From Non-Stick to Never Gone – The PFAS Story

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Summary

- My background
- What are PFAS?
- History of PFAS
- Current situation
- Toxicology
- Regulation
- Future

Who am I?

My Background

- Academic background in organic chemistry
- Broad analytical chemistry experience
- Worked in forensic chemistry for over 20 years
- Have worked with Hawkins for over 10 years
- Deal with investigations and litigation relating to chemistry
- Manage the Hawkins Birmingham Office

Office Locations

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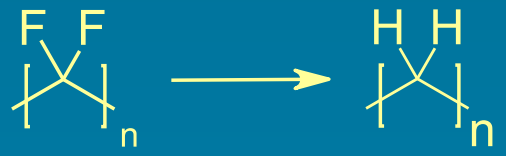
What are PFAS?

What are PFAS?

- PFAS are specified as perfluoro- or polyfluoro- hydrocarbon chemicals,

  Per / Poly Fluorinated Alkyl Substances = PFAS

- PFAS are a very large class of chemicals where carbon – hydrogen bonds have been replaced by carbon – fluorine bonds.
- Those 'perfluorinated' compounds have all of their C-H bonds replaced by C-F bonds.



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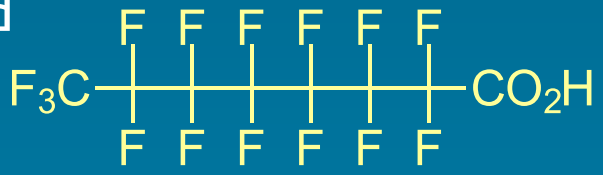
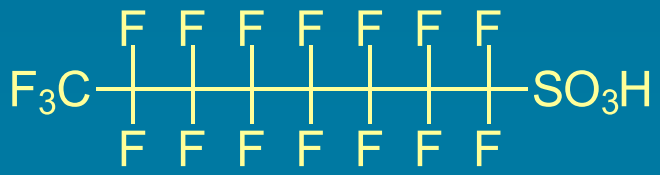
What are PFAS?

- Official chemical databases only record around several 000s substances, many more are not well documented.
- The class of substances included in PFAS now includes over 10,000 different substances.
- Two of the most common PFAS are:

PFOA = perfluorooctanoic acid



PFOS = perfluorooctanesulfonic acid



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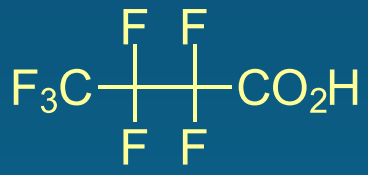
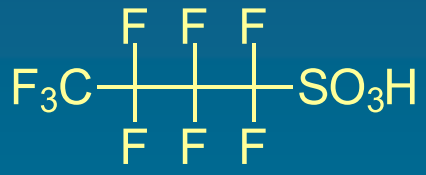
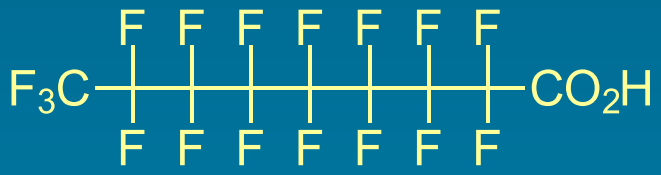
What are PFAS?

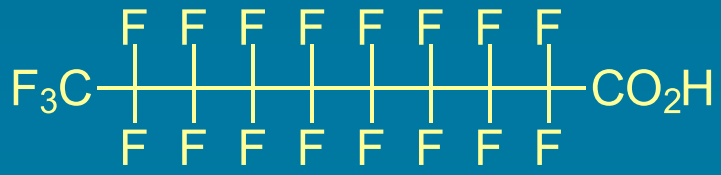
- PFOA and PFOS are two of the most common PFAS pollutants.
- Other specified PFAS pollutants have also been identified;
  - PFBS – Perfluorobutanesulfonic acid – C4
  - PFBA – Perfluorobutanoic acid – C4
  - PFNA – Perfluorononanoic acid – C9
  - PFDA – Perfluorodecanoic acid – C10
  - PFHxA – Perfluorohexanoic acid – C6
  - PFHxS – Perfluorohexanesulfonic acid – C6
  - HFPO-DA or GenX – Hexafluoropropylene oxide-dimer acid

What are PFAS?

