Managing Firefighting Foam
Queensland's experience

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FIRE AUSTRALIA2024

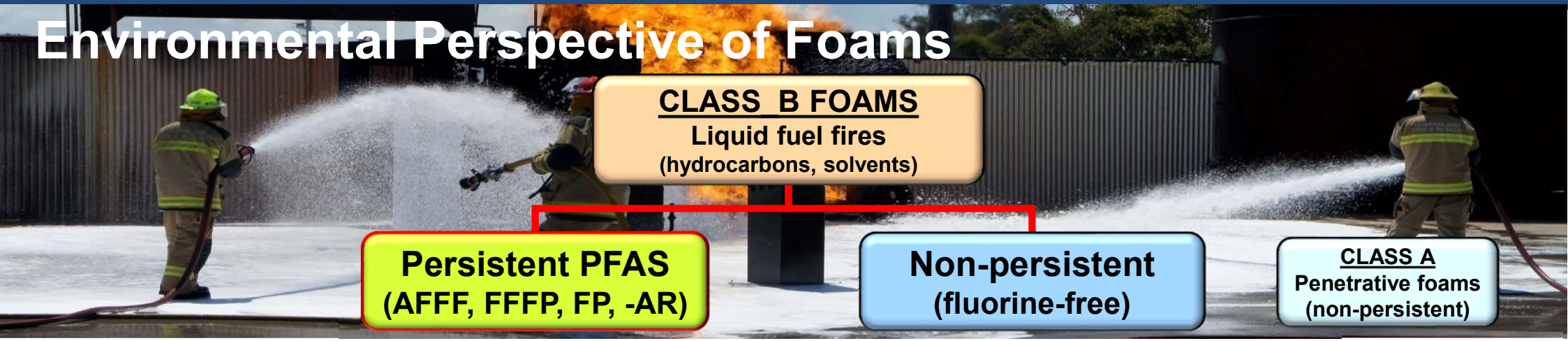
8 May 2024 - Gold Coast Convention and Exhibition Centre

Queensland Government

Managing Firefighting Foam
Queensland's experience

- Managing all types of firefighting foam
- What are PFAS and why are they a problem
- The global transition away from PFAS
- What are the alternatives
- Waste disposal problems and options

Environmental Perspective of Foams

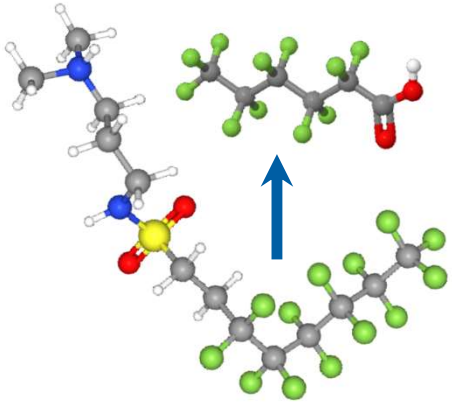


CLASS_B FOAMS
Liquid fuel fires
(hydrocarbons, solvents)

Persistent PFAS
(AFFF, FFFP, FP, -AR)

Non-persistent
(fluorine-free)

CLASS A
Penetrative foams
(non-persistent)

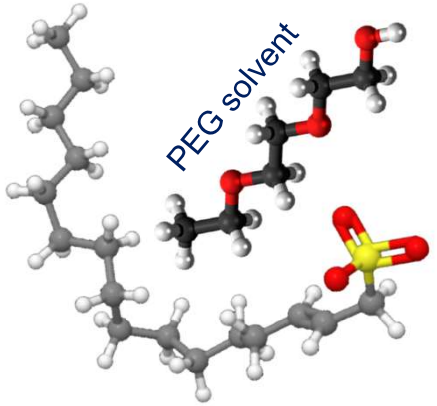


6:2FtSaPA & PFHxA

Short-term aquatic toxicity – ALL very LOW
Oxygen depletion potential – ALL HIGH but…
("BOD"…only an issue for enclosed waterways)

×PFAS - Persistent
Indefinitely persistent
Widespread effects
Chronic toxicity

✓Non-persistent
(Biodegradable)
(Short-term local effects)
(Naturally remediate)



Hydrocarbon surfactant
(Oleofin sulfonate)

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LONG-TERM, WIDE-SPREAD DIVERSE IMPACTS

