of these chemicals in the environment. The cost of this pollution of a persistent organic chemistry way exceeds any financial settlement between those affected and the manufacturer. The penetration of these fluorosurfactans into ground water, even through solid concrete airport aprons, let alone the direct discharge into ground, rivers, and the ocean has far reaching affects, even into the food chain were bioconcentration makes the situation even worse...."

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APPENDIX VIII

EXTRACTS FROM A STATEMENT BY KIM T. OLSEN, COPENHAGEN AIRPORTS, HEAD FIRE TRAINING ACADEMY, COPENHAGEN, DENMARK

"...First of all, a little bit about "foam history" from Copenhagen Airport (CPH), covering environmental issues, implementing the changeover to Fluorine-Free Foam and investment in cleaning up and remediating the contamination from using AFFF.

- *1972 CPH starts to use AFFF foam; two different products - 3M LightWater™ and SM AFFF from Svenska Skumbolaget.*
- *1995 CPH now uses only one foam type - 3M LightWater™ AFFF. Tests showed that the burn-back resistance was too poor with the foam from Sweden and it was decided to use only foam from 3M.*
- *2003 CPH and Copenhagen Environment Department investigate the PFOS /fluorochemical issue in regards to firewater run-off from the CPH training site/burn pit, resulting in restrictions on use of AFFF.*
- *2006 all training with AFFF is stopped at CPH.*
- *Copenhagen Airport Environment Department started to secure the CPH training area, not just the burn pit, but the whole area where AFFF foam has been used. A sewer system is put in place that collects the groundwater and pumps it back to the training area aimed at preventing any pollution spreading outside the confines of the airport.*
- *2008 CPH investigates new foam types. Tests using Solberg re-healing (RF) foam gives positive results and it is decided to change all foam in CPH to this type, with the implementation of 3 new Rosenbauer Panthers. A very important issue is the training for our firefighters!*
- *2009 Reports from OSL and ARL, indicate that we are "on the right track". The Chairman of the ICAO ARFF working group is concerned about aviation safety and asks the Airport Management for some documentation that Solberg re-healing (RF) foam rally works. Apart from several fire tests (at this time we had to do the test according to the US Mil-Spec test), all Panthers and re-healing (RF) foam pass the NFPA 403 test in CPH In December 2009.*
- *2014 A major program involving environmental clean-up, securing and re-construction of the Fire Training area are set into motion. This is a huge project! Copenhagen Airports AS invested more than 15 million EUR in this project.*
- *2018 CARFA (Copenhagen Airport Rescue & Firefighting Academy) is based on the new Fire Training area. This resulted in the training of firefighters from many different airports in different countries in a safe and an environmentally better way than before.*
- *Copenhagen Airport Environment department is still working on cleaning up AFFF pollution in other areas of the airport where AFFF foam had been used. Just maintaining the enclosed sewer system around the fire training ground, costs the airport more than 1,5 million EUR every year and we expect that we will have to do this at least the next 80 years...."*

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APPENDIX IX

STATEMENT BY NIGEL HOLMES, PRINCIPAL ADVISOR INCIDENT MANAGEMENT, DEPARTMENT OF ENVIRONMENT AND SCIENCE, QUEENSLAND GOVERNMENT, AUSTRALIA

AFFF VERSUS F3 (FLUORINE-FREE) PERFORMANCE AND INCIDENTS

There are many examples of fluorine-free foam performing to standard and effectively in real-world incidents despite some claims by commercial lobbyists opposed to phase-out of PFAS foams. Claims of poor performance by 3F foams rarely stand up to even basic scrutiny.

Fluorine-free foams are certified effective for use in all major vapor suppression and firefighting applications (UL, EN1568, ICAO, IMO, LASTFIRE, HOCNF) and have been in use globally for more than a decade across industries including aviation, fire brigades, military, power generation, shipping, onshore and offshore oil and gas, refineries, marinas, chemical manufacturing, mining, ports and bulk fuel storage. Examples of effective use in large incidents since 2003 include large fuel storage tank (30m) collapse vapor suppression, large-scale oil well blowout fires, fuel terminal tank (15m) fires, container ship fire, aircraft crashes, offshore oil platform and helideck protection and oil refinery fires.

