LASTFIRE
Large Atmospheric Storage Tank Fires

Firefighting Foam Summit – Budapest October 2017

Queensland Operational Policy Environmental Management of Firefighting Foam

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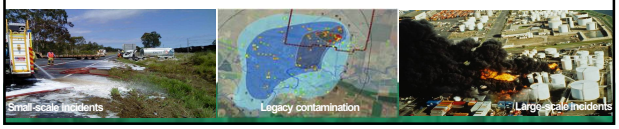
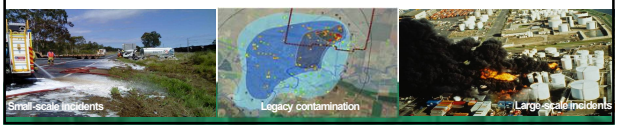
Queensland's Foam Policy - A Case History

- Policy development, content & implementation
- Historical context & drivers for change
- Relevant foam characteristics
- Review of the global state-of-knowledge
- Regulatory & legal context
- End-user responsibility for use & effects



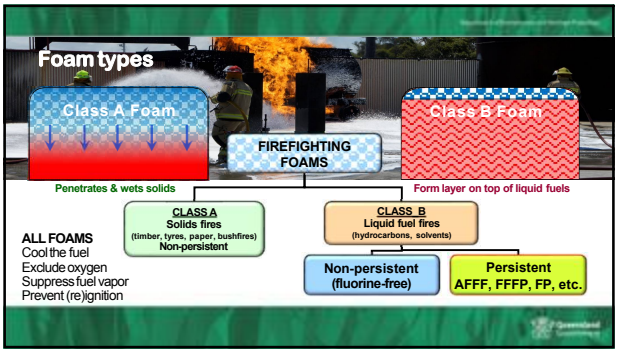
Foam characteristics and considerations

- Foam types & key environmental characteristics
- Implications for risk assessment, decision making & foam management
- Emerging evidence about persistent compounds
- Not just PFOS & PFOA (200-600 PFAS compounds)



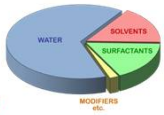
Emerging liabilities & costs driving change

- Health impacts (persistent toxic chemicals)
- Resource degradation (soils, water sources,...)
- Environmental values (waterways, wildlife,...)
- Social values (amenity, recreation, tourism,...)
- Economic values (fisheries, crops, land values,...)
- Cost to business (cleanup, land use limitations,...)
- Legacy sites (collateral impacts, cleanup costs,...)
- Reputation (corporate, industry, political, location,...)



Foam behaviour and effects 101

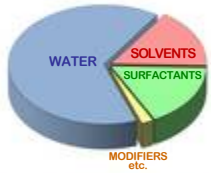
- Highly soluble components
- Highly dispersive in waterways
- Rapidly penetrate into soils↓
- Highly mobile in groundwater→
- Difficult to contain in an emergency



- ➢ Short-term effects from some components
- ➢ Long-term effects from highly persistent, toxic (usually fluorinated) organics in some foams.

Firefighting foam composition

Approximate composition



Foam concentrate

- MODIFIERS etc.
  Polysaccharide gum, salts/oxides, biocides, chelating agent, etc.
- SOLVENTS
  Glycol ethers, carbitol, alcohols, etc.
- SURFACTANTS (detergents)
  Hydrocarbon surfactants, protein-based, (fluoro-surfactants), etc.

SHORT & (LONG-TERM) → ADVERSE EFFECTS

Foam environmental impacts
Main factors in terms of:

SHORT–TERM (all foams)
Days → months
- Acute (direct) toxicity
- BOD
  (Biochemical Oxygen Demand)

LONG-TERM (persistent foams)
Years → centuries/millenia
- Persistence
  (PFAS, siloxanes, & ??)
- Chronic toxicity
- Exposure (constant & incr.)
- Bioaccumulation

Foam environmental impacts

SHORT–TERM (all foams)
- Acute direct toxicity (~low!)

