PFAS and Contaminants of Emerging Concern (CEC) – Landfill Liner Performance and Regulation

By Daniel Gibbs

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A Multidisciplinary Approach

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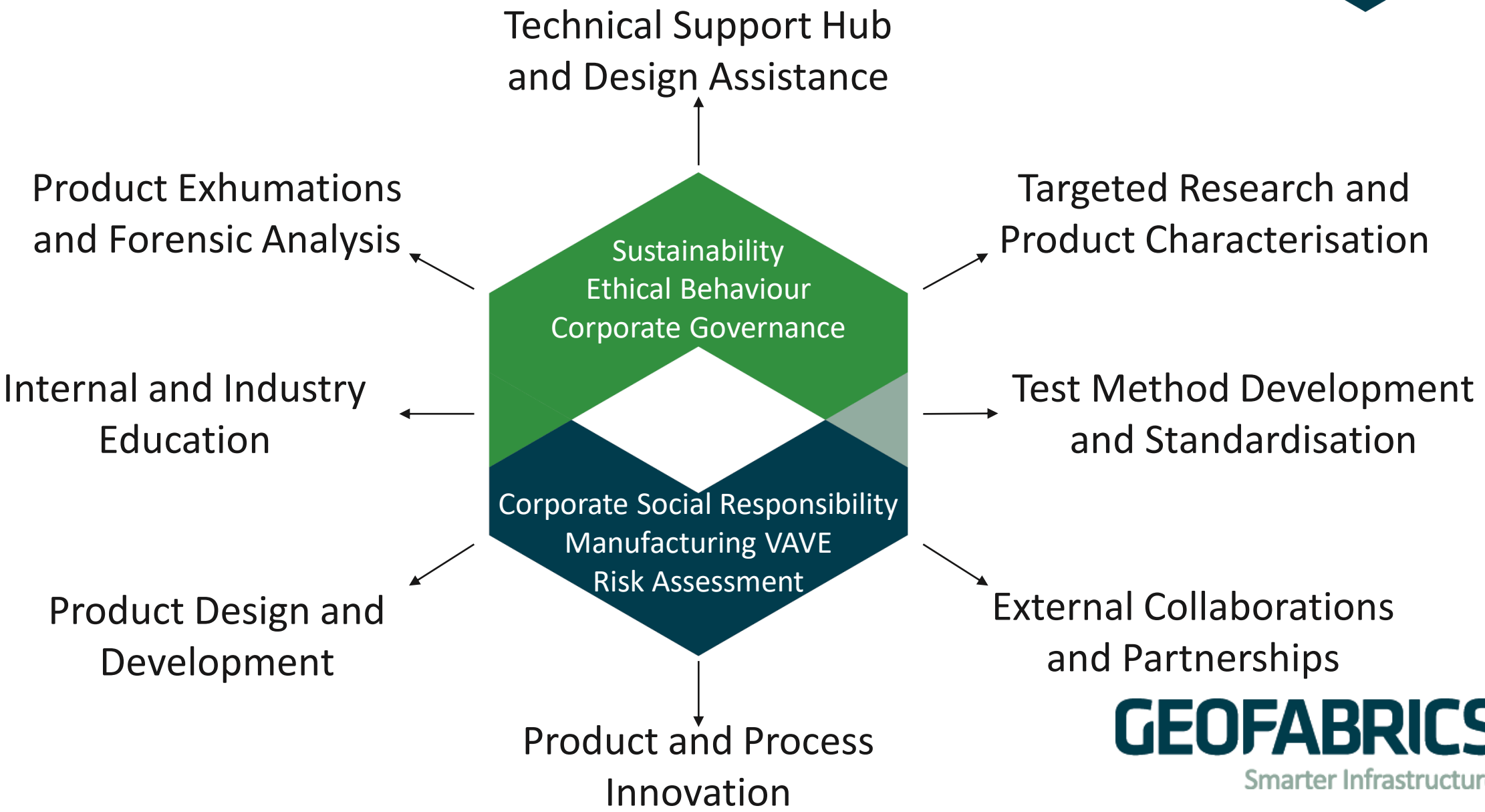

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During the last 10 years, the GRID has undertaken over 700 research and innovation projects, across a broad range of geosynthetic products used in a wide variety of infrastructure projects

How many chemicals?

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According to a *study* published in 2020, over **350,000** chemicals and mixtures of chemicals have been registered for production and used globally

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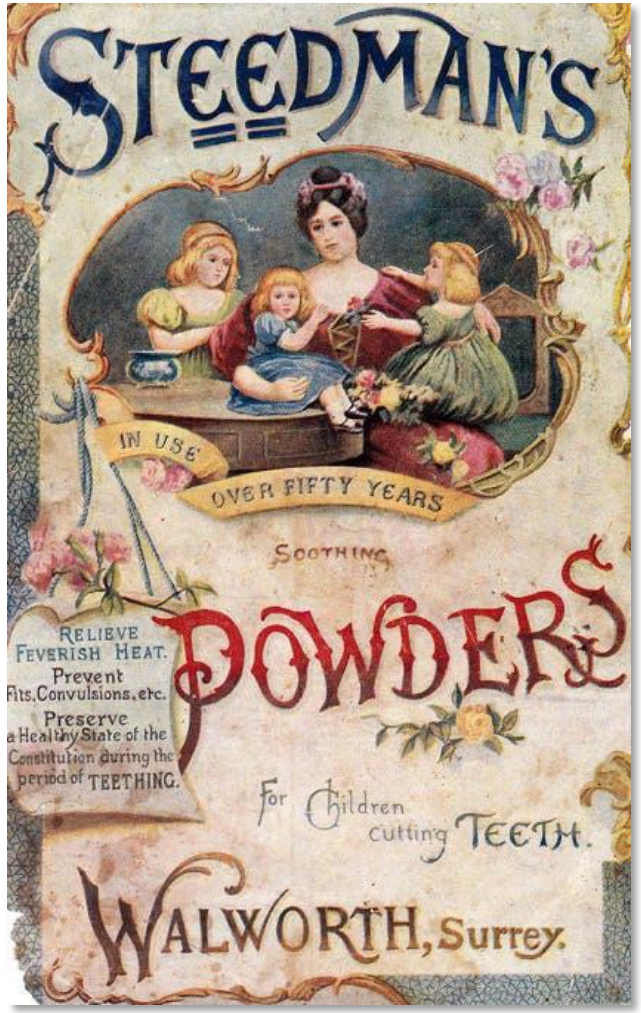
A colourful history of chemical use



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Dichlorodiphenyltrichloroethane

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"We have discovered many preventives against tropical diseases, and often against the onslaught of insects of all kinds, from lice to mosquitoes and back again. The excellent DDT powder which had been fully experimented with and found to yield astonishing results will henceforth be used on a great scale by the British forces in Burma and by the American and Australian forces in the Pacific and India in all theatres."
– Winston Churchill, September 24, 1944

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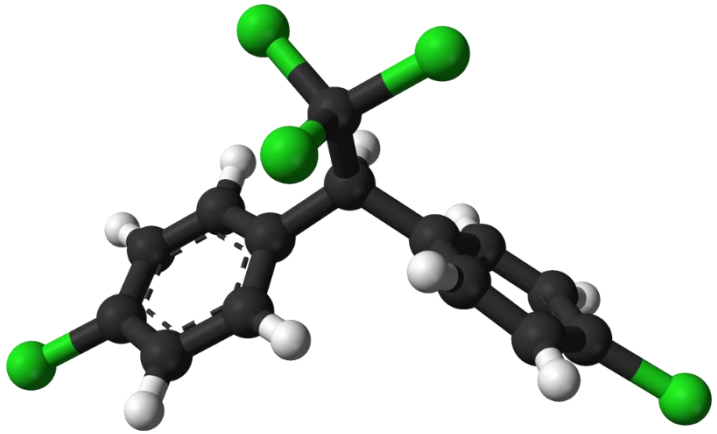
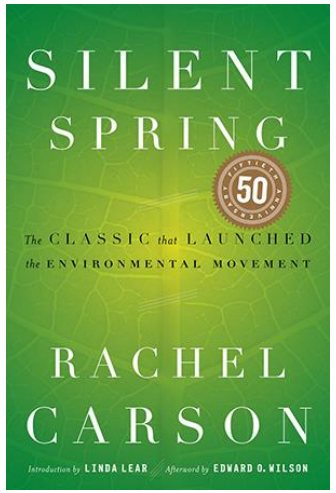
Dichlorodiphenyltrichloroethane





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What determines whether a chemical is helpful…

..or harmful?

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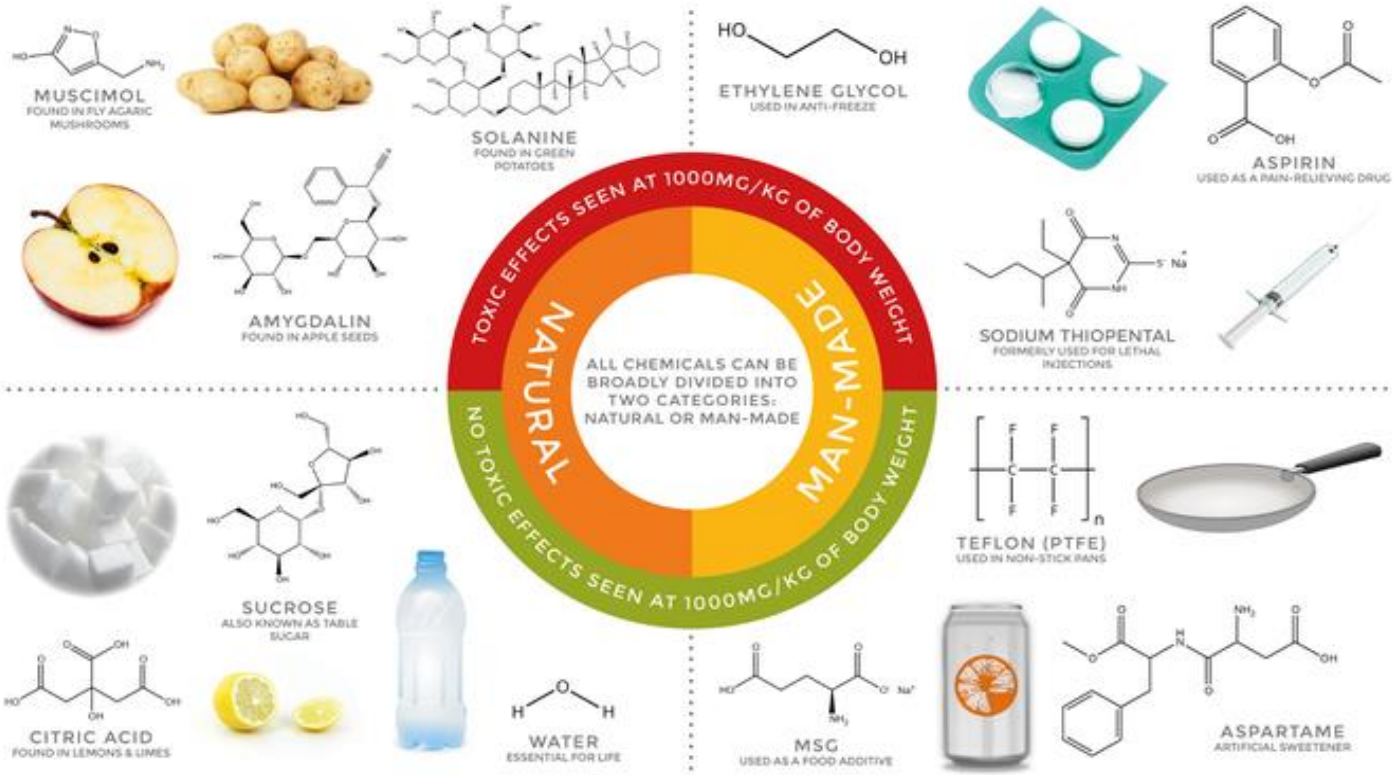
NATURAL & MAN-MADE CHEMICALS