SHORT-TERM, LOCALISED AQUATIC IMPACTS

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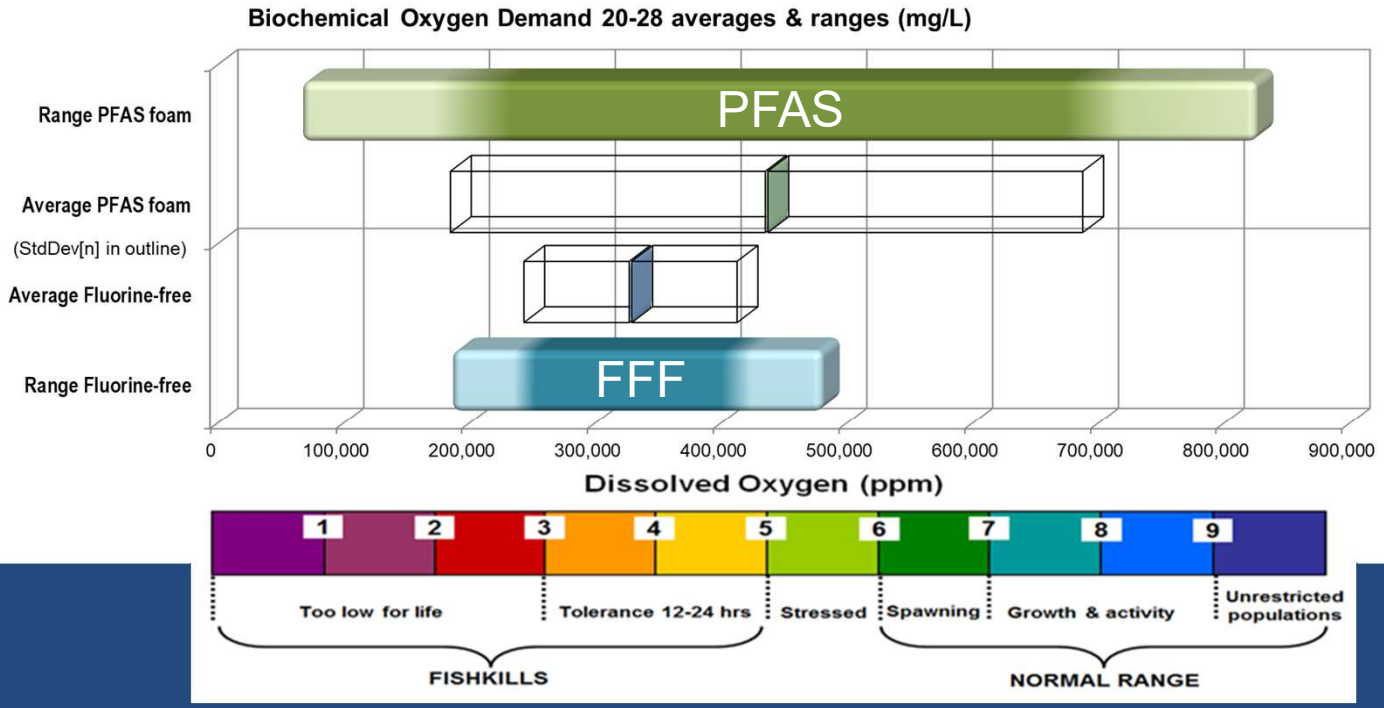
Environmental Perspective of Foams

Short-term aquatic toxicity – ALL very LOW
Oxygen depletion potential – ALL HIGH but…
("BOD" For FFF only an issue for enclosed waterways)



Toxicity Category	Effective concentration 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

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

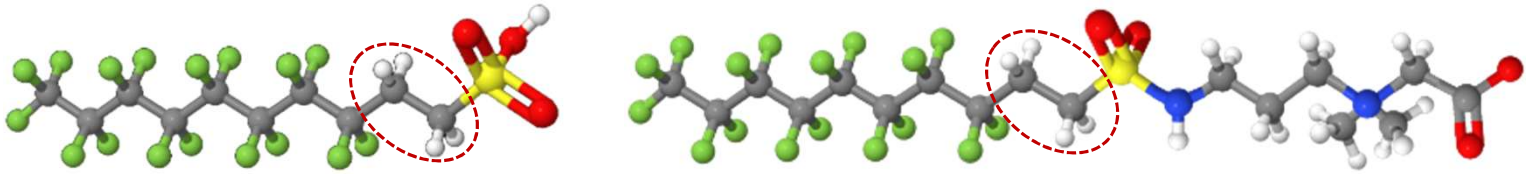
Why are they called "PFAS"?

"Per- and poly-Fluoro Alkyl Substances"

Per-fluoro fully fluorinated carbon chain (end-point PFAS)

C8 PFOS | C8 PFOA | C6 PFHxS

Poly-fluoro with non-fluorinated carbon(s) (fluorotelomers)



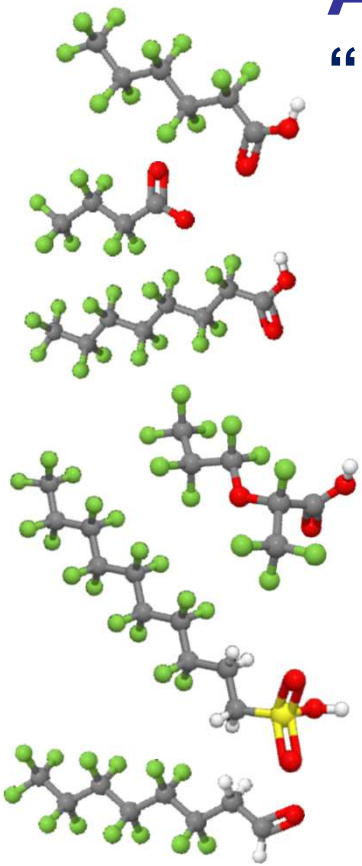
8:2 Fluorotelomer sulfonate

8:2 Fluorotelomer sulfonamido propyl betaine

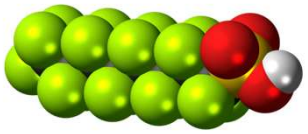
(Dimethylene –CH2-CH2- non-fluorinated carbons "spacer" circled)

All you need to know about "PFAS"

"Per- and poly-Fluoro Alkyl Substances"

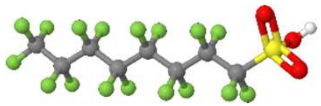


PFAS have fluorinated carbon chains:

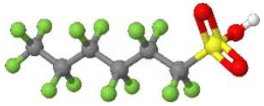


- **Indefinitely persistent.**
- **Toxic** to varying degrees.
- **Bio-accumulative.**
- **Highly mobile** and dispersive.
- "*Precursors*" are also PFAS.