Practically Nontoxic to Relatively Harmless

- ALL foams fall in this range
- Acute toxicity is NOT significant by itself
- (*but* BOD "toxic" effect must be considered…)

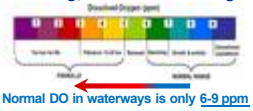
Toxicity Category	Range (mg/L)
Super Toxic	< 0.01
Extremely Toxic	0.01 –0.1
Highly Toxic	0.1 –1
Moderately Toxic	1 –10
Slightly Toxic	10 –100
Practically Nontoxic	100 –1,000
Relatively Harmless	> 1,000

NOTE : The standard acute toxicity test requires artificial aeration (60%↑ sat) that negates BOD effect

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

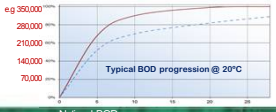
Foam environmental impacts

SHORT–TERM (all foams)
- Biochemical Oxygen Demand (BOD_N mg/L)
  (organic decay depletes oxygen in waterways)
- ALL foams – very high BOD ~350,000 mg/L (concentrate)
- Holding, dilution & flushing can mitigate effects



Normal DO in waterways is only 6-9 ppm

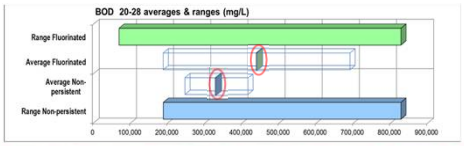
Adapted from *Dissolved oxygen in water*
Water Research Center, Dallas, Pennsylvania



Notional BOD curves
(Typical and delayed, % versus days)

Foam environmental impacts

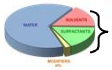
SHORT–TERM (all foams)
- Foam BOD ranges



Outlines are the standard deviation either side of the mean

Even with dilution foam BOD is 100s ppm
(Raw sewage BOD ~300-400 mg/L)

Foam environmental impacts
Main factors



SHORT–TERM (all foams)
Days → months
- ✓ Acute toxicity (≈Low)
- ✓ BOD (≈Massive)
  (Biochemical Oxygen Demand)

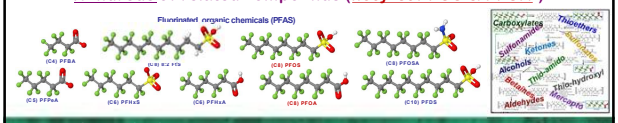
LONG-TERM (persistent foams)
Years → centuries/millenia
- Persistence
  (e.g. PFAS, siloxanes, & ??)
- Exposure (constant & incr.)
- Chronic toxicity
- Bioaccumulation

Foam environmental impacts

LONG-TERM (PFAS foams)

Persistent foams (fluorinated AFFF, FP, FFFP, etc.)

- Contain PFAS (Per/poly FluoroAlkyl Substances)
- Chronic toxicity for environmental & human health worldwide
- Hundreds of related compounds (*not just PFOS & PFOA*!)



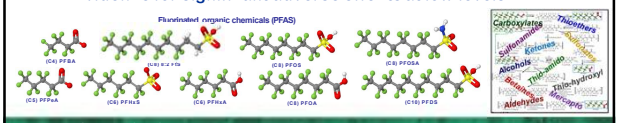
Atoms = Grey-carbon, Green–fluorine, Red–oxygen, White-hydrogen, Yellow-sulphur, Blue-nitrogen

Foam environmental impacts

LONG-TERM (PFAS foams)

PFAS

- ALL are ultimately highly persistent & highly mobile
- ALL are toxic and bio-accumulate to varying degrees
- Evidence for significant adverse effects at low levels

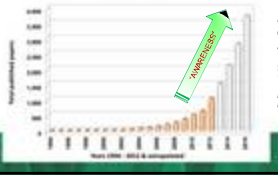


Atoms = Grey-carbon, Green–fluorine, Red–oxygen, White-hydrogen, Yellow-sulphur, Blue-nitrogen

PFAS - Pollutants of emerging concern

(e.g. Asbestos – Ozone-depleting CFCs – DDT pesticide – Leaded petrol – Diesel particulates – etc.)