A COMMON MISCONCEPTION IS THAT ALL MAN-MADE CHEMICALS ARE HARMFUL, AND ALL NATURAL CHEMICALS ARE GOOD FOR US. HOWEVER, MANY NATURAL CHEMICALS ARE JUST AS HARMFUL TO HUMAN HEALTH, IF NOT MORE SO, THAN MAN-MADE CHEMICALS.



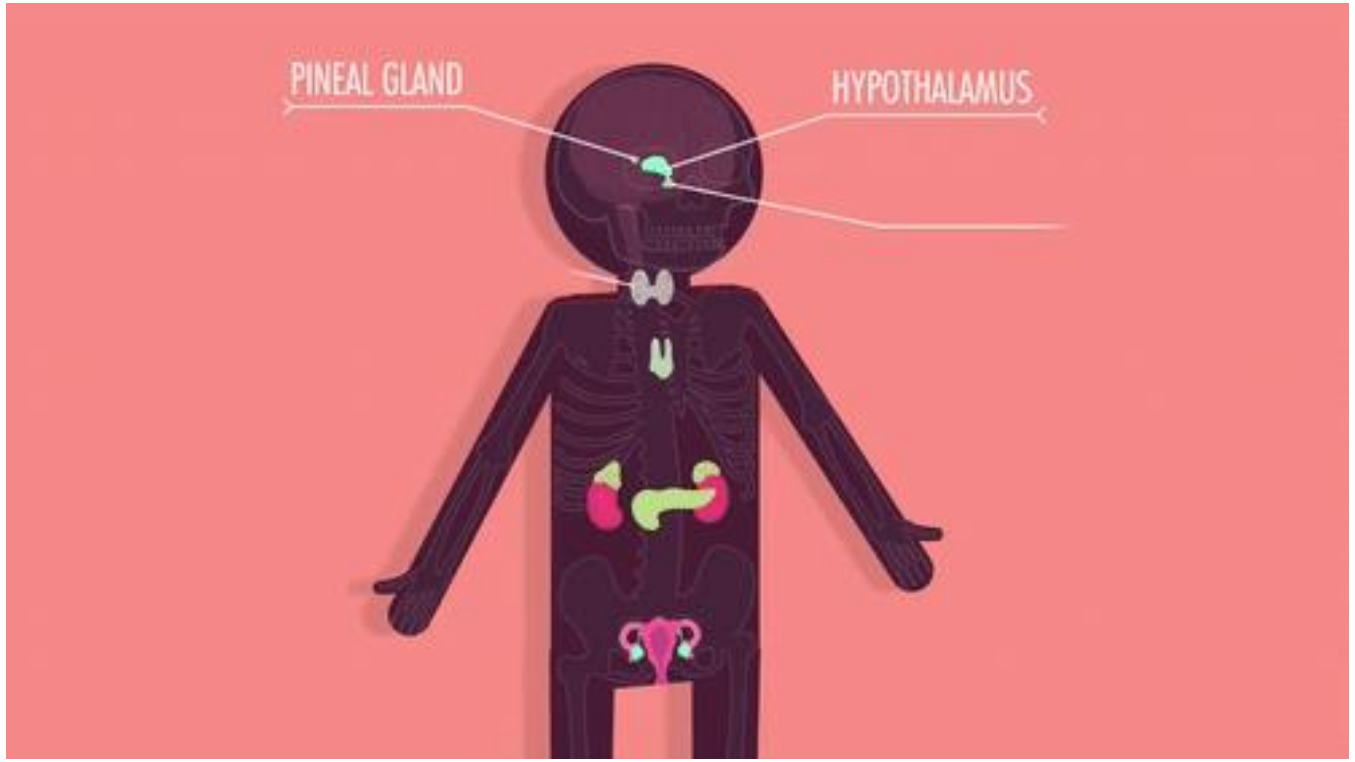
"EVERYTHING IS POISON, THERE IS POISON IN EVERYTHING. ONLY THE DOSE MAKES A THING NOT A POISON."

PARACELSUS, 1493-1541, 'THE FATHER OF TOXICOLOGY'

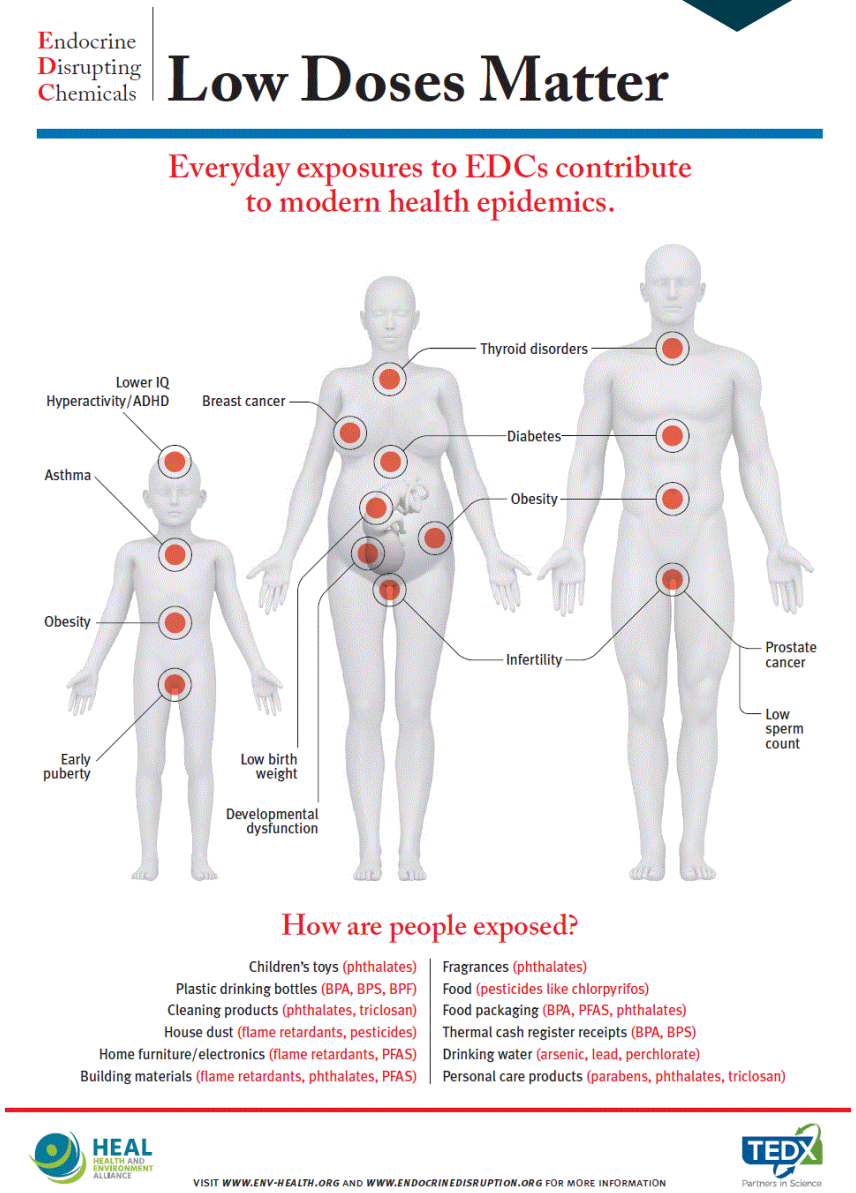
ANY SUBSTANCE, IF GIVEN IN LARGE ENOUGH AMOUNTS, CAN CAUSE DEATH. SOME ARE LETHAL AFTER ONLY A FEW NANOGRAMS, WHILST OTHERS REQUIRE KILOGRAMS TO ACHIEVE A LETHAL DOSE.