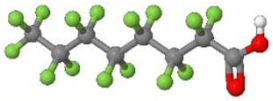
PFOS, PFOA and PFHxS are only <u>three</u> of 1,000s of PFAS



C8 PFOS



C6 PFHxS

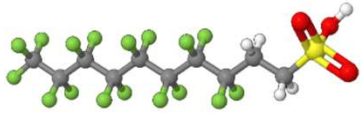


C8 PFOA

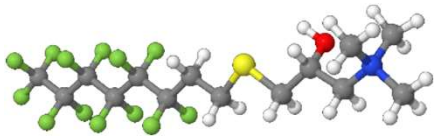
~14,000 PFAS

All are or transform to permanent pollutants

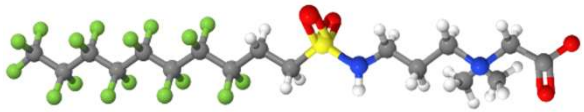
<u>Foam PFAS</u> (~200)



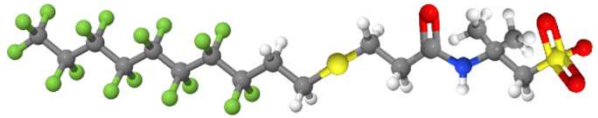
Fluorotelomer sulfonates **C4-C10 (4)**



Fluorotelomer thiohydroxy ammonium **C4-C14 (6)**



Fluorotelomer sulfonamido alkyl betaines **C4-C12 (5)**



Fluorotelomer thioamido sulfonates **C4-C14 (6)**

(21 PFAS for just these 4 functional moieties)

Queensland Government

The motivation to phase out PFAS

RISING SOCIAL & ECONOMIC COSTS

Increasing impact on a wide range of values especially:

- Resource degradation (**drinking water sources,** soils,...)
- Social values (amenity, recreation, fishing, tourism,...)
- Economic values (**fisheries, crops, livestock**, land values,...)
- Costs to business & community (disposal, land use limitations,...)
- Legacy sites (adjacent impacts, **cleanup costs $$$**, wastes,...)
- **Reputation** (**corporate**, industry, **political**, location,...)
- **Health impacts** (range of associated adverse health outcomes,…)
- Environmental values (waterways, wildlife,...)
- **Legal actions** & claims growing (against manufacturers & end users)

!! E.g., Low-level PFAS exposure reduces vaccine effectiveness

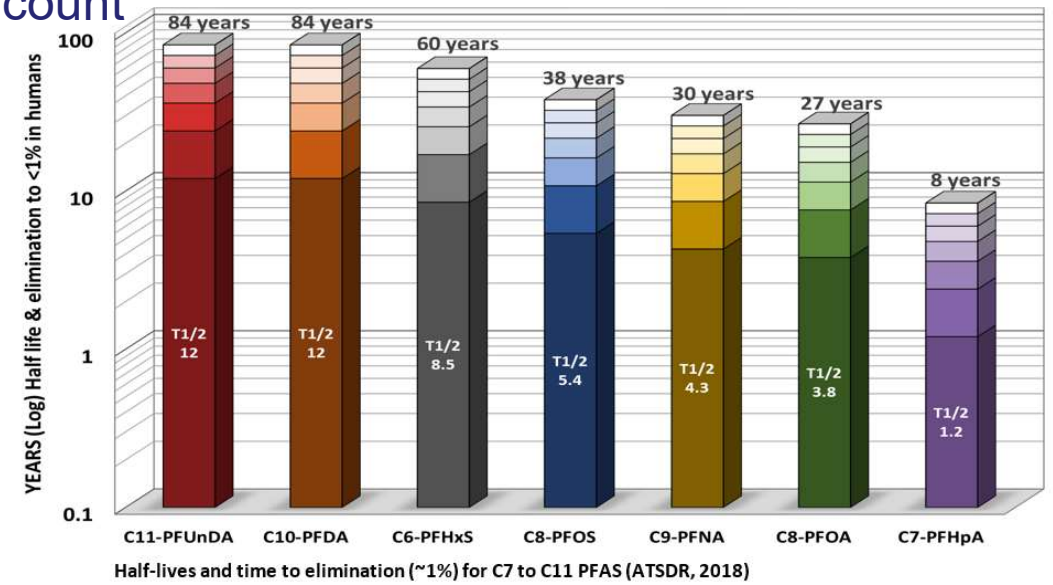
PFAS health exposure risks *"more likely than not"**

*3M Chief Health Officer

Possible & probable adverse effects:

- Reproductive impairment, low sperm count
- Chronic kidney & liver disease
- Type 2 diabetes
- Endocrine disruption
- Immune system depression
- Cholesterol elevation
- Vaccine interference (incl. Covid!)
- Testicular, thyroid & kidney cancer
- Early menopause, ovarian cysts
- Delayed development & puberty
- Osteoporosis, uterine nodules
- ADHD, low birth weight & others.