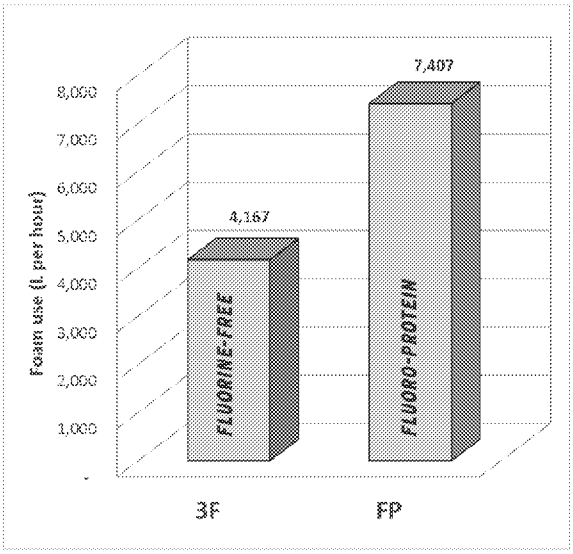
VAPOR SUPPRESSION - F3 VERSUS FP

In 2013 a large petrol spill of over 150,000 L into a bund at a fuel terminal had both AFFF and fluorine-free foam (3F) applied to it to suppress flammable vapors, both foams were found to be effective.

Initially FP fluorinated foam (3%) was applied to the spill, followed by fluorine-free foam (6%) from outside resources. Not only was the fluorine-free foam effective in suppressing fuel vapors it did so in spite of being mixed with the FP foam already applied to the spill as well as being applied with airport fire tender equipment not regarded as appropriate for foam application to bund spills.

A review of the amounts of each foam used and their application rates found that while the concentrate use rates were almost the same (3F 250 L/hr vs FP 222 L/hr) the final 6% fluorine-free foam blanket only needed to be applied at the rate of 4,200 L/hr versus the 3% FP foam applied at 7,400 L/hr (78% more).

Comparing the use and risks on the basis of only one foam or the other being used over the 26 hours of the incident the fluorine-free foam versus the PFAS foam would have generated far less firewater (3F 108KL vs FP 193KL) with a much lower risk of overtopping the containment, no potential long-term social, economic or environmental effects and no need for expensive specialised treatment and/or high-temperature destruction of the PFAS contamination. Had the fluorine-free foam been applied using methods appropriate to bund spills the quantity used may have been even less.



COST IMPLICATIONS OF SPILLS - F3 VERSUS PFAS FOAMS

A 22,000-litre spill of fluorinated AFFF foam concentrate at a facility in Australia occurred in 2017 due to the failure of a corroded connection in a foam pump system. The spill entered drains, the sewer and overflowed to a waterway before the discharge was noticed and stopped. As a result of the spill a fish kill occurred in the adjacent waterway; the sewage treatment plant effluent and biosolids were compromised; the operation of the industrial precinct was compromised by the loss of sewer access and warnings

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were issued to not consume seafood caught in the vicinity due to the fluorinated organic chemicals contamination.

Remediation of the spill required the specialised treatment of nearly 15 million liters of contaminated sewage and surface water to extract the fluorinated organic chemicals so that the remaining wastewater could be disposed of by standard wastewater treatment. **The cost of the basic contaminated water treatment was about €37M.** This does not include the cost of replacement foam or the ancillary social and economic impacts on adjacent businesses, fisheries and public amenity. On the basis of this experience the facility operator has commenced replacement of fluorinated foam with fluorine-free foam at all its other facilities.

The partial containment of the spill in the sewer and drains meant that it was possible (although very expensive) to recover and treat some of the contaminated water. The spilled material to the waterway cannot be recovered or treated and the PFAS component is a permanent pollutant in the ecosystem. The same sort of spill or foam use on an open area, for example at an aircraft crash or fire would be nearly impossible to contain and far more expensive to remediate plus the cost of the disruption while the area, such as an airport runway or a fisheries resource, was being remediated and unable to be used.