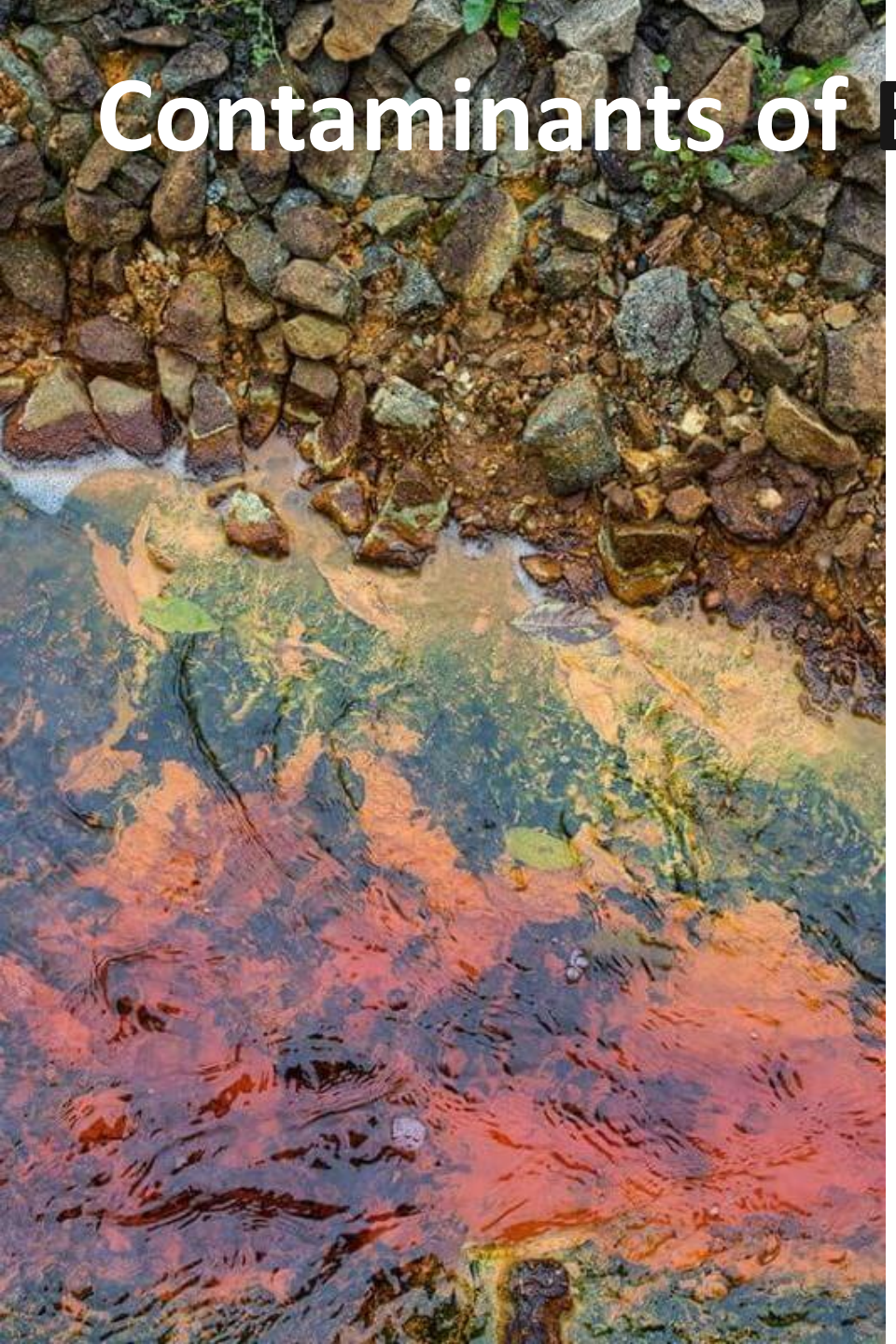
CHEMICAL TOXICITY IS A SLIDING SCALE, NOT BLACK AND WHITE - AND WHETHER A CHEMICAL IS NATURALLY OCCURING OR MAN-MADE TELLS US **NOTHING** ABOUT ITS TOXICITY.

Endocrine Disrupting Chemicals



The endocrine system is a complex collection of glands and organs that helps to regulate various bodily functions. This is accomplished through the production and release of hormones and steroids which act as chemical messengers.





Contaminants of Emerging Concern (CEC)

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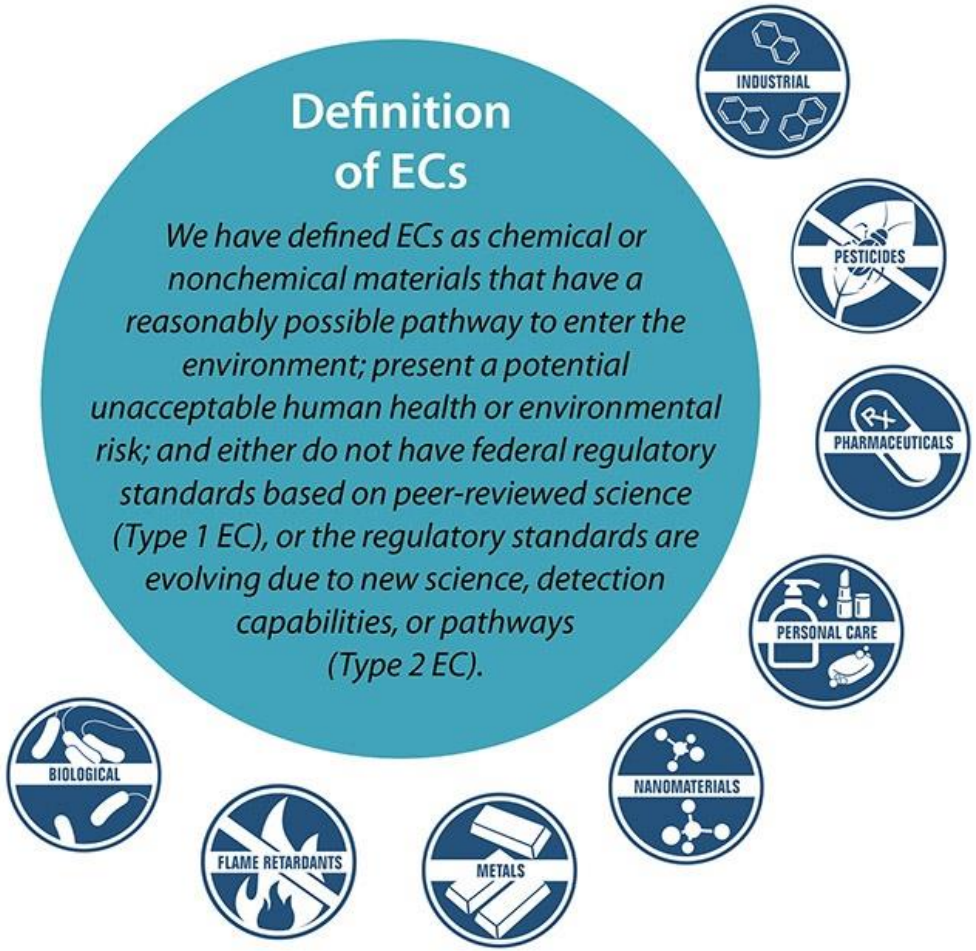

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Source: https://www.integral-corp.com/our-services/environment/emerging-contaminants/

Contaminants of Emerging Concern (CEC)

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EC Category		Description and Examples
	Industrial Chemicals	Plasticizers, surfactants, and solvents; examples include 1,4-dioxane, bisphenol-A, alkylphenols, and various phthalates
	Microbes and Viruses	Biological contaminants; examples include cyanobacteria, microcystins, and *Legionella pneumophila*
	Flame Retardants	Brominated flame retardants and poly- and perfluoroalkyl substances
	Metals	Mostly Type 2 ECs such as arsenic, lead, and hexavalent chromium

EC Category		Description and Examples
	Pharmaceuticals	Prescription and nonprescription over-the-counter drugs, synthetic hormones
	Pesticides	Herbicides and insecticides and their metabolic and environmental degradation products; examples include 2,4- dichlorophenoxyacetic acid, atrazine, alpha- and beta-hexachlorocyclohexane, chlorpyrifos, glyphosate, and metolachlor
	Nanomaterials	Chemicals or materials that range from approximately 1 to 100 nm in size and can be naturally occurring or engineered; examples include nanometal oxides, carbon nanotubes, and carbon buckyballs
	Personal Care Products	Chemicals in soaps, cosmetics, sunscreens, fragrances, lotions, preservatives, microbeads, and microplastics

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Contaminants of Emerging Concern (CEC)

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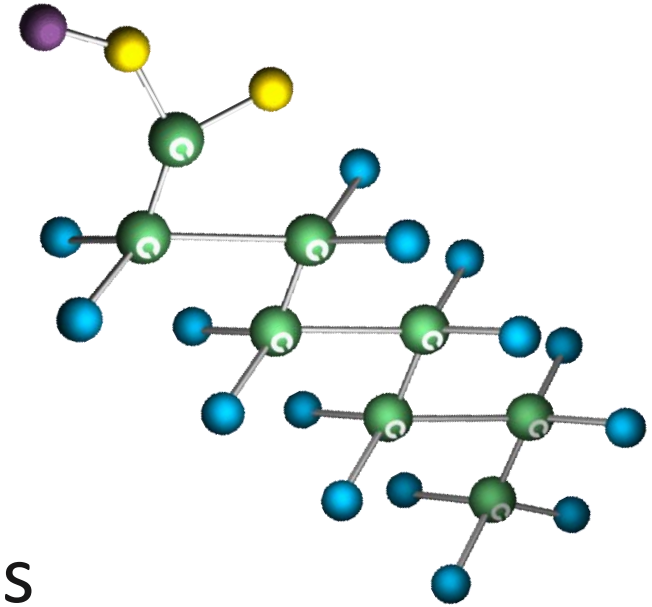
Per- and Polyfluoroalkyl Substances (PFAS)

- Used in everyday products
- Persistent in the environment
- Ubiquitous in landfill leachates
- A large range of chemicals (<4,700)
- Bioaccumulates in the human body
- Biomagnifies through the food chain
- Some PFAS are readily absorbed by plants
- Exposure may result in adverse health effects