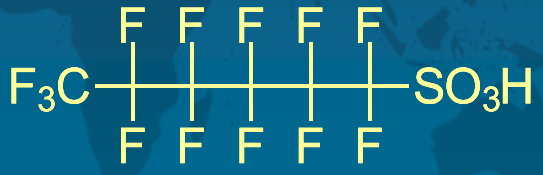
PFBA 

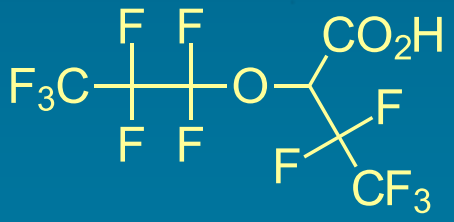
PFBS 

PFNA 

PFDA 

PFHxA 

PFHxS 

HFPO-DA / GenX 

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What are PFAS?

How do we measure PFAS??

- Requires expensive analytical laboratory equipment.
- Sensitive measurement methods that need to cope with the very common environmental prevalence of PFAS.
- Capacity for volume testing is generally limited due to costs.

How low do we go??

- Parts per billion (ppb)
- Parts per trillion (ppt)

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A History of PFAS

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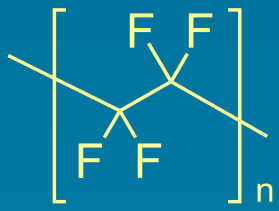
A History of PFAS

- The first PFAS compound was discovered in 1938 by Roy J Plunkett, a chemist at Du Pont.
- While making new refrigerants, a gas cylinder containing tetrafluoroethylene (TFE) was cut open, and a white, way solid found.

- The polymeric substance, PTFE, was commercialised as Teflon.



- Teflon was found to be very heat resistant, and resistant to both oil and water-based substances.

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A History of PFAS

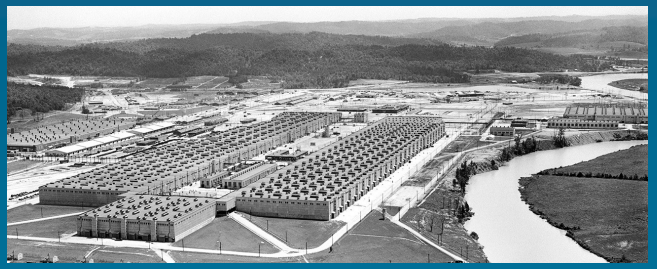
- Since the first commercial production of Teflon, many other PFAS have been manufactured for many applications.
- Use of fluorine in place of hydrogen produces a 'third phase' that is chemically separate from our common water and oil phases.

- Specific properties of PFAS that make them appealing:
  - Resistance to water and oil
  - Limited thermal changes
  - Ability to form thin films
  - Can provide low-friction surfaces

A History of PFAS

- Since the invention of Teflon, this material and other PFAS have been used in many applications;

Manhattan Project



Source: U.S. Department of Energy

Non-stick cookware

Outdoor Fabrics

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A History of PFAS

Gaskets and seals

Chemical resistant containers

Food packaging

Water treatment

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A History of PFAS

- Current estimated market size for PFAS and their related materials is around US$40 billion.
- The specific chemical properties of PFAS mean that finding suitable, less / non-toxic alternatives is difficult.
- Estimated clean-up costs much more expensive than the current market.

A History of PFAS

- Since their discovery, PFAS have been produced by notable manufacturers;

  - Minnesota Mining and Manufacturing Company (3M)
  - AGC (Japan)
  - Archroma
  - Arkema
  - BASF
  - Bayer
  - Daikin
  - Honeywell
  - Merck
  - Solvay
  - Dongyue

