An Industry Perspective on Understanding and Abating Organic Fluorinated Compounds

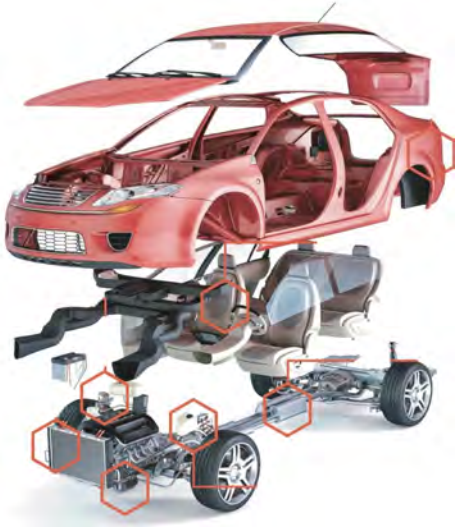
October 24, 2019

Modern Use of Fluoroproducts

Communication

Low-GWP Refrigerants

Automotive



Renewable Energy

Aerospace

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Per- and Polyfluoroalkyl Substances (PFAS)

Similarities

"highly fluorinated aliphatic substances that contain 1 or more C atoms on which all the H substituents …. have been replaced by F atoms, in such a manner that they contain the perfluoroalkyl moiety C_nF_{2n+1}–. "

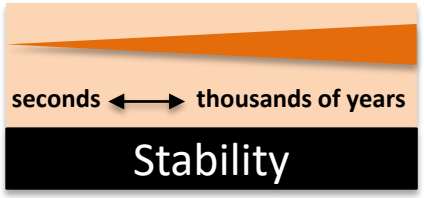
*IEAM **2011**, 7(4):513-541.
Open access: http://dx.doi.org/10.1002/ieam.258

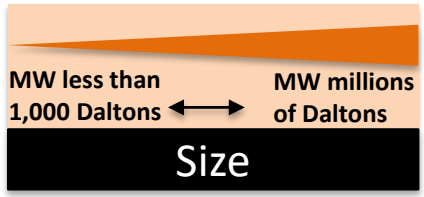
Differences

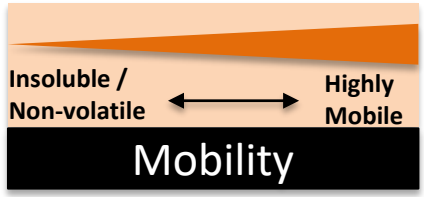
Solids

Liquids

Gases







Thousands of substances
with *very different* properties

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Hydrocarbon Analogy

A Big Universe of Very Different Substances

SOLID

Polyethylene

$(C_2H_4)_n$

LIQUID

Ethyl Alcohol

CH_3CH_2OH

GAS

Propane

$CH_3CH_2CH_3$

The PFAS Universe is equally diverse
Need to use clear, specific and descriptive terms