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PFAS Timeline

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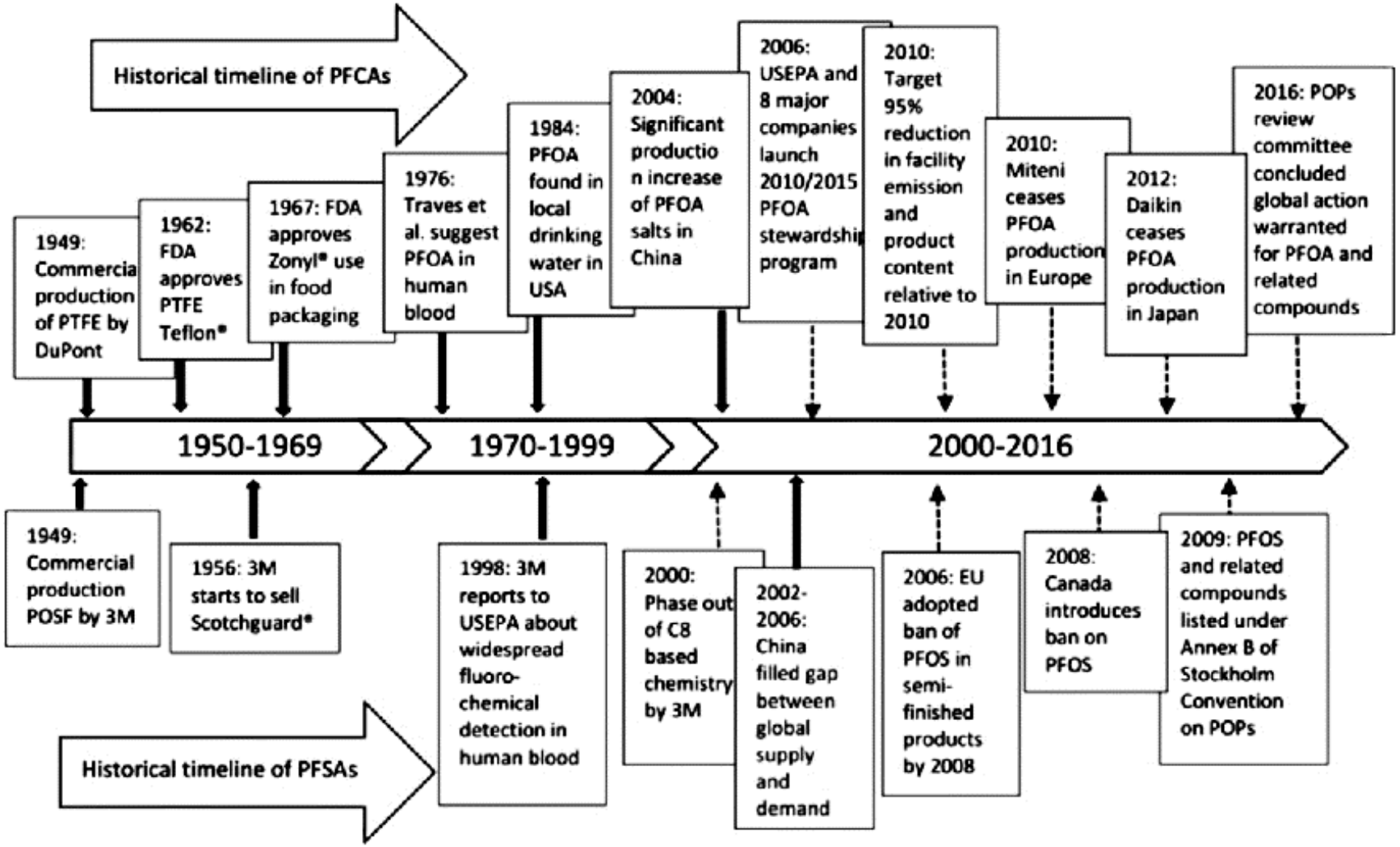

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Major Sources of PFAS in Waste

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Waste stream	Industry Application	Selected examples	Waste stream quantity destined for Australian landfill (approx.)[1]
Municipal solid waste	Cosmetics & personal care products	Cosmetics, shampoos	13.8 MT
	Food processing	PTFE liners (trays, ovens), food packaging	
	Household products	Non-stick coatings, surface treatments for textiles, upholstery, carpet and leather, floor polishes, cleaning agents, car waxes	
	Biocides (herbicides & pesticides)	EtFOSA in ant/termite baits, PFPAs and PFPiAs as anti-foaming agents	
Construction & demolition	Building & construction	Waste concrete and brick (contamination from AFFFs) Sealants, PTFE, PVDF coatings, adhesives, surface treatments	20.4 MT
Contaminated wastes & wastewaters	Metal plating	Wetting agent, mist suppressant, surfactants	1.8 MT
	Mining	Surfactants in ore mining	
	Firefighting & safety	AFFFs	

Source: Gates WP, MacLeod AJ, Fehervari A, Bouazza A, Gibbs D, Hackney R, Callahan DL, Watts M. Interactions of Per- and Polyfluoralkyl Substances (PFAS) with Landfill Liners. Adv Environ Eng Res 2020;1(4):40; doi:10.21926/aeer.2004007.

Major Sources of PFAS in Waste

Geofabrics Centre for GEOSYNTHETIC RESEARCH, INNOVATION & DEVELOPMENT

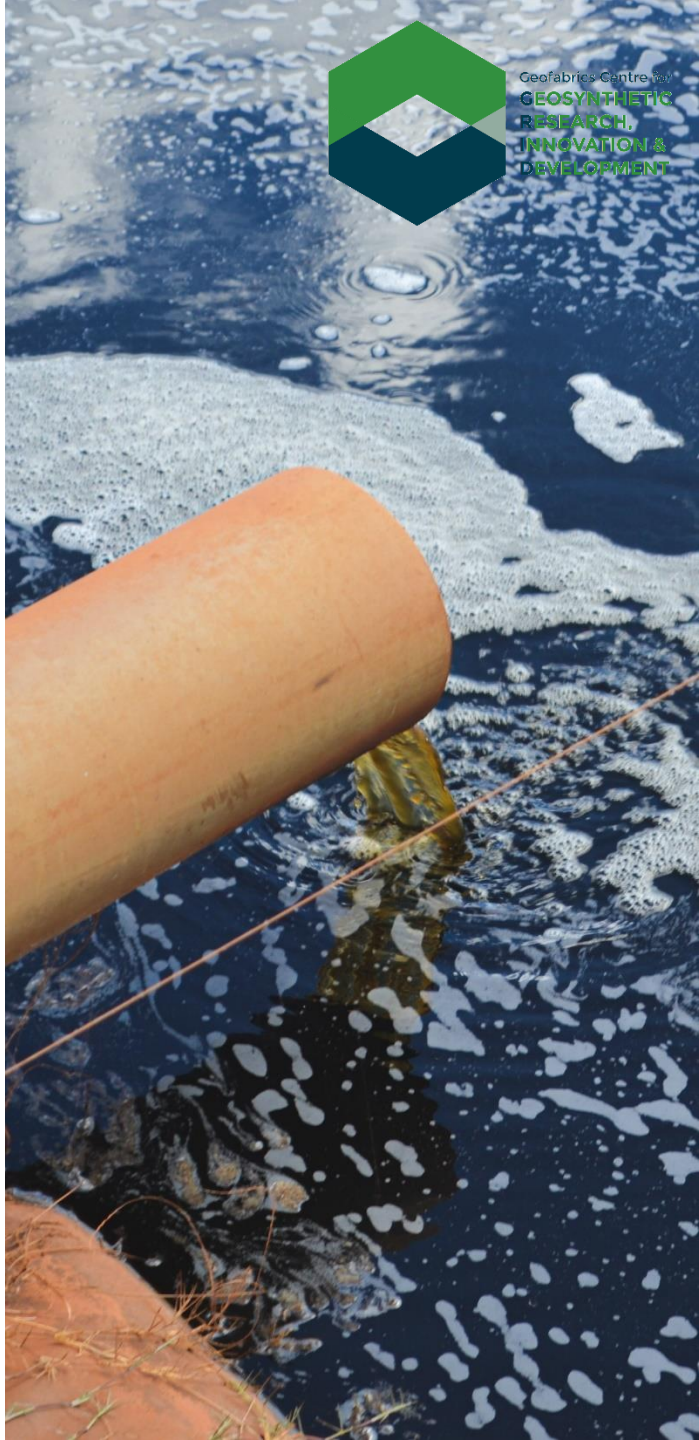
Waste stream	Industry Application	Selected examples	Waste stream quantity destined for Australian landfill (approx.)[1]
Commercial & industrial	Aviation & aerospace	PTFE and PFA tubing, gaskets, cables	20.4 MT
	Automotive	Wiring and cabling, seals, gaskets, lubricants	
	Electronics	PVDF and PTFE as insulators	
	Energy	FEP, PVDF films covering photovoltaic panels	
	Medical products	Biocompatible implants and surgical patches	
	Paper & packaging	Oil, grease and water repellent (including food packaging), LDPE bags	
	Textiles (upholstery, carpets), leather & apparel	PTFE in consumer products (outdoor equipment and clothing, housewares), oil- and water-repellent coatings, PFOA-based chromium treatment for paper and leather.	
	Photo-lithography & semi-conductors	PFOS used in chip manufacture	
	Cable & wiring	PTFE, PVDF coatings and jackets	
	PFAS production	Processing aids	

Source: Gates WP, MacLeod AJ, Fehervari A, Bouazza A, Gibbs D, Hackney R, Callahan DL, Watts M. Interactions of Per- and Polyfluoralkyl Substances (PFAS) with Landfill Liners. Adv Environ Eng Res 2020;1(4):40; doi:10.21926/aeer.2004007.