In 2018 the same facility had a similar spill of fluorine-free non-persistent foam that was fully contained with minimal costs for disposal compared to the previous AFFF PFAS spill costs. Even if the spill had been to sewer or open ground or directly to a waterway the effects would have been localise and temporary with natural biodegradation occurring with very little need for intervention.

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APPENDIX X

STATEMENT BY DR THIERRY BLUTEAU, LEIA LABORATORIES, LYON, FRANCE

SOLVENT-FREE FOAMS

The major component of many foams which contributes to the total oxygen demand when released into the environment, i.e., the BOD or COD value, is either a glycol or glycol derivative.

Foams concentrates, especially those with the ability to withstand very low storage temperatures or to produce foams capable of being used at low ambient temperatures can contain anything up to 10-20% glycol or glycol derivatives as anti-freeze agents. This results in an enormous oxidisable load or chemical oxygen demand (COD) value. For example, if a foam concentrate were to contain 15% ethylene glycol ($HOCH_2$-CH_2OH) then it is possible to calculate the COD value as follows:

$$2C_2H_6O_2 + 5O_2 \rightarrow 4CO_2 + 6H_2O$$

Oxygen required per mole ethylene glycol (62 gm) is 80 gm, or 1.29 gm O_2 per gm ethylene glycol. Thus, a foam concentrate containing 15% w/v ethylene glycol as for protection against freezing will have a minimum COD of 193,500 mg O_2 per litre. If the foam concentrate contains in addition protein, such as in an FP or FFFP, or other oxidisable components this will be substantially higher.

Most of conventional foams, whether F3 or fluorosurfactant-containing, i.e., AFFF, FP or FFFP and AR variants, contain solvents for one or more of the following reasons;

- as a co-solvent to allow or enhance solubility in water for some other additives;
- in order to enhance/adjust the finished foam stability and expansion;
- as an anti-freeze to lower the freezing-point in order to provide protection against very low ambient temperatures.

The common chemicals which are used are as follows: low carbon-number alcohols such as ethanol, iso-propanol (IPA), tert-butanol (TBA), sec-butanol; glycols such as mono-ethylene glycol (MEG), mono-propylene glycol (MPG), hexylene glycol, or glycol derivatives such as the ethylene glycol ethers butyl-glycol or butyl-carbitol, propylene glycol ethers (DPM, TPM) and some others.

Alcohols are mainly used by the PFC suppliers to help disperse their products as concentrates. They are not found in high quantities in firefighting foams, I would say a few percent only MEG is a classic anti-freeze agent and relatively cheap; but, as you know, potentially toxic replacement. Unfortunately, MPG is not that great as an antifreeze and is more expensive. Hexylene glycol is used as a co-solvent, mainly in protein foams because it is compatible. EG ethers are the most popular: BG is harmful, and BDG is irritant. Their main interest is foam stability and foam boosters. PG ethers are used to replace the EGE; but they are more expensive and not that great in foam.

Why does 3F replace all of them? The main reason is that most of the commonly used ones are either toxic, harmful or irritant. First of all butyl-carbitol (butyl diglycol or BDG) must be reported in the US if spilt; the second reason is that the "safe" alternatives like PG and derivates are more expensive and not that good in firefighting foams; the third reason is that they bring a lot of COD; in a typical AFFF, we reduce about 50% of the COD using the SF technology.

The development of solvent-free and fluorine-free foams has reduced the total chemical oxygen demand (COD), as well as BOD, values by approximately 40%-60% and thus their impact on the environment due to both acute and total oxygen stress.

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APPENDIX XI

STATEMENT BY GARY MCDOWALL, 3FFF LTD., CORBY, NORTHANTS, UK

HAND-HELD AND PORTABLE EXTINGUISHERS

The UK figures are unavailable as yet but my estimate of total extinguishers sold in the EU is reasonable at 6M units per annum and the percentage of foam extinguishers is also reasonable. In Germany foam extinguishers are about 30% of total sales; on foam alone with a Class B rating (meaning AFFF) the total foam solution is 4,018,511 for Germany in 2015. The UK is much higher than 35% because we use far less powder in the UK as do many other countries. This is due to concerns over visibility issues during escape from buildings and inhalation of powder particles in confined spaces.