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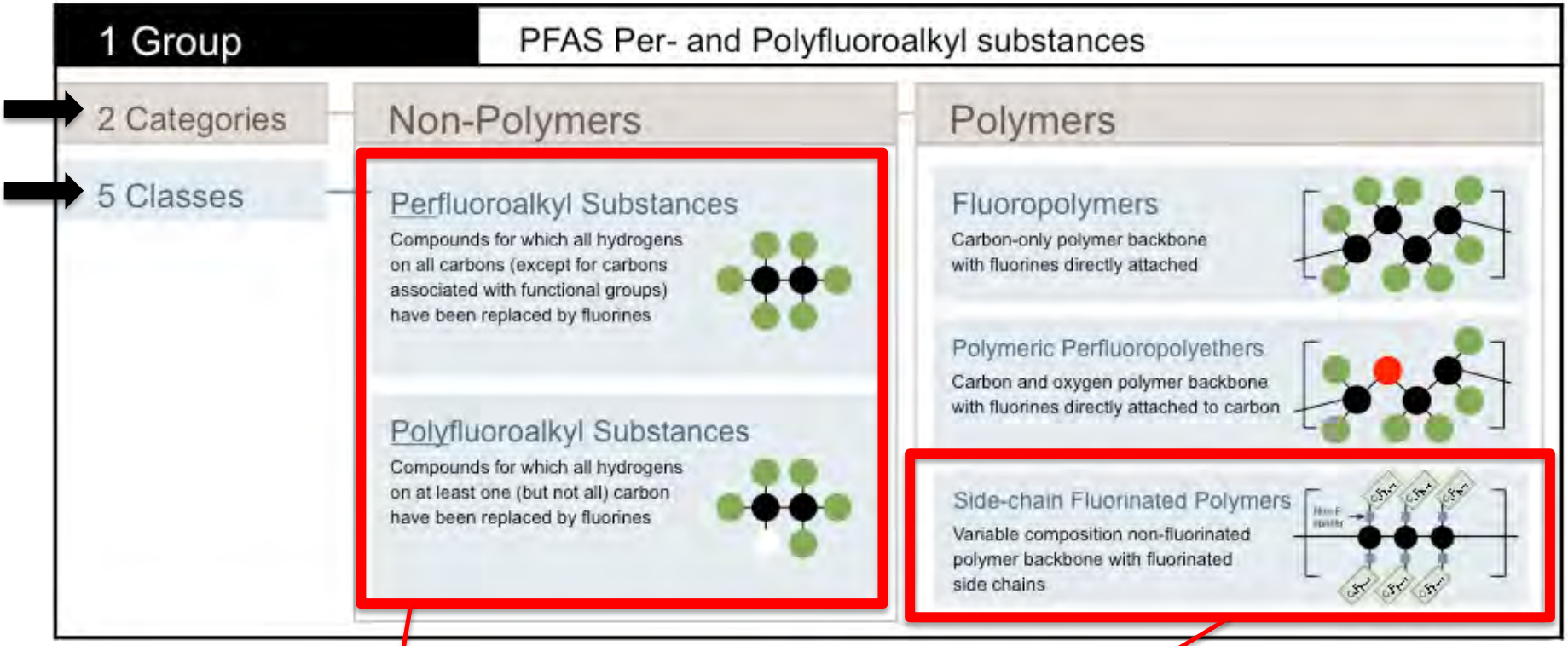
PFAS Overview



Small molecules like Perfluoroalkyl acids (PFAAs). EPA 537.1 analytes are all non-polymer PFAS

Substances that may degrade in the environment to form non-polymer PFAS

- Fluorine
- Carbon
- Oxygen
- Hydrogen

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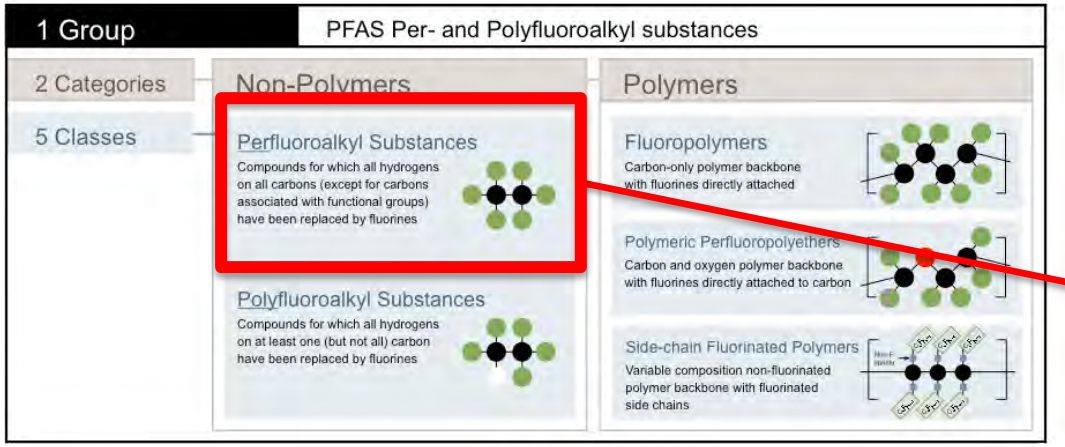
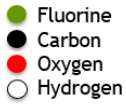
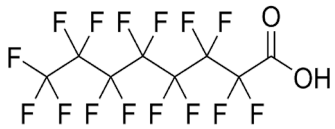
PFAS Overview – Continue to Converge

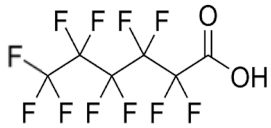




Perfluoro carboxylic acids (PFCAs)



PFOA



PFHxA

Michigan "Draft Regulations for PFAS MCL"*

8 ng/L (ppt)

400,000 ng/L (ppt)