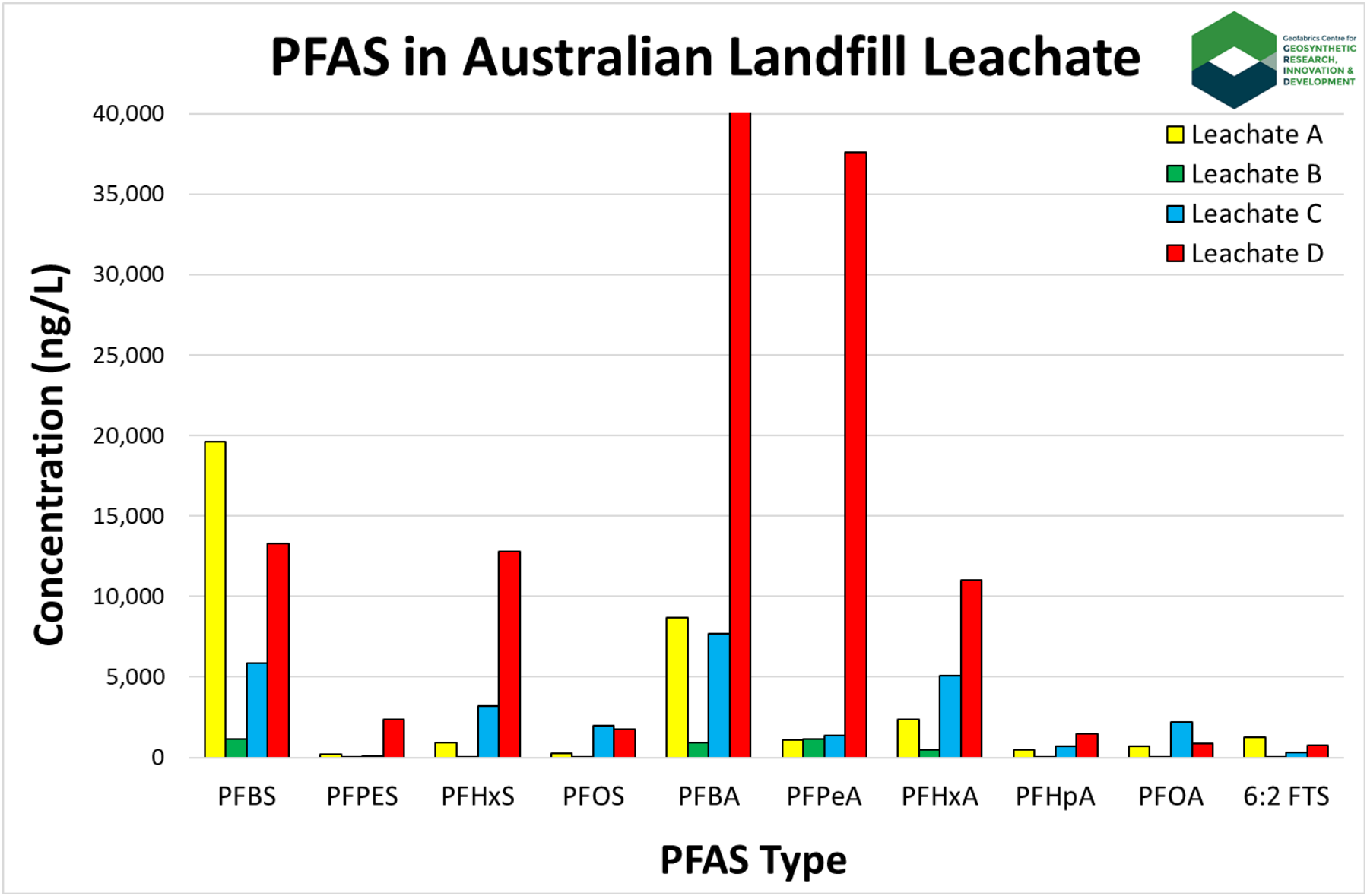
PFAS in Landfill Leachate

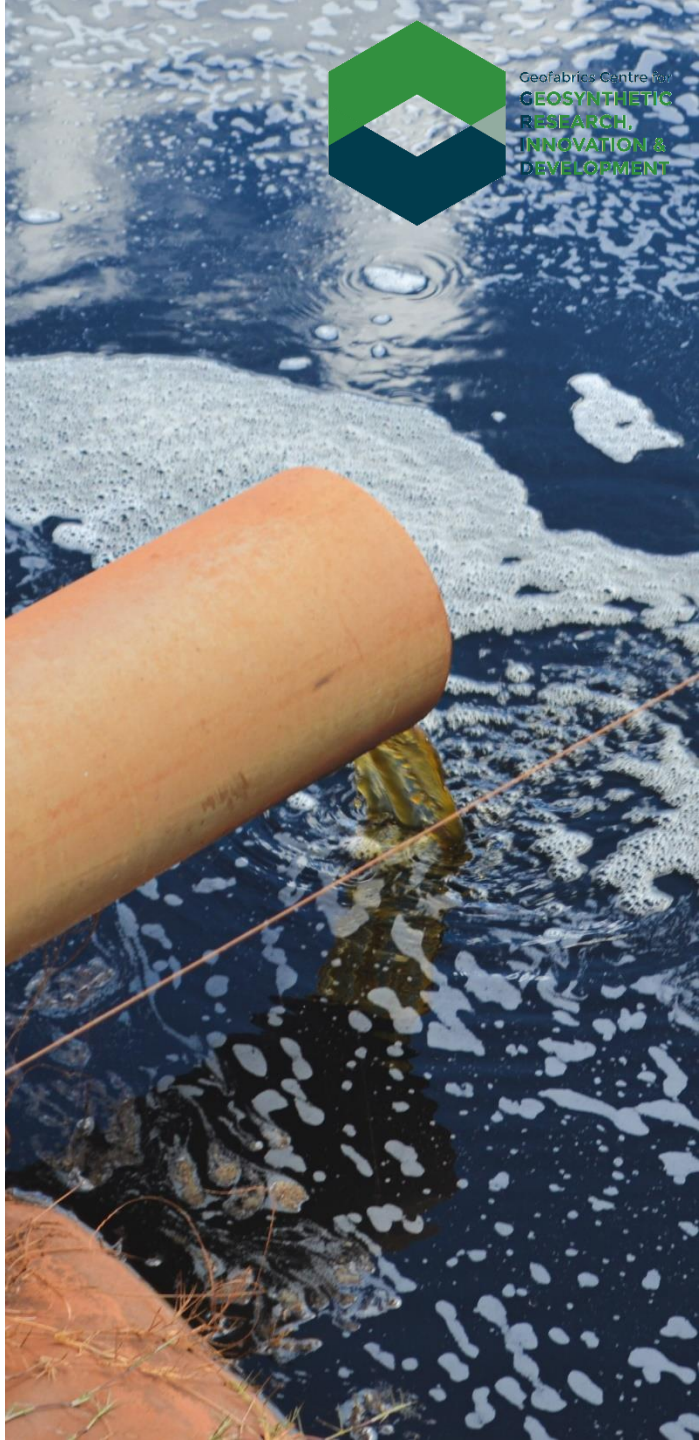
PFAS compound detected	Mean Concentration (ng/L)		
	Operating landfills (> 50% MSW) n = 12	Operating landfills (> 50% C&D) n = 7	Closed landfills (> 50% MSW) n = 7
PFHxA	1300 (1700)	5000 (8100)	660 (300)
PFHxS	940 (1000)	3700 (5100)	740 (490)
PFOA	510 (410)	1400 (1200)	390 (170)
PFHpA	360 (360)	760 (760)	220 (110)
PFOS	300 (330)	1100 (910)	180 (250)
PFNA	29 (24)	98 (110)	13 (6.8)
PFDA	22 (36)	46 (83)	11 (14)
PFUdA	3.0 (4.7)	4.6 (3.4)	2.2 (1.9)
PFDoDa	1.8 (3.5)	1.1 (1.6)	2.7 (3.3)

Source: Gates WP, MacLeod AJ, Fehervari A, Bouazza A, Gibbs D, Hackney R, Callahan DL, Watts M. Interactions of Per- and Polyfluoralkyl Substances (PFAS) with Landfill Liners. Adv Environ Eng Res 2020;1(4):40; doi:10.21926/aeer.2004007.

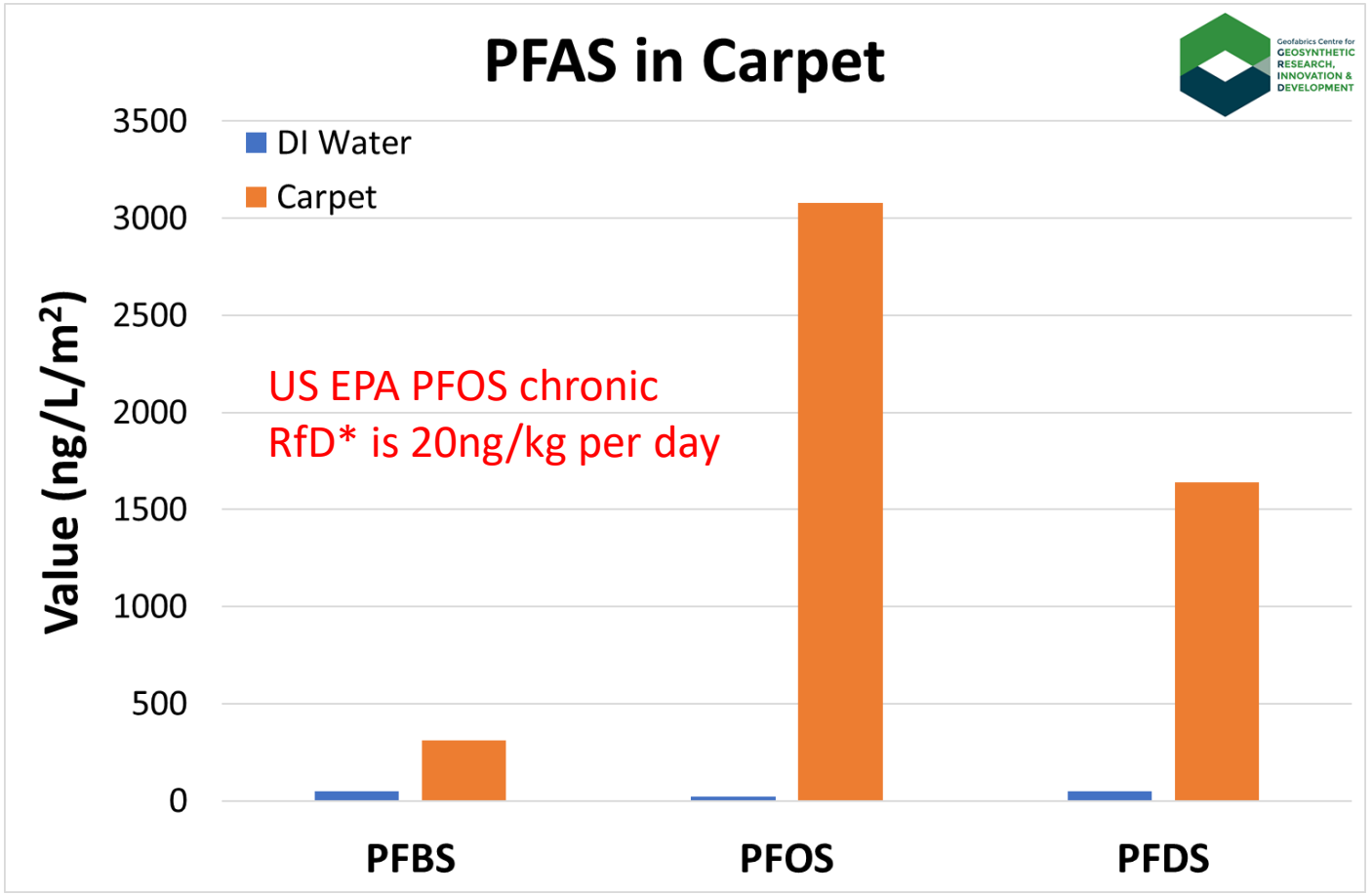


PFAS in Landfill Leachate





PFAS in Carpet



** A chronic reference dose (RfD) is an estimate of the amount of a chemical a person can ingest daily over a lifetime that is unlikely to lead to adverse health effects.*