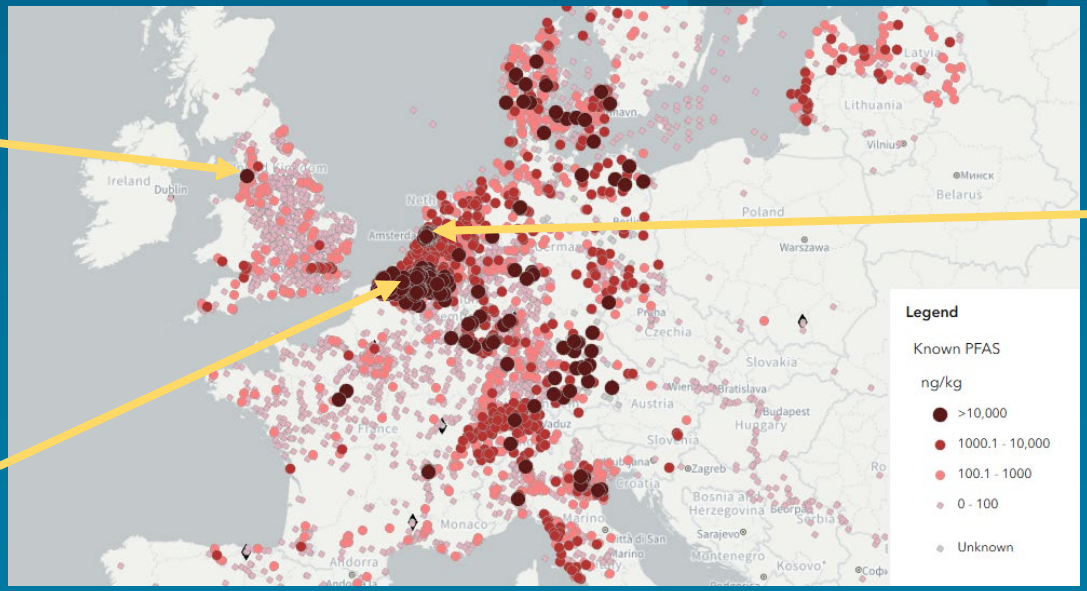
A History of PFAS

- PFAS have become prevalent in most parts of the globe, including isolated Artic and Antarctic regions.
- In the EU, studies have found PFAS in many areas, such as the interactive map provided by the EU Environment Agency:

River Wye, Thornton-Cleveleys

Schiphol Airport

Zwijndrecht, Belgium



https://www.eea.europa.eu/en/european-zero-pollution-dashboards/indicators/treatment-of-drinking-water-to-remove-pfas-signal

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A History of PFAS

- PFAS used extensively in fire-fighting foam:

AFFF

Aqueous Film Forming Foam

- Very effective foams and used commonly at airports and for military fire-fighting.
- Uncontained run-off water that contains AFFF has contaminated many ground-water sources.
- Example contamination events: Jersey and Schiphol airports.

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A History of PFAS

- Sites where PFAS have been manufactured are often found to have very high levels in nearby soil and groundwater.
- Previous PFAS production sites, such as Zwijndrecht, Belgium (formerly used by 3M) have been found to be highly contaminated.
- In such areas, and those contaminated by AFFF (e.g. near airports) blood testing schemes have found high levels of PFAS across populations.