The total number of hand portable extinguishers sold in Europe annually is ~6 million units. Of those 35% (2.1 million) are foam extinguishers (AFFF). The most common sizes throughout the EU are 6 and 9 litre units. Other sizes include 2 and 3 litre units mainly used for transport vehicles. So, for a conservative estimate of the level of foam solution to be used I will take 6 liters per unit for the calculation. This equates to 12.6 million liters of foam solution sold in extinguishers each year. If all 2.1 million extinguishers used GENEX ESC to reach the standard rating when tested under EN3 for a 1444B hydrocarbon fire, this would require 189,000 liters (198,000 kilo) of GENEX ESC, which is a 0.5% induction-rate AFFF super concentrate used at 90ml per unit to achieve this rating.

In total this would require approximately 50,000 kilograms of Capstone 1470 (or equivalent) fluorosurfactant to manufacture this volume. Capstone 1470 is said to have an active fluoro-content of between 11 and 12% which means as much as 5,500 to 6,000 kilo of pure fluorochemical would be used in European foam extinguishers each year. Each country has their individual standard protocols for extinguisher function testing of these units which vary between 4 and 6 years. The UK is every 5 years. This function test requires complete discharge in order to test that the equipment functions correctly, after which the equipment is refilled or replaced as necessary.

It is difficult to determine is how many extinguishers are sold as replacements or as new equipment. In any case, a minimum of 1,000 kilo of pure fluorochemical is being discharged every year. At my meeting with the Bund two years ago, my conclusions that the vast majority of this material was being discharged onto land, a surface water drain or a sewer drain was dismissed. When they were asked to produce figures of licensed disposal volume for the German market, none were produced. As with each country in Europe, there are guidelines and regulations in place, but these are not adequately policed, and we have all seen evidence of how service engineering companies dispose of this trade waste. Some years ago, an engineer from a well-known fire extinguisher company was caught on camera in the UK discharging foam extinguishers to open ground in a car park; this is was not unusual but very typical at the time, although more recently there have been moves to collect the discharged foam for disposal as regulated industrial waste.

To put this into some context, a typical petrochemical site would store between 300 and 600 tonne of AFFF-AR 1x3. Each tonne would contain around 15 kilograms of pure fluorochemical or a minimum of 4.5 tonne of pure fluorochemical for the site. This of course is unlikely to be used over its storage life of say 20 years but in the same 20 years we have discharged 20 tonnes of pure fluorochemical from extinguishers without too much of a song and dance, an unseen trickle release rather than a very visible and highly newsworthy release of a petrochemical fire such as occurred at the Buncefield storage terminal fire or any other large incident for that matter.

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APPENDIX XII

STATEMENT BY KEVAN WHITEHEAD, UNITY FIRE AND SAFETY, OMAN

END USER OIL AND GAS INDUSTRY FIREFIGHTING OBSERVATIONS

Unity Fire and Safety Services LLC, provides professional fire & rescue services to industry, predominantly in the Middle Eastern oil fields. Its senior management are career fire officers, with significant experience in Europe, the Middle East and the USA. We have worked with some of the major oil companies in the world. I have been active in challenging the environmental impact of firefighting foam for over two decades and have co-organised five international conferences (2002-2013) to debate and challenge the status quo. Some of our combined observations are given in the following text.

Oil and gas fields are habitually found in some of the most challenging environments, remote with difficult access, as well as with extreme climatic conditions and frequently in "hostile" environments due to political tensions and military activity.

Robust, sophisticated environmental laws and effective enforcement are frequently absent and, as a result, control and regulation often sits with the National Oil Company (NOC) or the International Oil Company (IOC) operating the field.

The oil or gas field will always transition through a life cycle, starting with exploration/drilling using geological data, followed by Front End Engineering and Design (FEED) of the Central Processing Facility (CPF) which at the project stage is passed to specialist organisations who manage and control the Engineering, Procurement and Construction (EPC) stages; and, finally, onto the production and export stages.

The CPF receives raw hydrocarbon from well heads and extracts some constituents such as water, hydrogen sulphide and other higher hydrocarbon products, often referred to as condensates.

The processed hydrocarbon fractions, either as gas (mainly methane, CH4) or oil, are initially stored on site before being exported from the field via pipeline or, in some cases, road tanker vehicles to LNG or refinery plants.