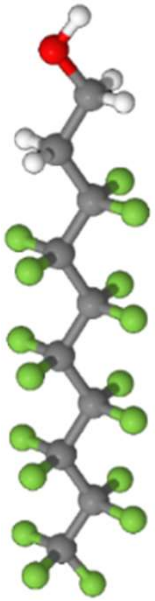
Long elimination times in humans



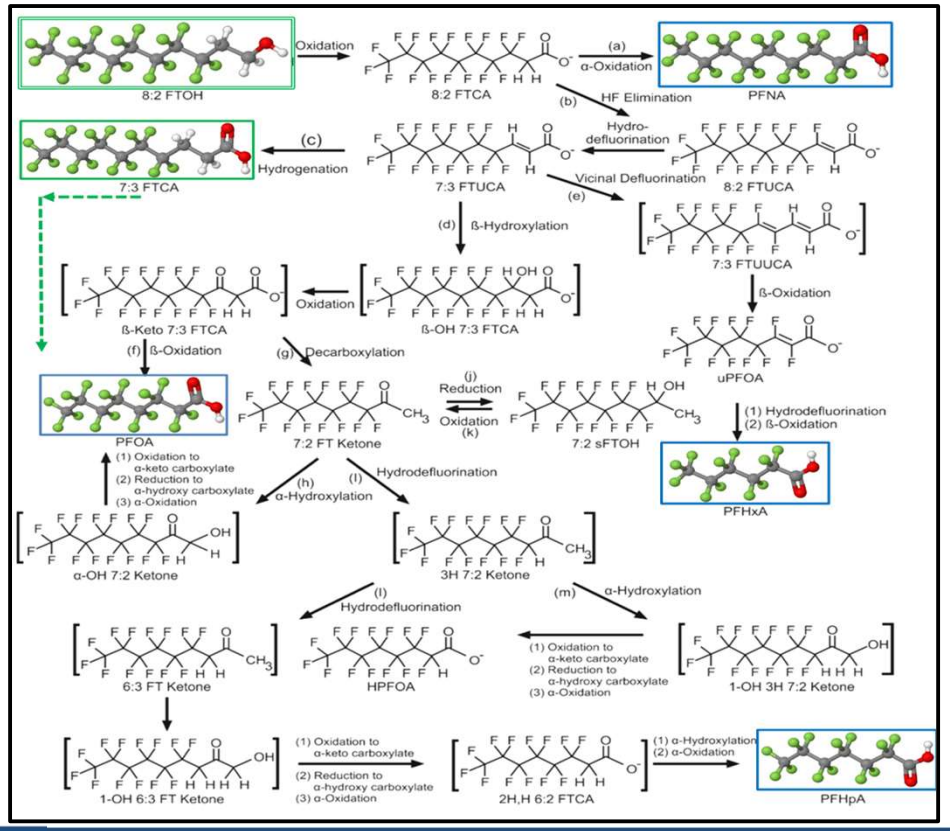
Half-lives and time to elimination (~1%) for C7 to C11 PFAS (ATSDR, 2018)

➢Evidence of adverse effects from low level exposure to PFAS <u>combinations</u> emerging.

What PFAS arise from firefighting foam?!

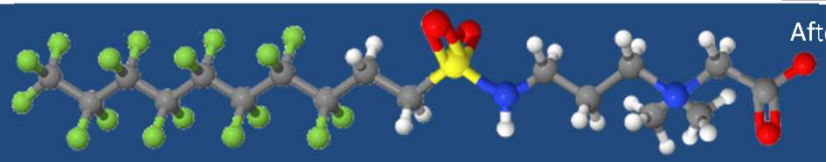


- **Complex PFAS used in current foams** transform to produce a diversity of intermediate PFAS that are likely to have greater adverse effects than the parent or the simple end-point carboxylates.
- The transformation shown is for the **simple** 8:2 fluorotelomer alcohol.
  - 1 parent PFAS (8:2 FTOH at top left)
  - 16 intermediate PFAS (?effects)
  - 5 end-points including PFOA (boxes)



After Washington, Jenkins & Webber, ES&T 2015, 49, 13256-63

→→→? ? ? ?



Global Directions on PFAS – ~Phase out all PFAS

Stockholm Convention

Recent Stockholm Convention decisions increasingly for phase out

- PFOS, PFOA and related substances flagged for phase out.
- PFHxS and related substances listed for elimination June 2022.
- Appropriate disposal of wastes in a sustainably sound manner (Basel Convention).

Short-chain (≤C6) PFAS not an alternative

The Stockholm Convention decisions and recommendations included:

> **"…** ***a transition to the use of short-chain per- and polyfluoroalkyl substances (PFASs) for dispersive applications, such as fire-fighting foams, is not a suitable option from an environmental and human health point of view*****".**

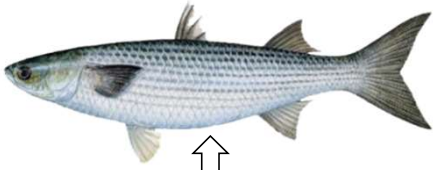
EU Commission 2021/1297 – C9-C14 PFCAs regulation of use and limits.

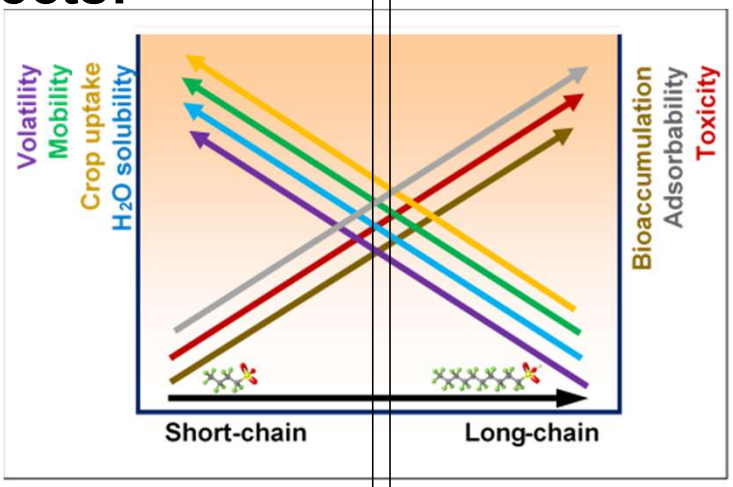
Global Directions - *Regrettable Substitutions (C6)*

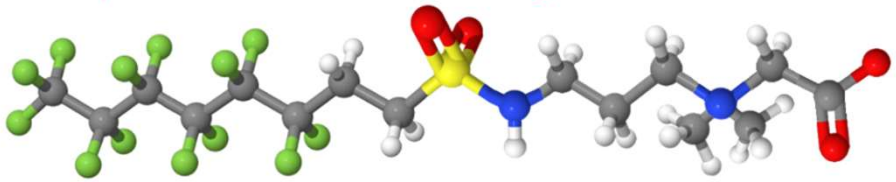
Short-chain PFAS risk same as long-chain risk

Increasing evidence for short-chain adverse effects:

- Increasing exposure from increasing releases.
- Much high mobility in soils and groundwater.
- Very difficult and expensive to remediate.
- Readily taken up into edible parts of food crops.
- Recirculate in the environment & food chain.
- Consumption limits already exceeded in places.