*https://www.michigan.gov/egle/0,9429,7-135-3308_3323-509830--,00.html

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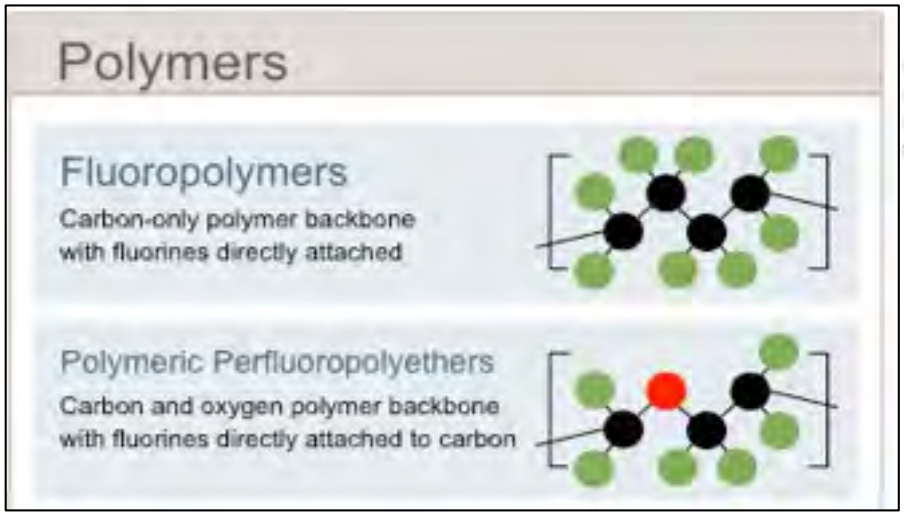
Polymer Category is Different



Thermal, chemical and biological stability*

High Molecular Weight; Not bioavailable or subject to long-range transport

Fluoropolymers shown to meet OECD Polymer of Low Concern (PLC) criteria*

*IEAM **2017**, 14(3):316-334
Open access: http://dx.doi.org/10.1002/ieam.4035

Electronics

High frequency signal transmission

Medical Devices

High dielectric insulators in medical equipment that relies on high frequency signals

Aerospace/Auto

Weight reducing fuel lines; heat/chemical resistant wire coatings

Semiconductor Manufacturing

Providing pure environments to transport/store harsh chemicals

Alternative Energy

Insulation properties, durability, and safety enabling, fuel cells and solar panels

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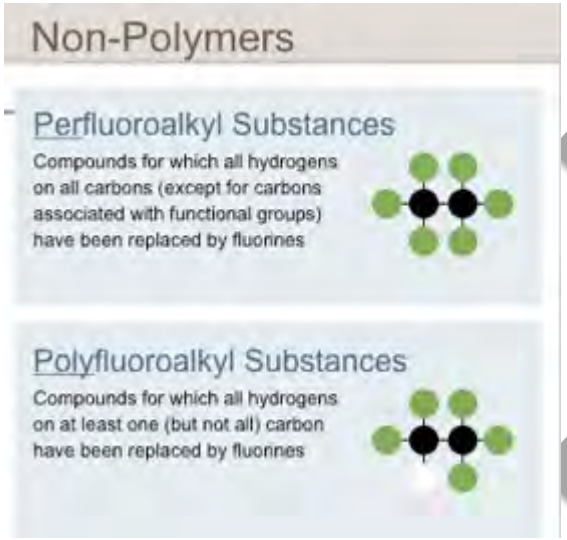
Fluoropolymer Manufacturing

Major manufacturers phased out the use of PFOA and moved to approved alternatives*.



HFPO-DA, CAS# 62037-80-3

$F_3C\text{-}CF_2CF_2\text{-}O\text{-}CF(CF_3)\text{-}CO_2^-$

CAS# 908020-52-0

$F_3C\text{-}CF_2\text{-}O\text{-}CF_2CF_2\text{-}O\text{-}CF_2CO_2^-$

ADONA, CAS# 958445-44

$F_3C\text{-}O\text{-}CF_2CF_2CF_2\text{-}O\text{-}CFHCF_2\text{-}CO_2^-$

CAS# 329238-24-6

$ClC_3F_6\text{-}O\text{-}[CF_2CF(CF_3)O\text{-}]_n\text{-}[CF(CF_3)\text{-}O\text{-}]_m\text{-}CF_2\text{-}CO_2^-$

Why do we need to be specific and descriptive? Characterizing emissions requires authentic reference standards and validated analytical methods