Clearly, the CPF always has a significant tonnage of fuel onsite, for which the NOC and IOC will develop a whole suite of Site-Specific Emergency Response Plans (SSERP). The SSERPs must be based on credible scenarios. A credible scenario should be developed using data on incidence type and frequency of occurrence on the original site and neighbouring sites, as well as at other sites in the same country or same industry.

Once an SSERP is developed, the EPC contractor and, later, the NOC/IOC, progress to testing the equipment and associated procedures, developing expertise amongst the firefighting teams and other operational staff on site.

IOC and NOC procedures are referenced to international standards such as the NFPA 11 standard for Low, Medium and High Expansion Foam (NFPA 2010) and the NFPA 11A standard for Medium and High Expansion Foam Systems (NFPA 1999), which detail the amount of foam concentrate and flow rates required to extinguish any given hydrocarbon fire.

In the field, therefore, we observe large quantities of finished foam being used operationally on an infrequent basis. More often than not, the finished foam is not contained and is allowed to simply soak away into the surrounding environment. This runoff will invariably find its way into and contaminate the ecosystem. The desert areas of the Middle East are covered by Wadis (dry river beds) which, when seasonal rains occur, discharge directly into the surrounding onshore marine environment. Fishing around the Arabia peninsular is not as commercialised as in Europe or the USA and is often very much a subsistence industry, with fish being sold by local fishermen directly to the indigenous populations. One of the more popular fish is line-caught yellow-fin tuna, a top predator known to concentrate PFAS from the marine environment. There is a very high chance that the local population are consuming fish which has been contaminated by PFOS and other PFAS products. Contamination of such a major local protein-rich food source poses a potentially serious socio-economic impact.

When senior field managers of the NOC/IOC are challenged over this practise, our arguments are often dismissed as unfounded by reference to the MSDS (material safety data sheet) issued with the raw foam concentrate.

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Invariably the MSDS sheets do not indicate that the foam concentrate should not be released to the environment or may be harmful to health.

When equipment is tested and calibrated, or firefighters are being trained, there is often no fire. The whole exercise is based on ensuring the correct use and functioning of equipment and on the use of firefighting foam as a visual aid. Under these circumstances it is possible to utilise an alternative, environmentally acceptable product for this purpose...if there is a will.

We have observed that the problem habitually starts at the FEED stage, at which stage the IOC or NOC produces a Scope of Works (SOW) for EPC tender. The SOW may be as simple as "provide 20,000 liters of 6% firefighting foam concentrate"

Now, herein lies the problem. The EPC is a commercial company, bidding via tender with other EPC organisations. Their bid submission will therefore always be based on the lowest priced, compliant option. Thus, they will not be forced by either tender SOW or Government regulations to procure the least environmentally damaging foam concentrates.

There are still numerous foam-concentrate manufacturers producing foams containing fluorine products and they will continue to sell to whoever is willing to buy them. After all, they are commercial concerns.

Once the oil field has moved into the operational phase, replacement foam stocks are required to top-up extending supplies. Unity Fire and Safety has always tried to influence the SOW for subsequent "Request for Quote" (RFQ) or tenders to ensure that the description of the required foam concentrate should include a requirement that it should be fluorine-free. In this way, all bidders must supply the stated product in order to be compliant.

The hard truth is that governmental bodies in these oil producing areas will take time to develop statutory environmental regulation with robust enforcement agencies such as those observed in Australia and Europe. The additional fact that the enormous revenue generated via oil and gas production encourages corruption means that there are always those who will be tempted to increase their chances of winning a tender by offering a lower priced non-compliant option by use of corrupt practises.

It is, therefore, concluded that the responsibility at the present time lies with the client, the IOCs and NOCs. They undoubtedly have the power and influence to ensure that all SOW specifications are written in such a way so as to ensure that the more environmentally damaging foam products are no longer supplied and used. They can also ensure that the supplied product meets the original specification as detailed in the SOW.

Furthermore, the IOCs have a global reach and can assist Governments to develop protocols to protect the environment and their populations from exposure to PFOS and similar products.

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ENDNOTES

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