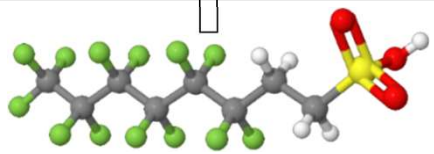






AFFF - 6:2 Fluorotelomer sulfonamide propyl betaine

20-30 intermediates?



6:2 Fluorotelomer sulfonate
(bioaccumulative)

Industry-Regulator Partnerships Approach

THE QLD POLICY FOUNDATIONS (2012-2016)

Identifying and defining the relevant issues:

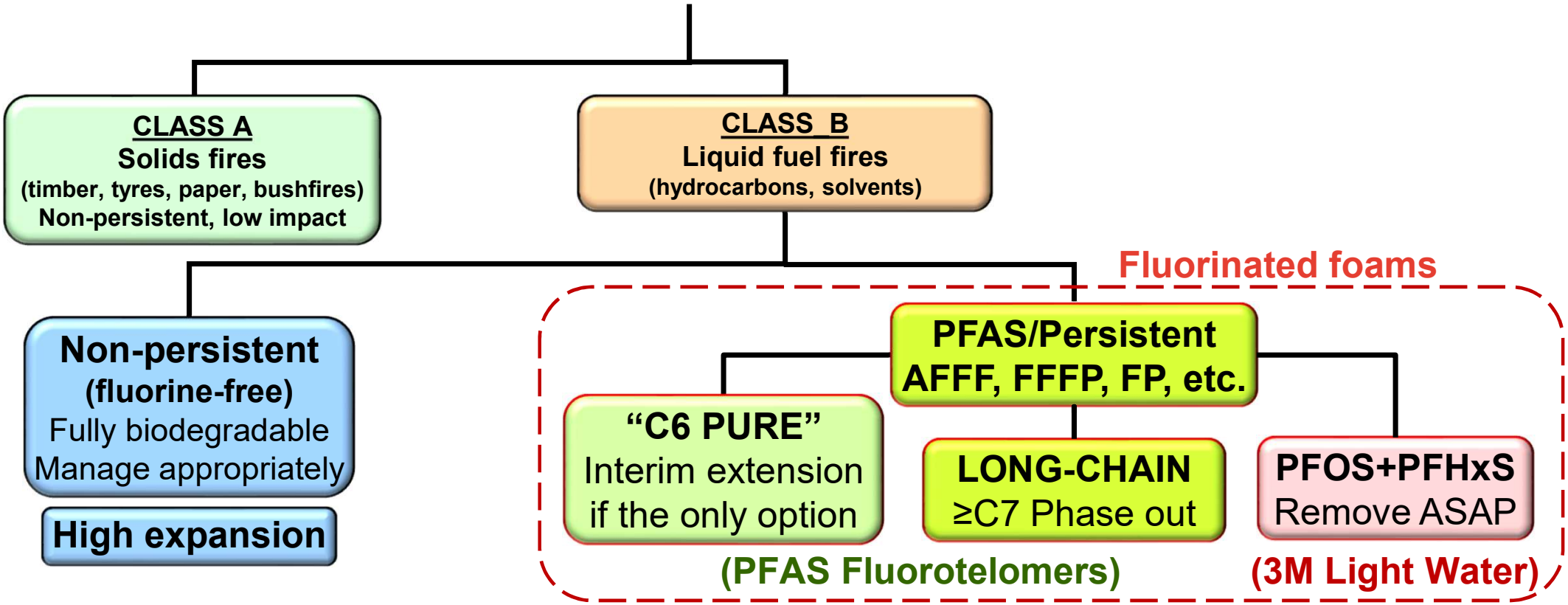
- Achieving a common understanding of the current state-of-knowledge, risks and liabilities driving change.
- Assessing real risks, setting priorities and achievable goals.
- Recognising the practicalities and balancing against risks.
- Myth Busting, breaking old habits, sorting facts from fiction.
- Sharing information and perspectives.
- Making decisions on emerging but substantial information.
- Staging transition realistically to take into account all factors.

The Queensland Foam Policy Experience

PRACTICALITIES & CONCESSIONS

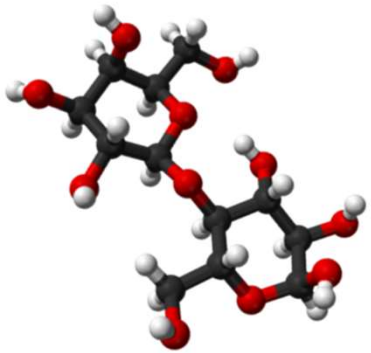
- ✓ Balancing Safety-Performance-Cost-Health-Environment issues.
- ✓ Assessing risks to values as inputs to setting priorities.
- ✓ Setting achievable stages and timelines for transition.
- ✓ Physical or procedural interim measures to reduce risk (releases).
- ✓ Setting achievable standards for cleanout of systems.
- ✓ Accepting contamination of new foam by PFAS residues.
  - (C6 PURE only for very limited use – no longer relevant).
- ✓ Facilitating new PFAS waste disposal technologies.