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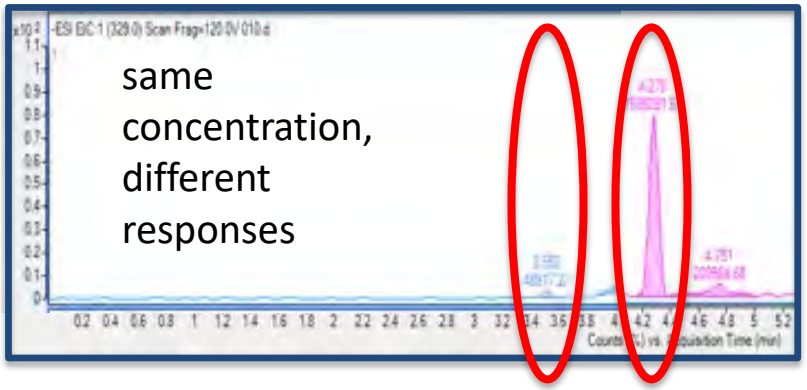
*Environment International, **2013**, 60 : 242-248
Open access: http://dx.doi.org/10.1016/j.envint.2013.08.021

Advancements – Analytical Methodology

Reliable, validated, reproducible analytical methods are *essential* to be able to make *sound, fact-based decisions*

- Instrumentation - non-targeted and targeted analysis
- Authentic reference standards
- Method development



In order to accurately *identify* compounds and determine *concentrations*, authentic reference standards are required.

Recent Advancements

- Analytical detection capability
- Sampling - stack testing methods for non-polymer PFAS
- Significant baseline emissions and abatement technology research with low detection capability.
- Progress towards our 2030 Corporate Responsibility Commitment

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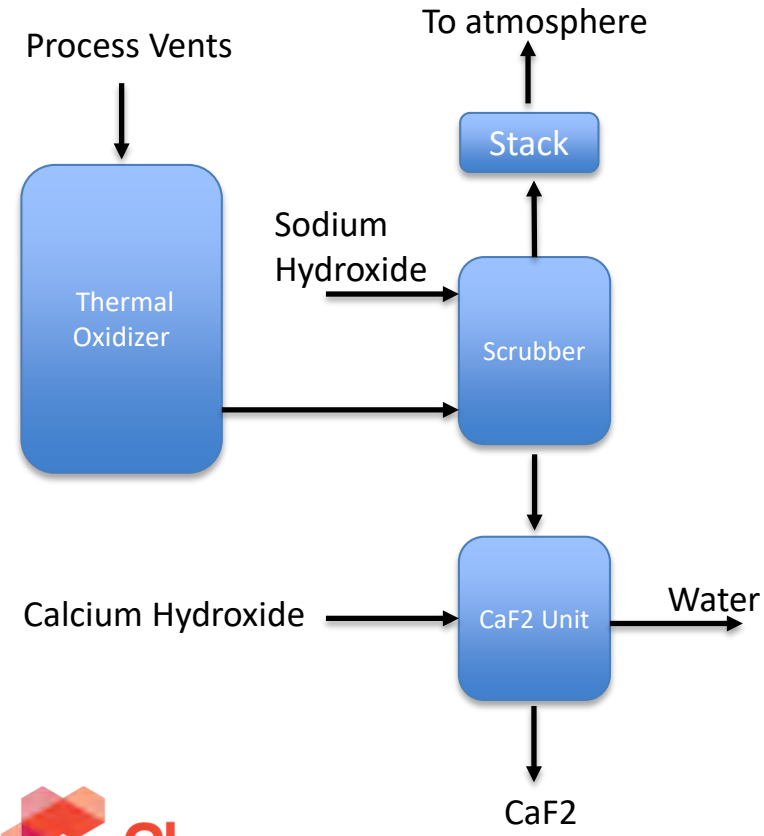
Abatement Technology - Vapor

- Concentrated Vapor – Thermal Oxidizer
  - Inputs mixed with oxygen at high temperatures to oxidize fluorinated organic compounds. 99.99% destruction capability.