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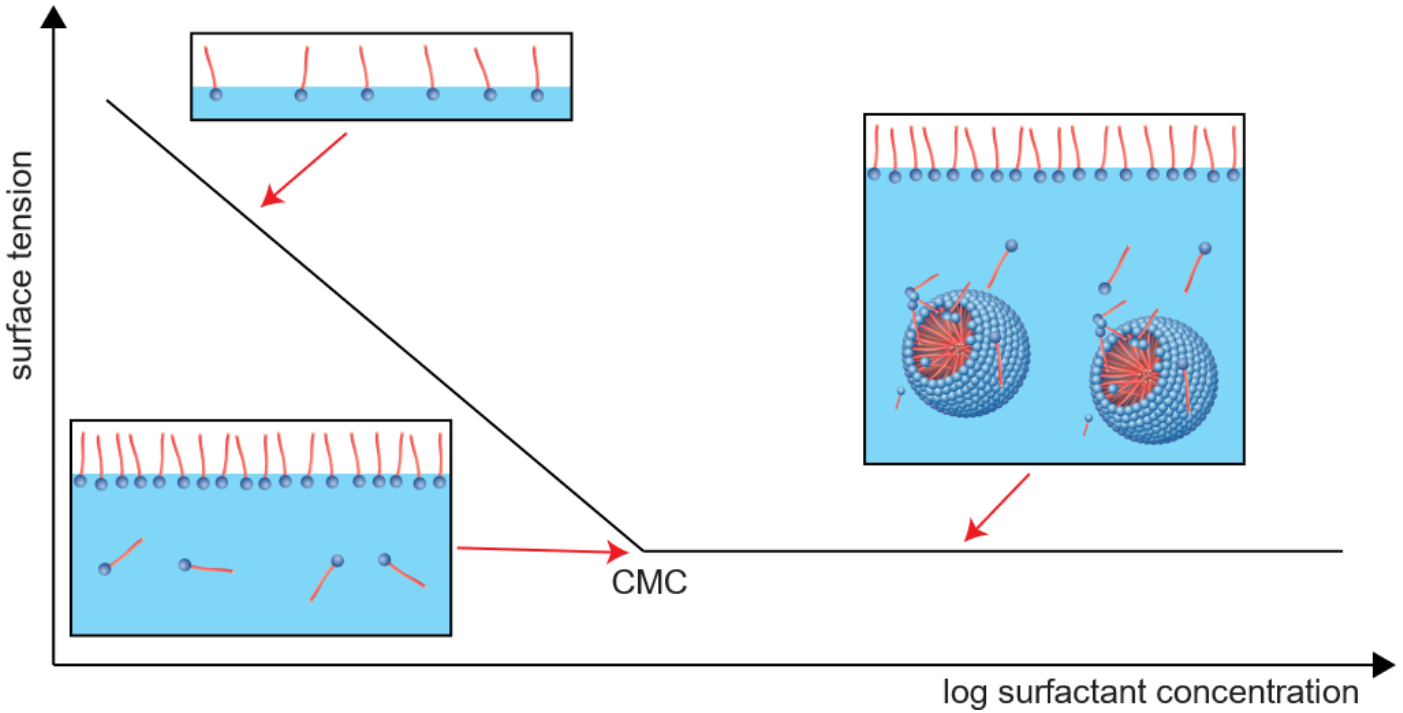
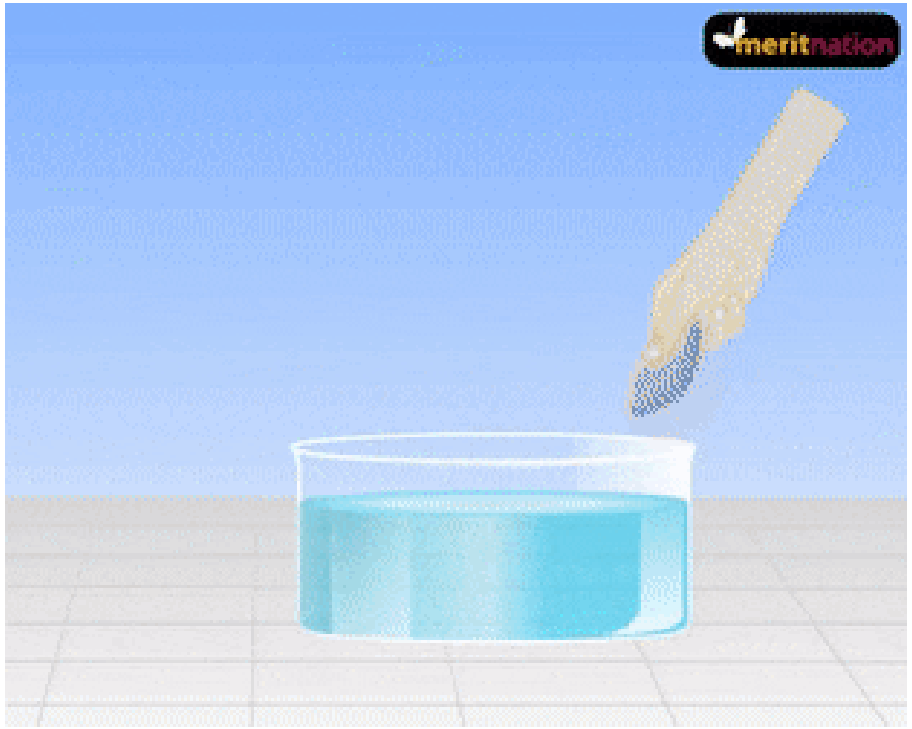
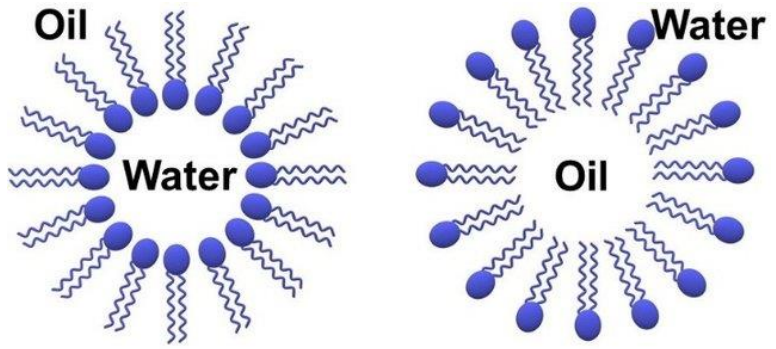
Concentration drives liner performance





When the PFAS reaches its Critical Micelle Concentration (CMC) it forms micelles with either the polar head group facing out in polar liquids such as water, or inverted micelles in non-polar liquids such as oil.



Source: https://www.dataphysics-instruments.com/us/knowledge/understanding-interfaces/surfactants-cmc/

PFAS migration through Geomembranes

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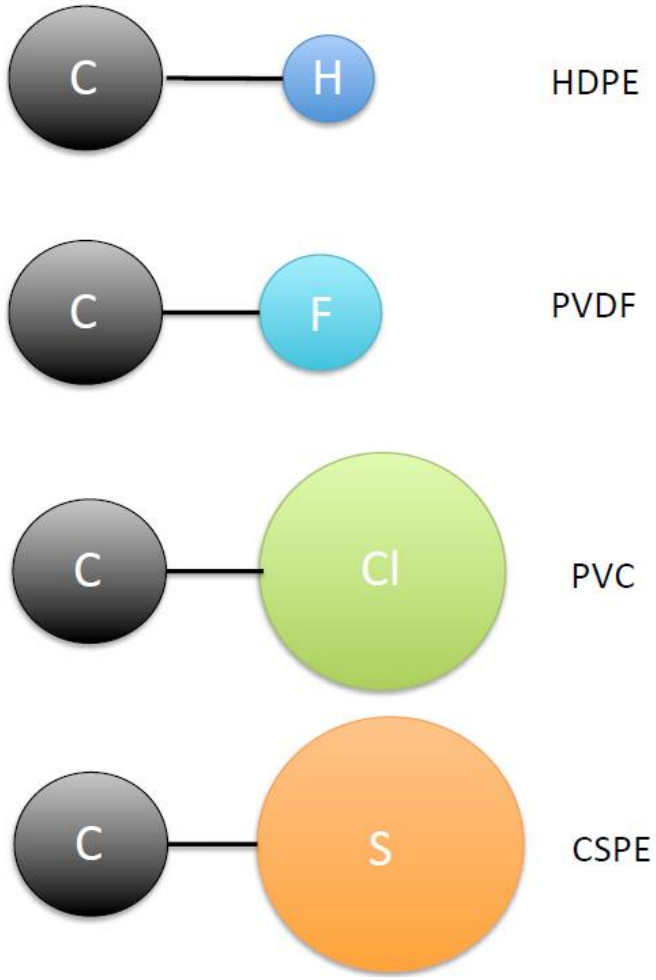
- Thickness of the liner (thicker is better to reduce migration)
- Atomic radius of atoms in liner backbone (larger AR is better to reduce migration)
- Polarity of the polymer liner (high polarity is better to reduce migration)
- Size of PFAS molecules (shorter migrate faster)
- Temperature (diffusion increases with temp.)