Foam management under the Queensland Policy

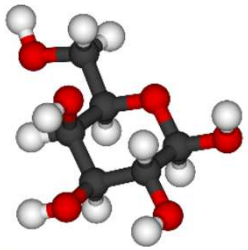


Non-persistent ⇔ **Persistent**

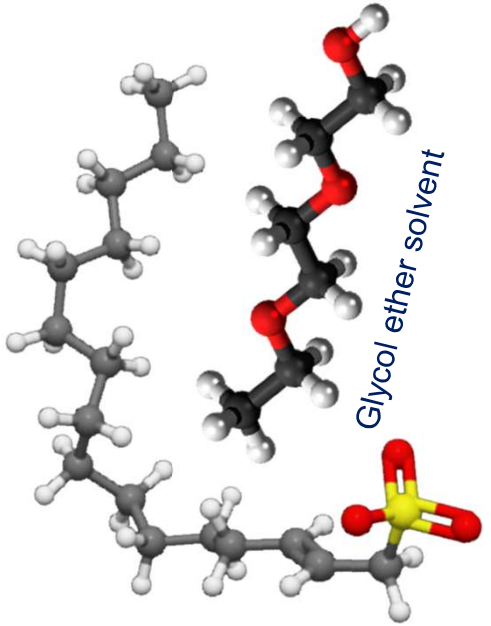
Non-persistent (fluorine-free) alternatives



Carbohydrates/Saccharides



Industry application	Australia/New Zealand	FFF certified
LAST terminal facilities & refineries Hydrocarbons, blends and polar solvents	LASTfire batch test & EN1568 (some UL / FM for fixed systems)	**Yes**
Very large fuel storage tanks (including crude oil)	LASTfire batch test & EN1568 (some UL / FM for fixed systems)	**Yes**
Aviation hydrocarbon fuels	ICAO & EN1568	**Yes**
Offshore (hydrocarbon fuels, some methanol polar solvents)	ICAO & EN1568	**Yes**
Fire brigades Hydrocarbons, blends and polar solvents	ICAO & EN1568	**Yes**
Defence	DEF(Aust)5706 / ICAO Level B	**Yes**
Ports, tugs and ships	EN1568 / DNV / IMO	**Yes**
Oil and gas	LASTfire batch test & EN1568 (some UL / FM for fixed systems)	**Yes**
Mines	EN1568	**Yes**
General industries (Chemicals, power stations, etc.)	LASTfire batch test & EN1568 (some UL / FM for fixed systems)	**Yes**
Mining heavy vehicles	AS5062	**Yes**
Hand-held extinguishers	AS1841	**Yes**
Note – US Mil-Spec MIL-PRF-32725 (I1) SFFF is fluorine-free and no longer requires PFAS		



Hydrocarbon surfactant (Oleofin sulfonate)

Atoms:
Carbon
Oxygen
Sulfur
Hydrogen

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Fully biodegradable organic components

Queensland Government

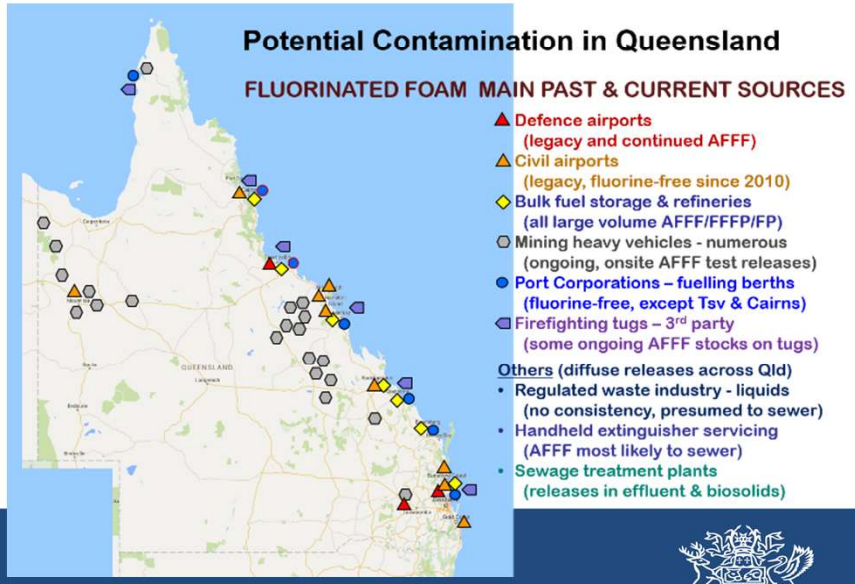
Queensland's transition away from PFAS foam

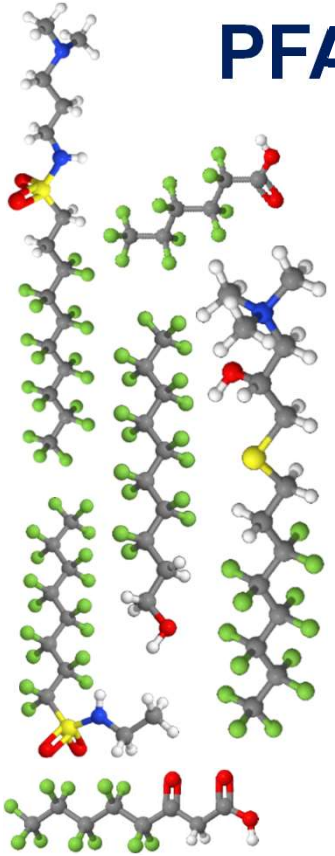
Outstanding regulatory issues

- ✓ Fluorine-free now available for all applications.
- ✓ Very large fuel tank facilities have transitioned or will finish shortly.
- ✓ About +90% of users have transitioned, most in the first year.