- Rapidly emerging indications of long-term adverse effects for human health, environmental, social & economic values worldwide.
- Numerous legacy contaminated sites (& ongoing releases).
- Very high cleanup costs (e.g Airport €100M, truck fire €880K).
- Increasing class actions & claims (against manufacturers & end users)



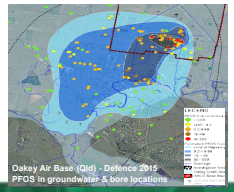
Rapidly growing (public) information on fluorinated compounds in peer-reviewed scientific publications since 2008. Grandjean & Clapp 2015

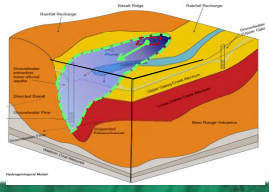
>2,500 papers on PFASs from 2001-2011 Trojanowicz & Koc 2013

Industry knowledge (cancer) since 1997 US (Ohio) PFOA compensation trial evidence in 2015

PUBLIC ATTENTION TO LEGACY SITE IMPACTS

- e.g. Oakey 1.2ML AFFF foam released over 25 years.
- High solubility (dissolve & move in surface & ground water)
- High mobility in soils (to waterways and groundwater)





Short-chain C4-C6 plume likely to be well ahead of C8 PFOS extent

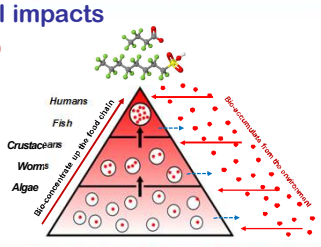
Airports and Defence bases affected by legacy PFAS contamination
(Graphic - ABC Four Corners Program 08 October 2017)

Foam environmental impacts

LONG-TERM (PFAS foams)

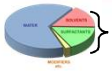
- **Persistence**
  Long half-life, highly mobile
- **Bioaccumulation**
  & bio-concentration (All BCF >1)
- **Toxicity (chronic)**
  NOEC/PNEC exceeded

Increasing exposure to ALL PFAS is of particular concern worldwide



BCF = Bio-concentration factor (UN GHS). NOEC = No observable effect concentration
PNEC = Predicted no effect concentration (for relevant receptors)

Foam environmental impacts Policy considerations



SHORT–TERM (all foams)
Days → months
- ✓ Acute toxicity
- ✓ BOD (Biochemical Oxygen Demand)

LONG-TERM (persistent foams)
Years → centuries/millenia
- ✓ Persistence (PFAS, siloxanes, & ??)
- ✓ Exposure (constant & incr.)
- ✓ Chronic toxicity
- ✓ Bioaccumulation

LEGISLATION
THREATENED VALUES
LEGACY EXPERIENCE
PRECAUTIONARY PRINCIPLE
REGULATORY STRATEGY
→ FOAM MANAGEMENT REQUIREMENTS

Essential foam characteristics information

What information do you need...
- No foam is "*environmentally friendly*"
- All foams can have adverse effects
- Risks are specific to the type & situation

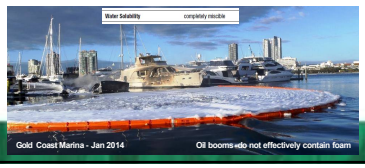
Characteristics information is essential to:
- Assess the relative sensitivities & risks
- Determine what might be practical mitigation
- Make a balanced decision on options

(e.g. Product-Procedures-Containment- etc.)

(Other contaminants considered separately)

Myths & Myth-information

- MYTH – *Foam can be contained on waterways by oil spill booms* (recent industry guideline).
- BUSTED! – Foam is completely soluble in water, the floating foam represents only a tiny fraction of the foam.
- Almost all the foam is rapidly dissolved in the water column.



Gold Coast Marina - Jan 2014 — Oil booms do not effectively contain foam

Myths & Myth-information

- MYTH – *Some foams are 10 times more toxic than others* (ongoing marketing claims).
- BUSTED! – Foam acute toxicity is not significant.
- All foams are *Practically Nontoxic to Relatively Harmless*

- *but* BOD effect can be significant
- BOD is rarely cited in SDS and product data
- All foam BODs are extremely high

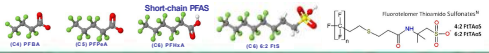
Toxicity Category	Range (mg/L)
Super Toxic	< 0.01
Extremely Toxic	0.01 –0.1
Highly Toxic	0.1 –1
Moderately Toxic	1 –10
Slightly Toxic	10 –100
Practically Nontoxic	100 –1,000
Relatively Harmless	> 1,000

BOD = Biochemical Oxygen Demand from degradation of organics

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

Myths & Myth-information

- MYTH – Alternative C6 short-chain PFAS are harmless if released (*we were hoping for this*).
- BUSTED! – Significant evidence has now emerged on short-chain PFAS adverse health & environmental risks.
  (enhanced mobility, uptake in crops, bioaccumulation, binding to proteins, increasing exposure, very difficult to capture, very difficult to clean up)
- Risk = liability for the end-user (✓manage by full containment)
- Triggers *Precautionary Principle* = *Better Safe than Sorry*.