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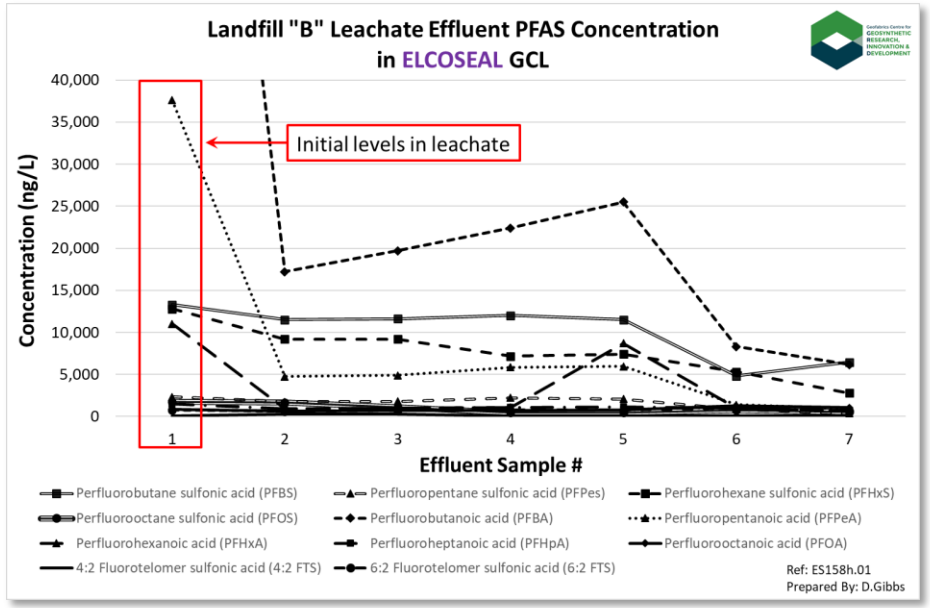
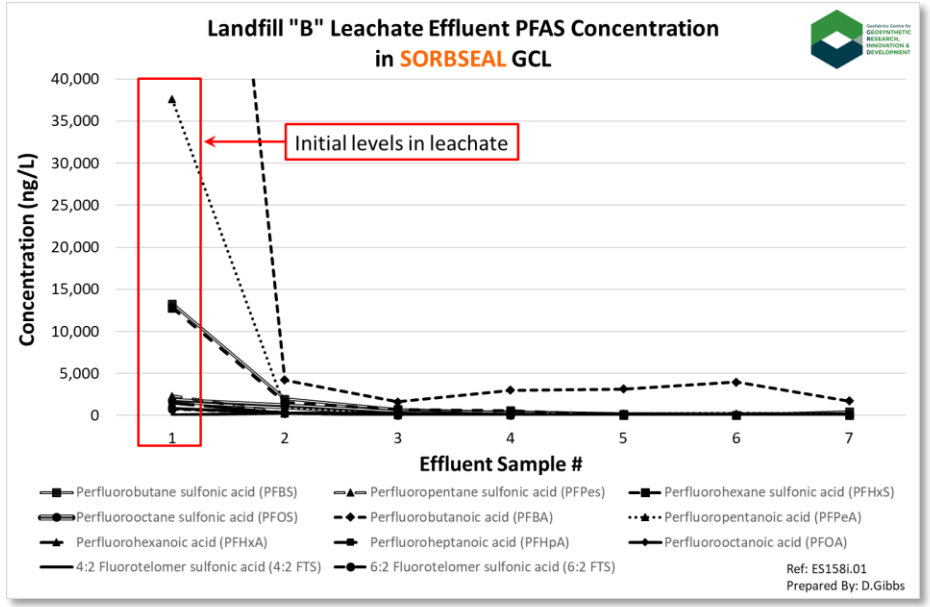
Source: John Scheirs EXCELPLAS - Geomembrane Barrier Properties for Containment of PFAS Emerging Contaminants

PFAS migration through GCLs





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PFAS migration through GCLs

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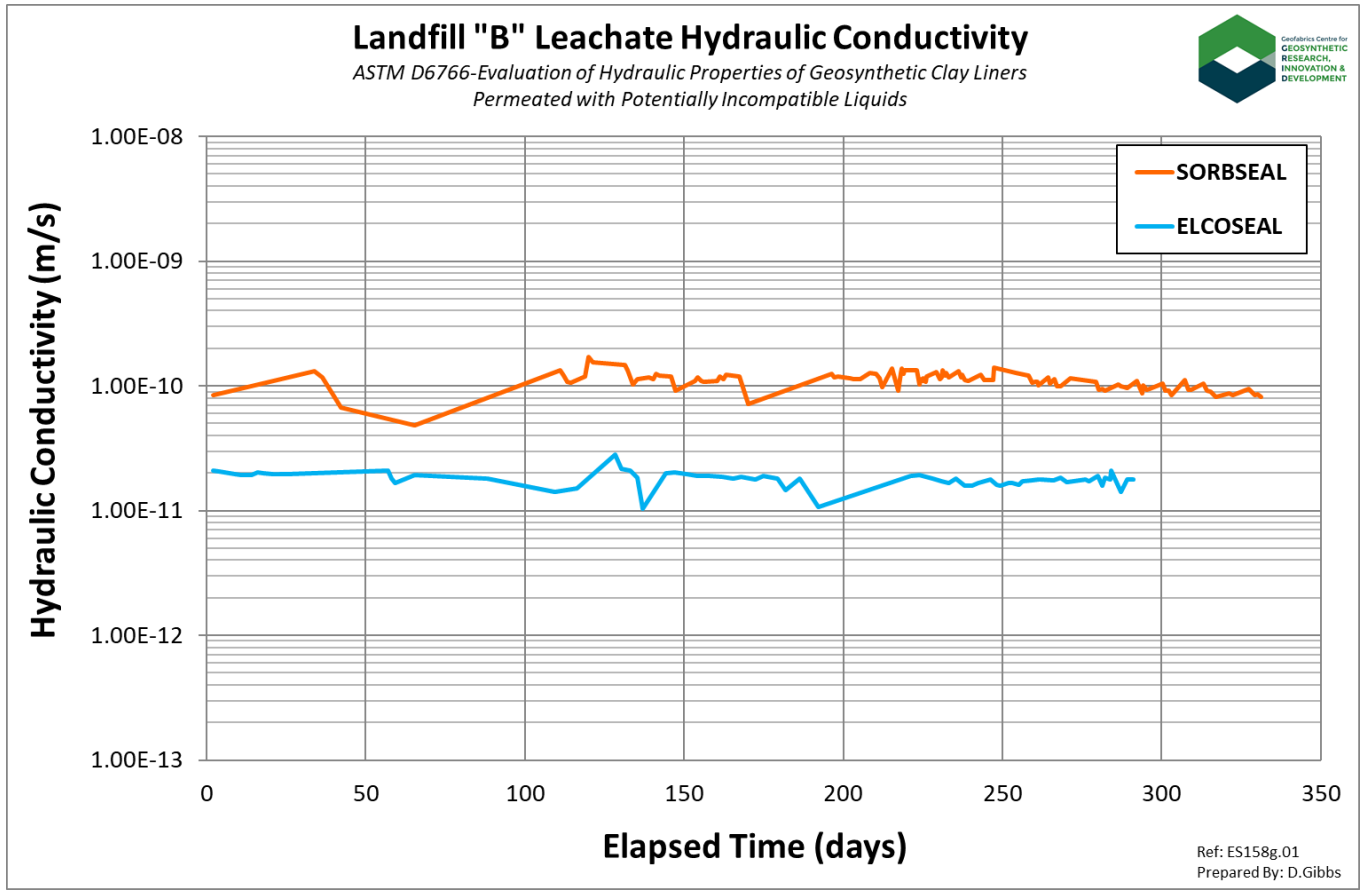

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Removal Efficiency of Activated Carbon

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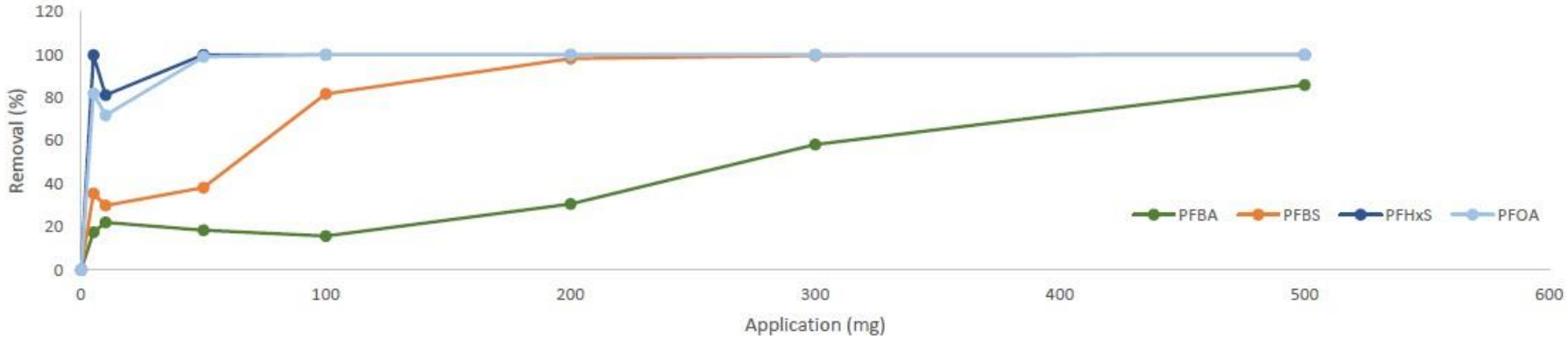
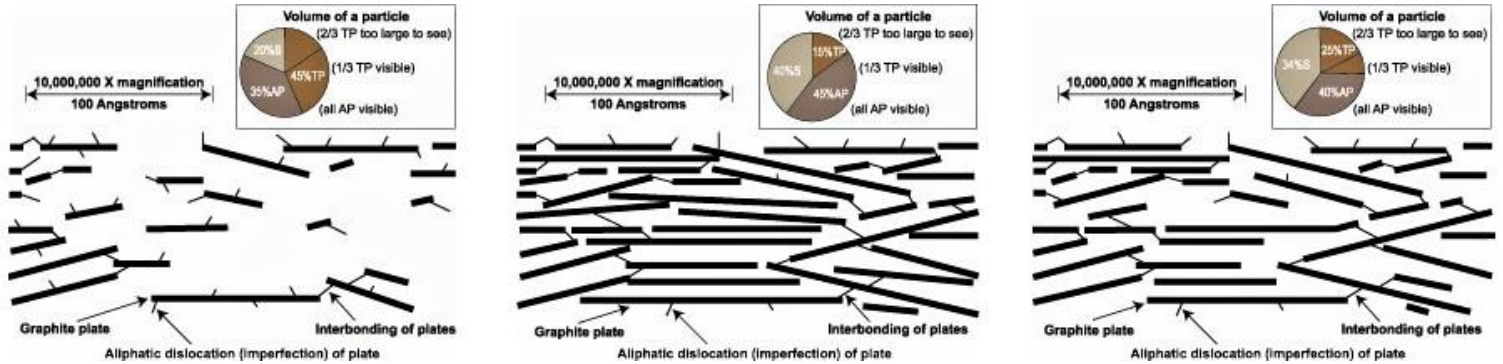


Figure 7 - Percent removal of target PFAS congeners from solution for PS-1300 ver sorbent application rate 0 – 500 mg



Source: Henry Nowicki, Wayne Schuliger, George Nowicki and Barbara Sherman. 2014. "*Evaluation of Activated Carbon Performance*". http://wcponline.com/2014/06/17/evaluation-activated-carbon-performance/

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International Regulation and Initiatives

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REACH COMPLIANCE

OECD BETTER POLICIES FOR BETTER LIVES

ATSDR AGENCY FOR TOXIC SUBSTANCES AND DISEASE REGISTRY

GHS The Global Harmonization System of Classification and Labeling

INTERSTATE COUNCIL ITRC TECHNOLOGY REGULATORY

nhanes National Health and Nutrition Examination Survey

MINAMATA CONVENTION ON MERCURY

saicm

ECHA EUROPEAN CHEMICALS AGENCY

SERDP DOD • EPA • DOE

ESTCP

BASEL CONVENTION

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

World Health Organization

UNEP

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US Regulation

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- USEPA Safe Drinking Water Act (SDWA).
- Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) — "Superfund"
- Toxic Substances Control Act (TSCA). (https://www.epa.gov/assessing-and-managing-chemicalsunder-tsca/risk-management-and-polyfluoroalkyl-substances-pfas).
- Toxics Release Inventory (TRI) Program. (https://www.epa.gov/toxics-release-inventory-tri-program/implementing-statutory-additioncertain-and-polyfluoroalkyl).
- Resource Conservation and Recovery Act (RCRA).