COMPLIANCE ISSUES

- × Transition grace period ended in 2019
- × PFAS foam actively on regulatory radar
- × PFAS by licensed waste disposal



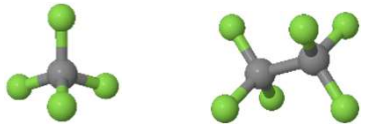


PFAS waste disposal options

PFAS ARE HIGHLY RESISTANT

- **NOT Sewage treatment plants** – PFAS pass straight through to release.
- **NOT Composting** – PFAS do not biodegrade and are taken up by crops.
- **NOT Landfills** – PFAS outlast the life of the landfill liner and are released.
- **NOT Domestic incineration** – Temperatures are too low for complete destruction with PFAS releases to air→ →

WASTES MUST BE MANAGED RESPONSIBLY



Perfluoromethane Hexafluoroethane

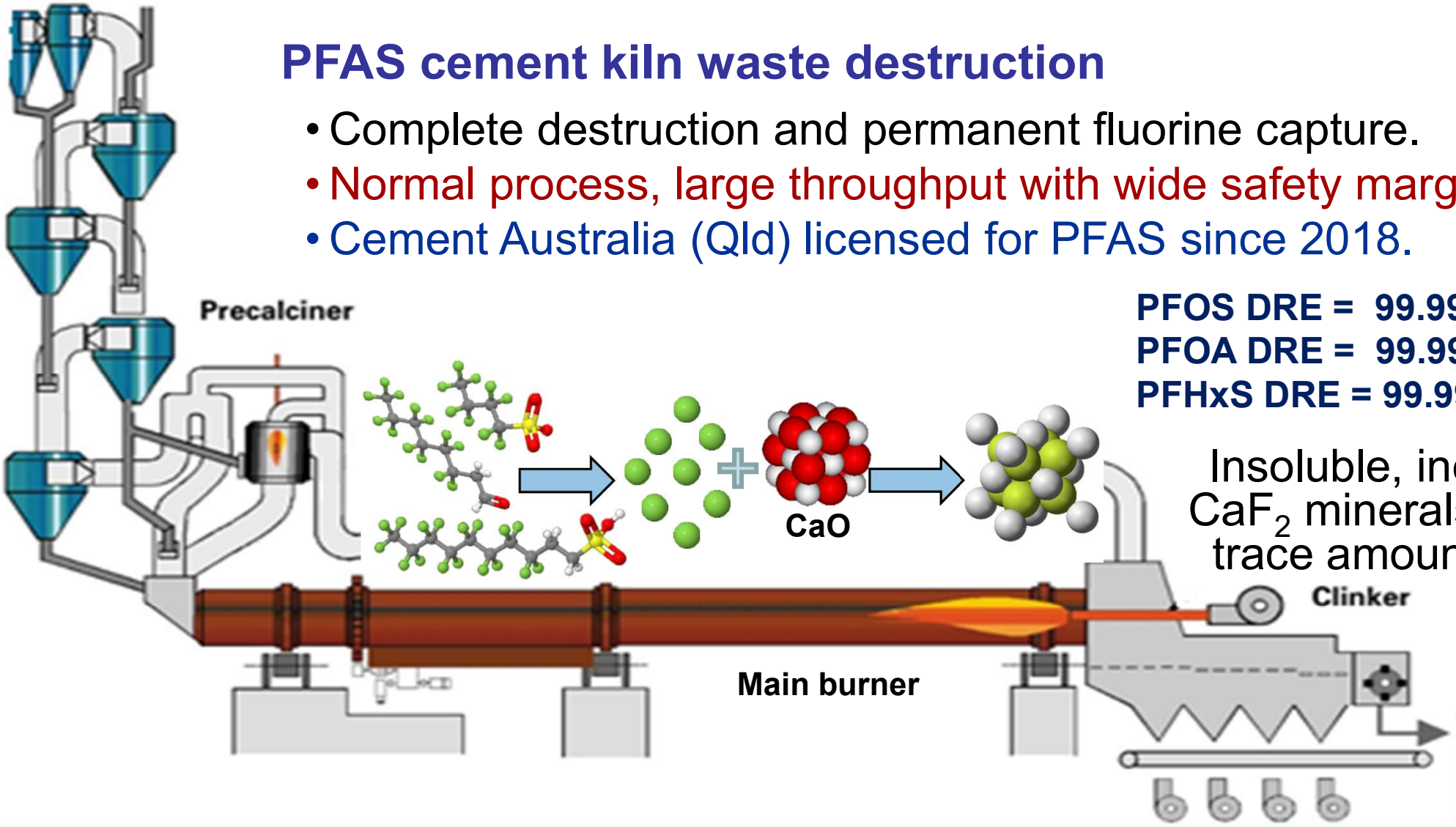
Potent greenhouse gases

1/2 –life ~50,000y.

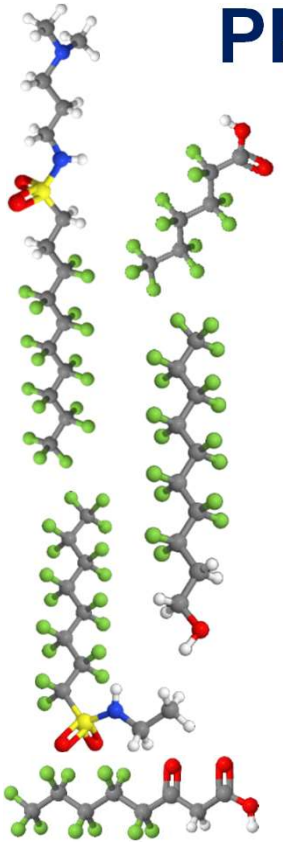
PFAS cement kiln waste destruction

- Complete destruction and permanent fluorine capture.
- Normal process, large throughput with wide safety margins.
- Cement Australia (Qld) licensed for PFAS since 2018.