Atoms = Grey-carbon, Green–fluorine, Red–oxygen, White-hydrogen, Yellow-sulphur, Blue-nitrogen

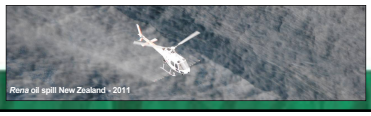
Myths & Myth-information

- MYTH – *The air emissions are worse than foam use* (fails on net benefit versus harm assessment for PFAS).
- BUSTED! – Air emissions are spectacular but disperse rapidly with dilution to below levels of concern.
- Permanent local & broader long-term PFAS pollution & harm far outweigh transient short-term plume effects.

Buncefield UK - 2005

Myths & Myth-information

- MYTH – *Foams mobilise other contaminants in releases* (e.g. allowing fuels to pass through oil skimmers)
- PLAUSIBLE, BUT! – If a release to waters is likely then permanent pollution by toxic PFAS is not acceptable.
- In waterways dispersal of oils by biodegradable surfactants reduces concentrations & promotes biodegradation.
- E.g., use of surfactant dispersants on oil spills at sea.



Rena oil spill New Zealand - 2011

The *Precautionary Principle*

- Most countries are party to the Rio Declaration (& ESD principles)
- ESD - The *Precautionary Principle* required for decisions that may have long-term environmental impacts
- Applies when there is insufficient scientific evidence for decisions
- Especially where suspicions and/or indications of adverse effects exist

UN 1992 Rio Declaration on Environment and Development (Agenda 21)

↓

Ecologically Sustainable Development
- The *Precautionary Principle*
- Intergenerational Equity
- Conservation of biological & ecological values
- The *Polluter Pays* principle

↓

National, State & Local implementation
- Legislation & Regulations
- Agreements on the basis of ESD
- Planning approval processes

Hon. Preston CJ - "Burden of proof for evidence for safety rests on the proposers of a new technology" (i.e. ultimately the END-USER)

Precautionary Principle triggers

Triggered where there is:

- ✓ A threat of serious or irreversible environmental damage; and
- ✓ Scientific uncertainty as to the nature and scope of the threat

"The lack 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."

I.e. Solid proof of no adverse effects is required.

Precautionary Principle triggers
✓ Threat of serious or irreversible damage; and
✓ Scientific uncertainty or suspicions

↓

Precautionary Principle Assessment
1. **Spatial scale** of the threat
2. **Magnitude** of possible impacts
3. **Perceived value** of the threatened receptor
4. **Temporal scale** of possible impacts
5. **Manageability** of possible impacts
6. **Public concern & scientific evidence**
7. **Reversibility** of possible impacts

UNKNOWN — INDICATIONS — (C8) SIGNIFICANT EVIDENCE
SUSPICIONS — EMERGING EVIDENCE — (C8) CERTAINTY

The *Precautionary Principle* Assessment

Assessment factors	Persistent compounds	Non-persistent compounds
1 **Spatial scale** of the threat	Local, regional, state-wide, national & global	Localised impacts
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 Rapidly mounting evidence	Limited concern about harm based on established 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

Hon. Preston CJ - "Burden of proof for evidence for safety rests on the proposers of a new technology" (i.e. ultimately the END-USER)

PFASs exposure risks *"more likely than not"*

Possible & probable adverse effects:

- Reproductive impairment
- Chronic kidney disease
- Liver disease
- Endocrine disruption
- Developmental impairment
- Immune system depression
- Cholesterol elevation
- Vaccine interference
- Testicular & kidney cancer
- Early menopause
- Delayed puberty
- ADHD, & others.

Elimination in humans ($t_{1/2}$):
- C8, PFOS – 5.4 years
- C8, PFOA – 2.3 to 3.8 yrs
- C6, PFHxS – 8.5 years (≈C8)
  (! x 5 half lives [↓] 15-40 years)
- ~200-600 similar compounds.
- Extensive information now published about diversity of adverse effects & behaviour.

➢ Adverse effects of increasing exposure to PFAS combinations emerging.