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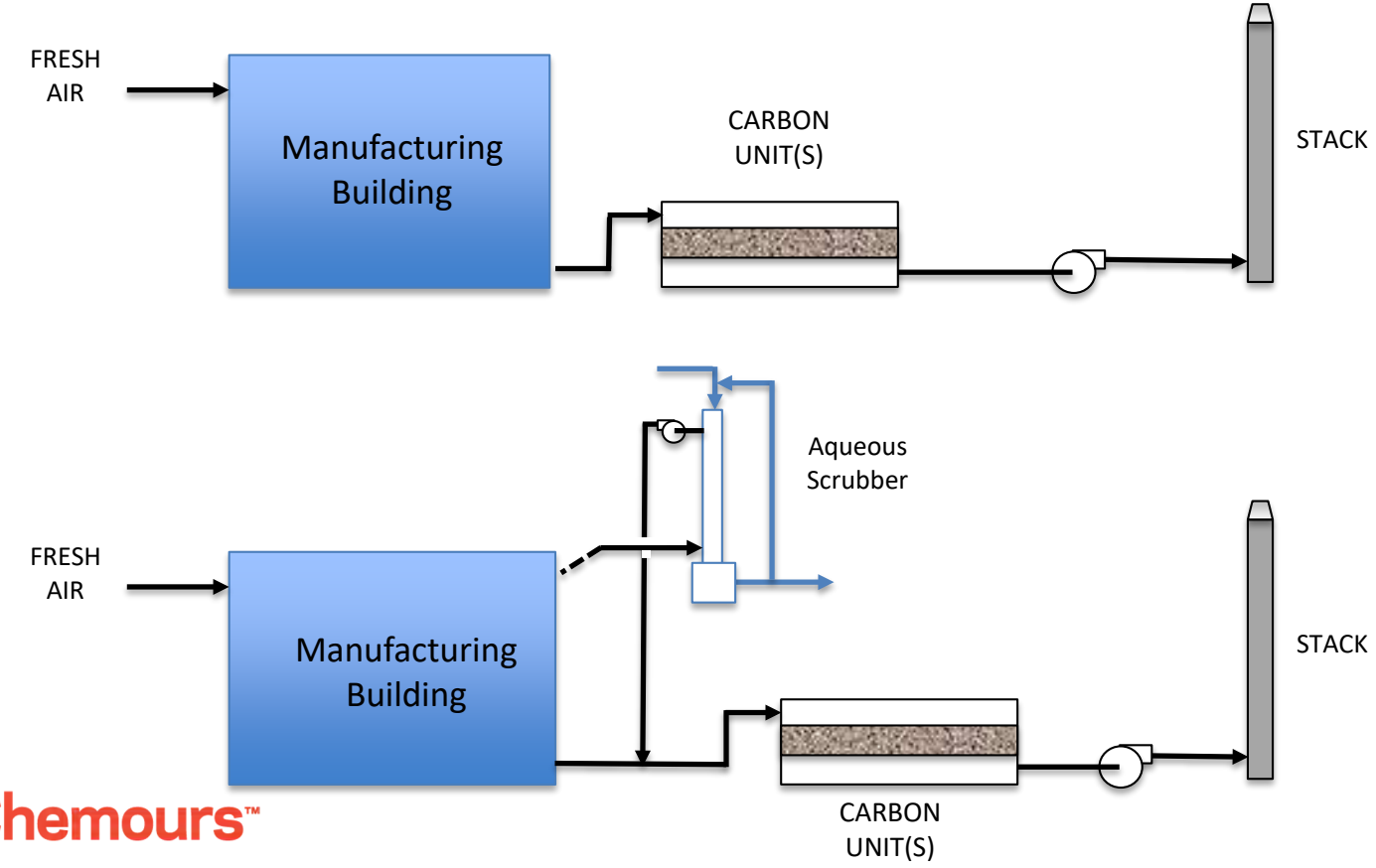
Abatement Technology - Vapor

- Dilute Vapor
  - Adsorption utilizing granular activated carbon (GAC) for higher molecular weight, higher boiling non-polymer PFAS.



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Abatement Technology - Aqueous

- Adsorption (GAC) and ion exchange.
  - Used in both process water and finished product applications.

- Significant research ongoing
  - Thermolysis for more concentrated aqueous streams
  - Have tested several types of adsorbents and ion exchange resins vs non-polymer PFAS compounds.
  - Researching combinations of technologies that ultimately enable recycle of process water internal to the manufacturing facilities.

Our 2030 Corporate Responsibility Commitment

Inspired People

Safety Excellence
- Improve employee, contractor, process, and distribution safety performance by at least 75%.

Vibrant Communities
- Invest $50M in our communities to increase access to STEM skills and improve lives through environment and safety programs.

Empowered Employees
- 50% of all positions globally filled with women.
- 20% of all US positions filled with ethnically diverse employees.

Shared Planet

Climate
- Reduce greenhouse gas emission intensity by 60%.
- Progress our plan to become carbon positive by 2050.

Water
- Reduce air and water process emissions of fluorinated organic chemicals by 99% or greater.

Waste
- Reduce landfill volume intensity by 70%.

Evolved Portfolio

Sustainable Offerings
- 50% or more of our revenues will be from solutions that make a specific contribution to the 2030 United Nations Sustainable Development Goals.

Sustainable Supply Chain
- Baseline the sustainability performance of 80% of suppliers by spend and demonstrate 15% improvement.

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