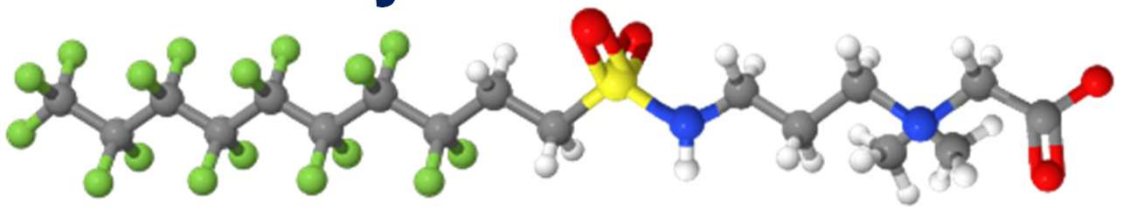
PFOS DRE = 99.99993%
PFOA DRE = 99.99975%
PFHxS DRE = 99.99936%



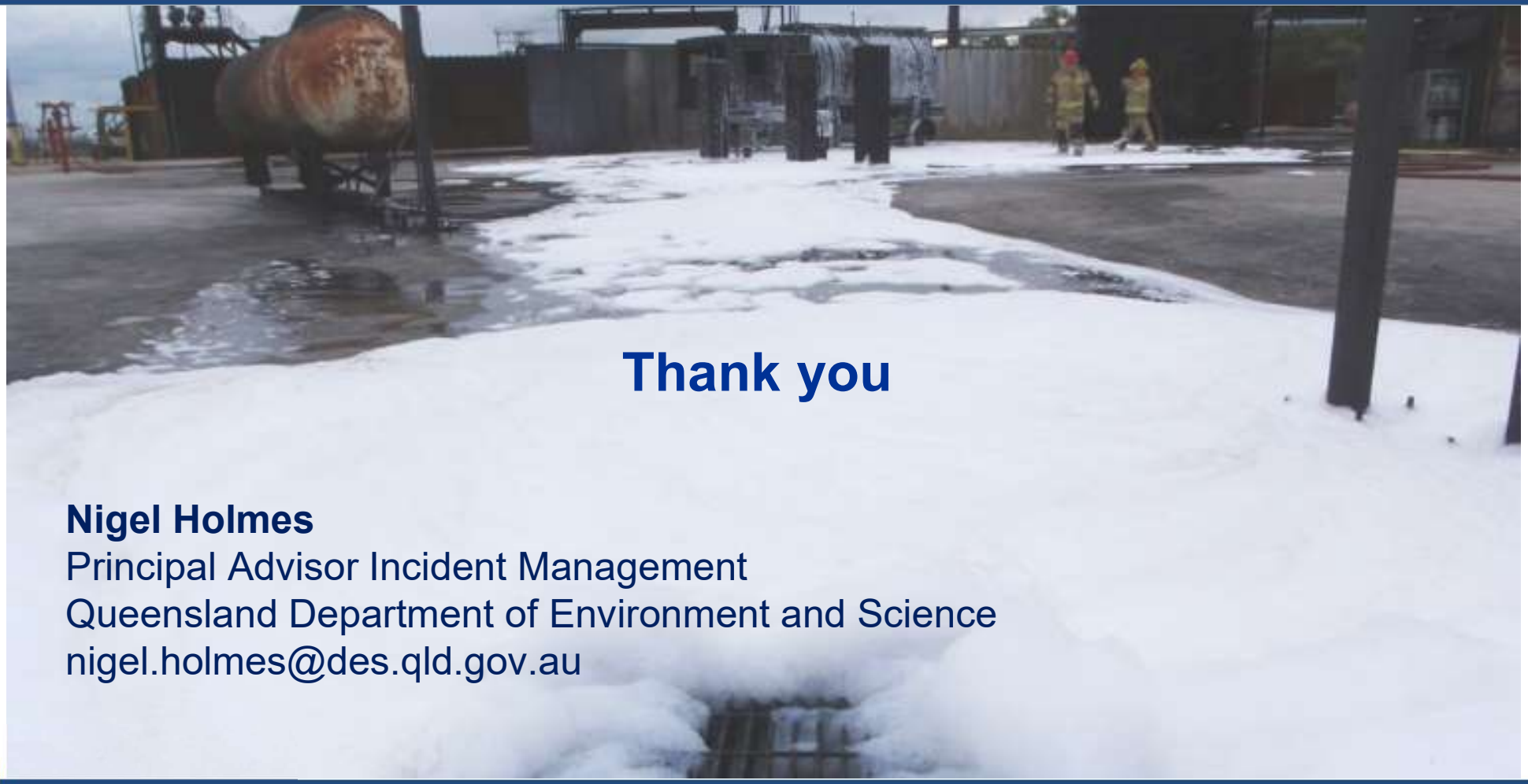
Insoluble, inert CaF_2 minerals in trace amounts



PFAS, the short story



- Anything with a carbon-fluorine group is a PFAS.
- All PFAS are of concern (toxic, indefinitely persistent, bioaccumulative to varying degrees, very dispersive).
- Qld Foam Policy & *EP Act* ultimately ban PFAS foam.
- Fluorine-free foams are now certified for all uses.
- PFAS wastes must be disposed of properly.



Thank you

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