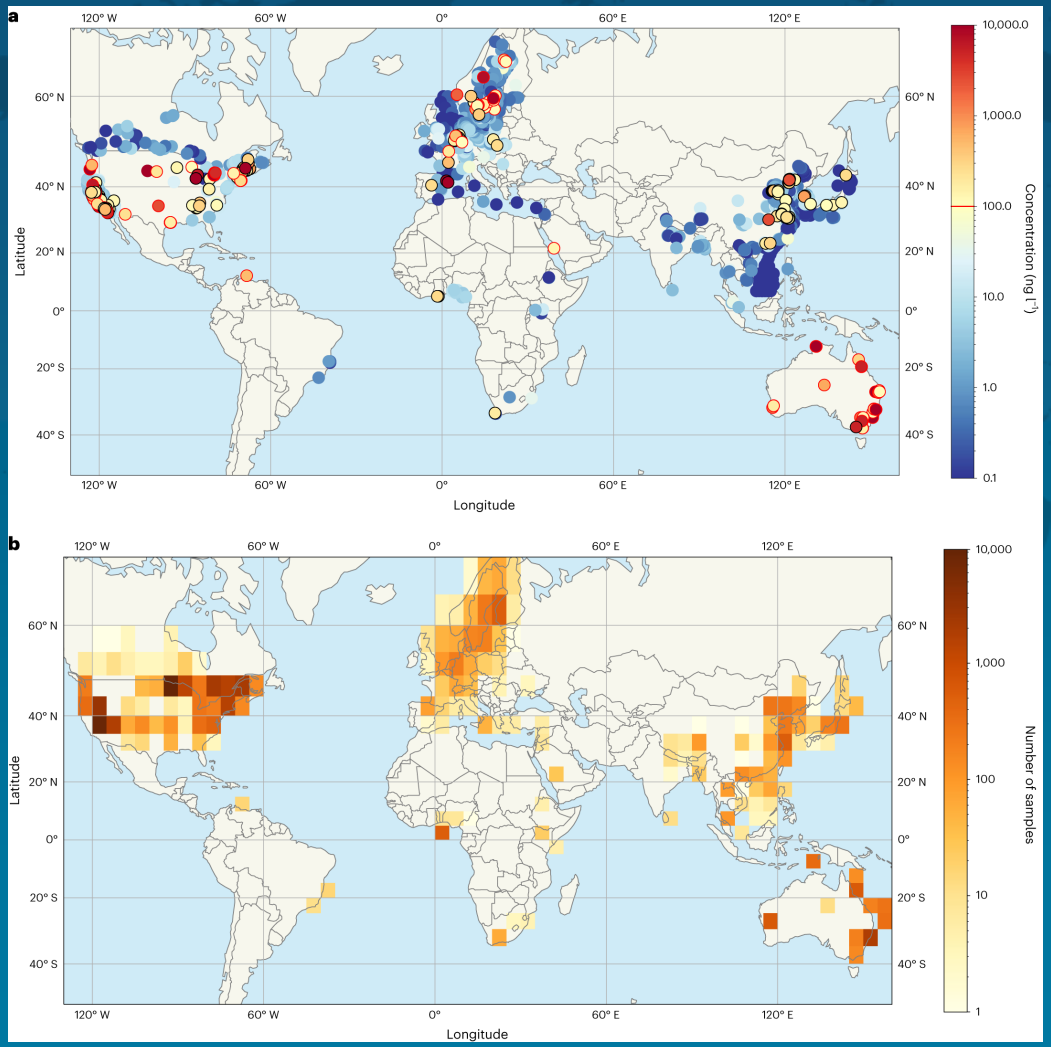
A History of PFAS

- PFAS have also been used for many types of packaging applications.
- A notable US case involved the use of PFAS treated containers used for a mosquito pesticide applied in some areas of the US.
- The presence of PFAS were detected in the pesticide following US EPA testing in 2021.
- Traced to containers made by Inhance Technologies LLC.
- By 2024, US EPA placed a prohibition order on Inhance to stop production of PFOS, PFNA and PFDA, along with some other PFAS products.

A History of PFAS

- PFAS global distribution (measured!!!):

- The number of samples taken in some areas is low (e.g. UK).



Nature GeoScience, Nature Geoscience volume 17, pages340–346 (2024)
DOI https://doi.org/10.1038/s41561-024-01402-8

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A History of PFAS

Production of PFAS is relatively cheap (~£1000 per kg)

Destruction of PFAS is very expensive (≥£200000 per kg)

- High cost of destruction is due to the difficulty in breaking down the C-F bond.
- Emerging technologies are finding means to extract PFAS from water and soil, but there are expensive.

PFAS Toxicology

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PFAS Toxicology

- Many studies have looked at the health effects of PFAS.

Cancers – considered a carcinogen and suspected to contribute to kidney, testicular, prostate and liver cancers.

Thyroid disease – suspected to affect thyroid function and lead to thyroid failure and related problems.

Auto-Immune Disease – suspected to contribute to autoimmune disorders.

Heart Disease – can lead to increased cholesterol

PFAS Toxicology

- PFAS can have health effects at low levels.
- Threshold levels for regulation are in the order of ppt.

ppt – parts per trillion

- Equates to around 1 gram in 400 Olympic swimming pools.
- Or 1 metre of the journey from the Earth to Saturn.

Units of measure are often recorded in:

ppb – parts per billion	ppt – parts per trillion
µg / kg	ng / kg
µg / L	ng / L

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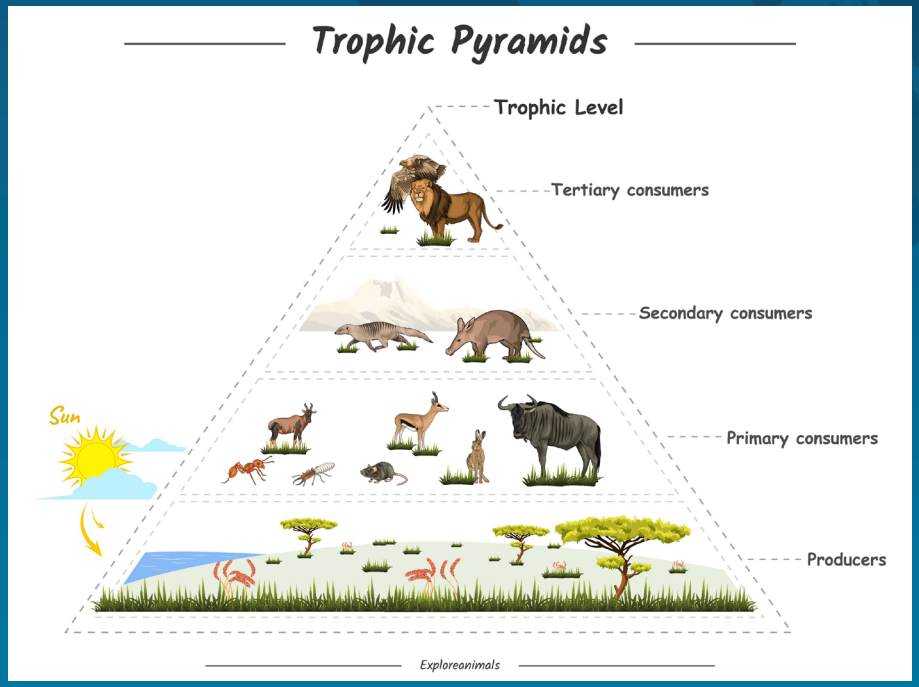
PFAS Toxicology

- PFAS are known to ‘bioaccumulate’ through the food chain.



- PFAS are persistent contaminants, and have been termed; ‘forever chemicals’.

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PFAS Toxicology

- PFAS can stay in the body for long periods.
- US government data suggests;

PFOA – C8	2.1 – 10.1 years
PFOS – C8	3.3 – 27 years
PFHxS – C6	2.5 – 4.3 years
PFNA – C9	665 hours
PFBA – C4	72 – 81 hours

https://www.atsdr.cdc.gov/toxguides/toxguide-200.pdf

- Measured levels of PFAS in blood across the US population is up to 4.7 ng/mL (4.7 ppb).

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PFAS Toxicology

- PFAS have been found in animals and water across most areas of the world, including:
  - Penguins
  - Polar bears
  - Seals
  - Sea birds (some of which almost never spend time on land)
  - People
- Snow and ice core studies in the Antarctic have shown a significant rise in levels of shorter chain PFAS (e.g. PFBA – C4 and PFHpA – C7) from the mid-2000s.

https://www.vlaanderen.be/pfas-vervuiling/pfas-aanpak-regio-zwijndrecht/zwijndrecht-no-regret-maatregelen

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PFAS Toxicology

- Some measures for the ‘no-regret’ measures near Zwijndrecht;
  - Eat a varied diet.
  - Wash fresh produce (do not home-grow if vulnerable).
  - Limit contact with food packaging.
  - Do not eat home-grown livestock or their products.
  - Limit consumption of organ meat.
  - Do not use non-stick or Teflon (water/grease repellent) products.
  - Do not use ground water.
  - Avoid blowing soil, children play in unvegetated areas.
  - Increase exercise.

https://www.vlaanderen.be/pfas-vervuiling/pfas-aanpak-regio-zwijndrecht/zwijndrecht-no-regret-maatregelen

PFAS and Regulation

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PFAS and Regulation

- Different approaches in different jurisdictions
- Brief coverage of regulation in;
  - United States
  - European Union
  - United Kingdom
- For reference, UK Drinking Water Limits for other pollutants are:
  - Lead – 10 ppb
  - Mercury – 1 ppb
  - Polyaromatic hydrocarbons (PAHs) – 100 ppt
  - Total Pesticides – 500 ppt

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PFAS and Regulation

In the USA:

- Many different approaches at both state and federal level.

Federal level;

- Safe Drinking Water Act
- Comprehensive Environmental Response, Compensation, and Liability Act (the USA 'Superfund')
- Toxic Substances Control Act
- Toxics Release Inventory (TRI) Program
- Clean Water and Clean Air Acts
- National Defense Authorization Act

PFAS and Regulation

- Many different approaches taken at the US state level.
- Key development at the US EPA in April 2024;

  President Biden stated *"Every American deserves to be able to turn on their water tap or faucet and be able to drink clean water."*

- This has resulted in first US federal Safe Drinking Water limits.
  - For PFOS and PFOA limits are 4 ppt ('combined' total).
  - For other PFAS limits are 10 ppt ('combined' total).
- Introduces a Hazard Index for specified PFAS to further limit their aggregate concentration in drinking water.