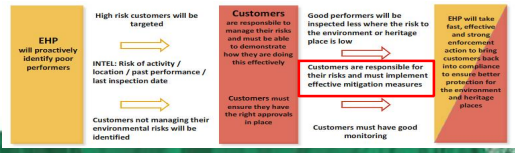
Precautionary Principle obligations

- **Environmental legislation** & regulations establish the application of ESD (including the *Precautionary Principle*).
- **Legal precedents** containing clear definitions (2006→).
- **Legal precedents on obligations** and application across a wide range of environmental and health issues.
- **Obligations** for manufacturers/suppliers, consultants, government regulators and end-users (i.e., everyone!).
- **Regulatory model** for clarification, application and the *Polluter Pays* principle.

Hon. Preston CJ - "Burden of proof for evidence for safety rests on the proposers of a new technology" (i.e. ultimately the END-USER)

The Regulatory Model (*Polluter Pays*)

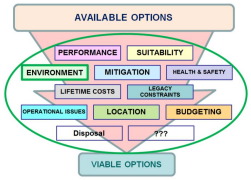
- Recognised as a risk by Queensland in 2011-12
- Extensive review of issues & Policy development (2013-16)
- Industry has not self-regulated effectively
- Policy to clarify End-user Responsibility
- Prompt, staged implementation needs to occur



END-USER LIABILITY & RESPONSIBILITY

Challenges for achieving balanced best practice

- Life and safety are paramount
- Options depend on situation
- Re-engineering systems
- Interim containment measures
- Decontamination of systems
- Whole-of-life costs (incl. wastes)
- Long-term effects management
- Site contamination remediation



(Operational Policy Explanatory Notes)

Polluter Pays Regulatory Model

No new legislation or regulation

- Existing *Environmental Protection Act 1994* and *Environmental Protection Regulation 2008* provisions
- Policy clarifies compliance requirements
- *General Environmental Duty* requires all reasonable and practical measures to prevent environmental harm
- Application of the *Precautionary Principle* under ESD by regulators and users for emerging long-term harm issues
- Classification of persistent fluorinated organics as regulated wastes requiring special management

Operational Policy

Non-persistent foams (e.g. fluorine-free, QFES)

- BOD & acute toxicity issues for enclosed waterways
- Contain wastes on site if possible
- Treat wastes on site or disposal to sewer/trade
- Largely self remediating
- Emergency direct releases tolerable
- No significant restriction on dispersed rural firefighting, roadside incidents, ports use or controlled essential testing of critical systems (e.g. fuel berth to port waters)

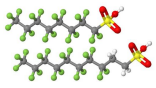
(Other contaminants considered separately)

Operational Policy

Persistent long-chain foams (≥C7)

(e.g. all fluorinated, AFFF, FP, FFFP…)

- PFOS – take out of service now
- ≥C7 foams – Phase out by July 2019
  (Provision for extension in special cases)
- Interim containment measures during phase out
- No testing with persistent foams (unless fully contained)
- High temperature destruction of all PFAS wastes
- No sale or "donation" of foams to 3rd parties



(Other contaminants considered separately)

Operational Policy

Persistent short-chain foams (≤C6)

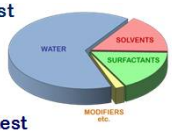
(e.g. all fluorinated, AFFF, FP, FFFP…)

- C6-PURE foam acceptable (limit of 50 mg/kg ≥C7, 10 mg/kg of PFOS/PFHxS)
- PROVIDED it is fully contained in impervious bunding
- No testing with persistent foams unless essential & contained
- Avoid cross-contamination from legacy long-chain foam
- High temperature destruction of all PFAS wastes

(Other contaminants considered separately)

Essential foam characteristics information

- Insist on ALL essential product information relevant to management & risk assessment
- The Regulator will assess the risk against the same information set
- Information needs to be for the product as-sold not just isolated components
- Consider all short and long-term issues
- Foam Operational Policy lists standard test methods for characteristics information



(Other contaminants considered separately)

Managing foam use

Life & Safety Considerations are PARAMOUNT

Environmental considerations need to be taken seriously in balanced decision making

Forward planning:
Product selection, facilities and contingency planning for firewater and wastes containment.

Incident management:
Contain and manage firewater & wastewater.

Waste disposal:
Lifetime costs & provision for proper waste disposal.

Questions?

Further information is available from www.ehp.qld.gov.au

Queensland Firefighting Foam Operational Policy