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US PFAS Regulations

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- EPA's drinking water Lifetime Health Advisory (LHA) limit (70ppt for PFOS and/or PFOA) are not enforceable standards

- Not yet identified as hazardous substances under CERCLA (1980)

- Investigations/risk managements actions driven by other forces
  - ❖Action due to pressure from the public or regulatory agencies
  - ❖Litigation
  - ❖Clean Water Act (TMDL)
  - ❖State-driven regulatory action

Source: https://pfas-1.itrcweb.org/

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Australian PFAS Regulation

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FOOD STANDARDS Australia New Zealand
Te Mana Kounga Kai – Ahitereiria me Aotearoa

EPA VICTORIA

Australian Government
National Health and Medical Research Council

Australian Government

PFAS Per- And Polyfluoroalkyl Substances

Australian Government
Department of Defence

NEPC
National Environment Protection Council

Australian Government
Department of Health
National Industrial Chemicals Notification and Assessment Scheme

nicnas.gov.au

AELERT
AUSTRALASIAN ENVIRONMENTAL LAW ENFORCEMENT AND REGULATORS NETWORK

HEPA
National Chemicals Working Group

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Australian PFAS Regulation

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Table 7. Landfill acceptance criteria

Landfill type		Interim landfill acceptance criteria[60, 61]		Comments
		Sum of PFOS + PFHxS	PFOA	
Unlined	ASLP leachable concentration (µg/L)	0.07 µg/L	0.56 µg/L	Drinking water x 1 (Department of Health 2017)
	Total concentration (mg/kg)	20 mg/kg	50 mg/kg	Soil - Human health industrial/commercial x 1 Total concentration for PFOA of 50 mg/kg based on the low content limit
Clay/single composite lined	ASLP leachable concentration (µg/L)	0.7 µg/L	5.6 µg/L	Drinking water x 10 (Department of Health 2017)
	Total concentration (mg/kg)	50 mg/kg	50 mg/kg	Soil - Human health industrial/commercial x 10 Total concentration for PFOS + PFHxS and PFOA of 50 mg/kg based on the low content limit
Double composite lined	ASLP leachable concentration (µg/L)	7 µg/L	56 µg/L	Drinking water x 100 (Department of Health 2017)
	Total concentration (mg/kg)	50 mg/kg	50 mg/kg	Soil - Human health industrial/commercial x100

HEPA

PFAS National Environmental Management Plan

Version 2.0 – January 2020

National Chemicals Working Group of the Heads of EPAs Australia and New Zealand

Table 1. Human health guideline values developed by health regulators

Sum of PFOS and PFHxS	PFOA	Description	Comments and source
0.02 µg/kg $_{bw}$ /day	0.16 µg/kg $_{bw}$ /day	Tolerable daily intake (TDI)	FSANZ 2017
0.07 µg/L	0.56 µg/L	Drinking water quality guideline value	Australian Government Department of Health 2019
2 µg/L	10 µg/L	Recreational water quality guideline value*	NHMRC 2019

Notes: bw = body weight, µg = micrograms.

Where the guideline values refer to the sum of PFOS and PFHxS, this includes PFOS only, PFHxS only, and the sum of the two.

*NHMRC (2019) notes that people's use of recreational water is not the same, given Australia's climate and geography. Some recreational water resources may be used less frequently than the assumed guidelines (150 days/year), and (in rare cases) some may be used more frequently. In such cases more locally-appropriate event frequency based recreational guidelines can be considered in consultation with the state and regulatory health regulator.

Further Reading

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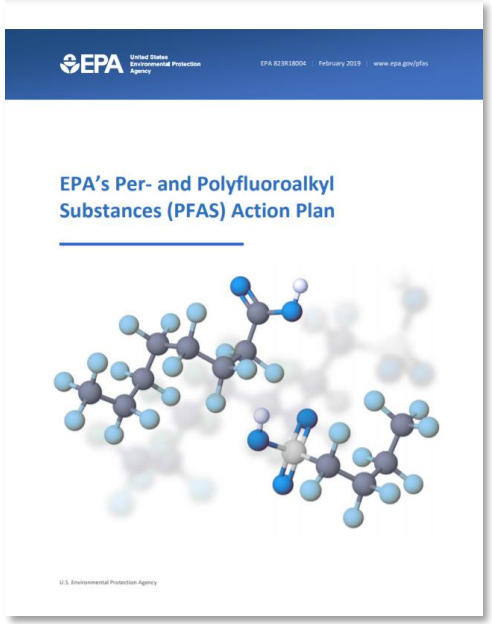

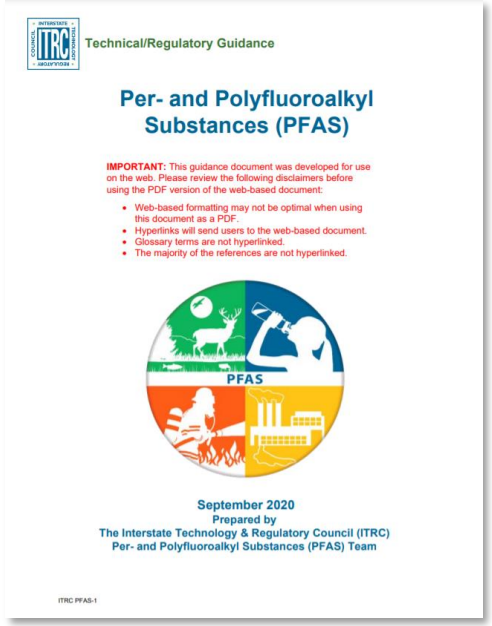

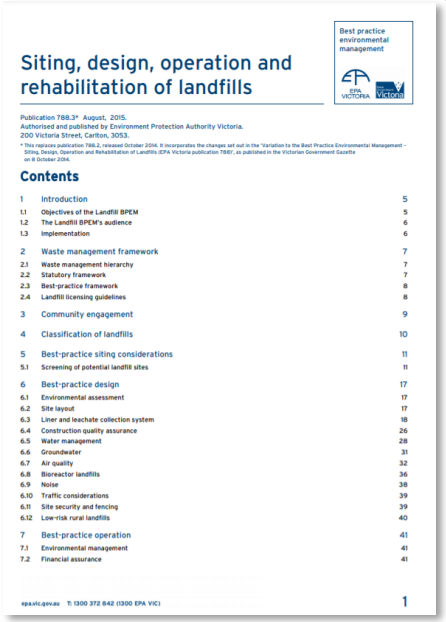

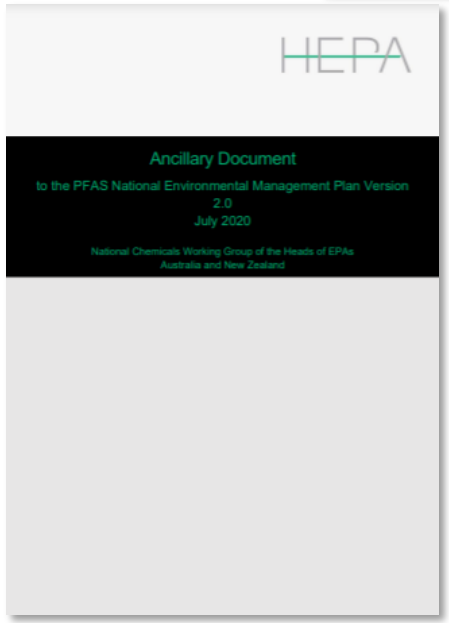

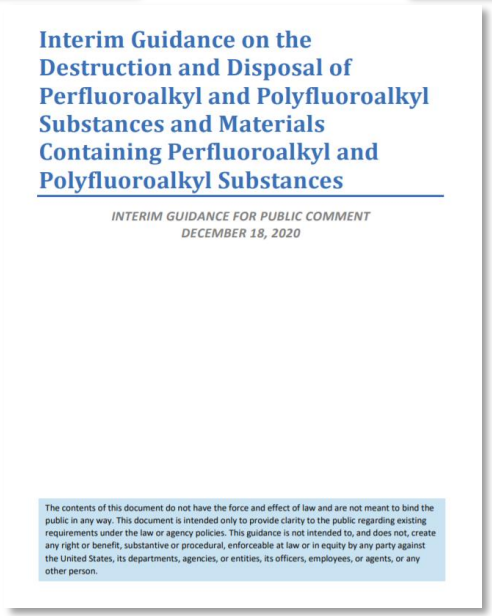

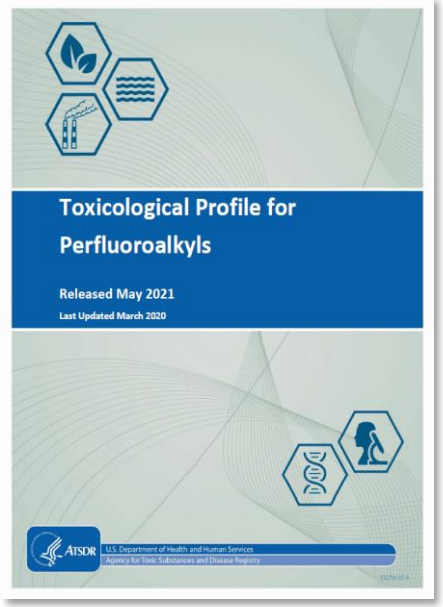

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Final thoughts

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- Our understanding of CEC's in landfill will continue to grow and with it, a likelihood of increasing regulation around containment.

- Given the large variety of PFAS chemicals, we may see guidance move towards a single maximum total value assigned to a nominated group of PFAS.

- If this occurs, and as we learn more about the performance of different geosynthetic lining materials, lining design may change depending on site-specific contaminant concentrations, and may include one or more higher performing materials than those used currently and/or more double composite liners.

- Monash University's "Fate and migration of PFAS through containment liner systems" currently underway to understand fate and transport and to assist designers and regulators with the next generation of lining system design.

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Thank you

for your attention

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