PFAS and Regulation

- Many different approaches taken at the US state level.
- Some states have set low levels, e.g. Michigan 8 ppt PFOA and 16 ppt PFOS
- Target for US EPA is to achieve 0 ppt PFAS in drinking water!

PFAS and Regulation

In the EU

- The EU regulation has generally lagged behind the US
- Current EU drinking water limits are:
  - 500 ppt summed for all PFAS.
  - 100 ppt for 20 specific PFAS
- For food and drink the European Food Safety Authority (EFSA) set limits:
  - Tolerable weekly intake (TWI) of 4.4 ng / kg bodyweight / week

For a 60kg person ⇨ 264 ng / week.

PFAS and Regulation

In the UK

- Currently, the UK Drinking Water Inspectorate guidelines are:

Teir	PFAS* Level	Required Action
1	<10 ppt	Limited action and further monitoring
2	<100 ppt	Preliminary action in case levels increase, further monitoring
3	>100 ppt	Immediate action and notification to DWI

* Sum of all PFAS

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PFAS and Regulation

- Other countries have set varied (but low) limits on PFAS in drinking water:
  - Japan – <50 ppt
  - Australia – Combined PFOS and PFHxS <70 ppt and for PFOA <560 ppt
  - New Zealand – similar to Australian limits
  - Canada – Some of the tightest limits, <25 ppt (summed PFAS)
  - China – <40 ppt for PFOS and <80 ppt for PFOA, with tighter regulation expected.

PFAS and Regulation

- Many countries are looking to phase out entirely PFAS:
  - Fire-fighting foams
  - Food and product packaging
  - Cosmetics
- Manufacturers are actively seeking replacement PFAS-free products.

PFAS – Challenges

In respect of litigation

- What was the source of the PFAS?
- Are there any other sources?
- Can any toxicological effects be traced to a specific PFAS?
- Are there regulatory limits, have they been breached?

Possible challenges could be difficult, need to consider outcomes from other countries…..

PFAS – Challenges

Notable (US) litigation claims:

- Du Pont, Chemours & Corteva agreed to US$1.2 billon
- 3M agreed to US$10.3 billon
- BASF (purchased Ciba) agreed to settle for US$320 million
- Current consolidated multidistrict litigation (MDL) in progress.

Thank you

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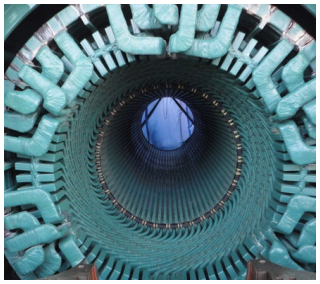
- Fires in buildings
- Fire stop and spread
- Fire modelling
- Explosions

Road Traffic Collisions
- Collison reconstruction
- Vehicle examinations

Cyber, Digital & Technology
- 3D modelling
- Data recovery
- Digital forensics
- Video analysis

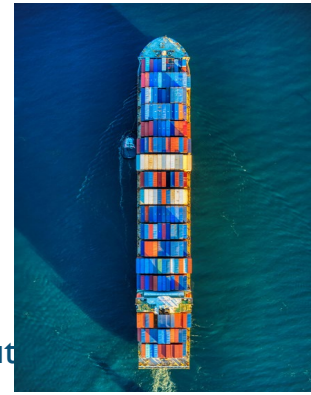
Power & Energy
- Thermal Power
- Oil & Gas
- Renewables



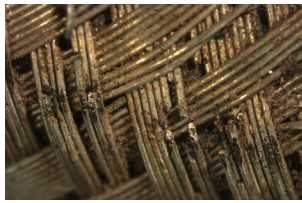
Engineering
- Electrical/Electronics
- Mechanical
- Chemistry & process

Built Environment
- Acoustics & vibration
- Forensic architecture
- Civil engineering
- Fire engineering
- Flooding & hydrology
- Health & Safety

Marine
- Cargo spoilage
- IMDG / IMSBC cargo
- Liquefaction
- Master mariner
- Contamination / pollut



Materials, Chemistry & Biology
- Metallurgy
- Composites
- Plant pathology



Personal Injury
- Construction injuries
- Falls from height
- Lifting operations
- Manual handling

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Any Questions?

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