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**Per- and Poly-fluoroalkyl substances  
(PFASs), Geosynthetics & Environmental  
Protection:**


**A New Era of Concerns or Opportunities**

**A. (Malek) Bouazza**

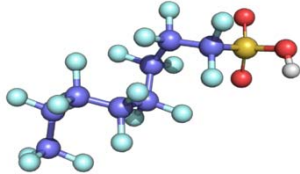
 **GROUP  
OF EIGHT  
AUSTRALIA**

Keynote Lecture:  
ALTS Conf., Sydney, 8-10 June 2021.

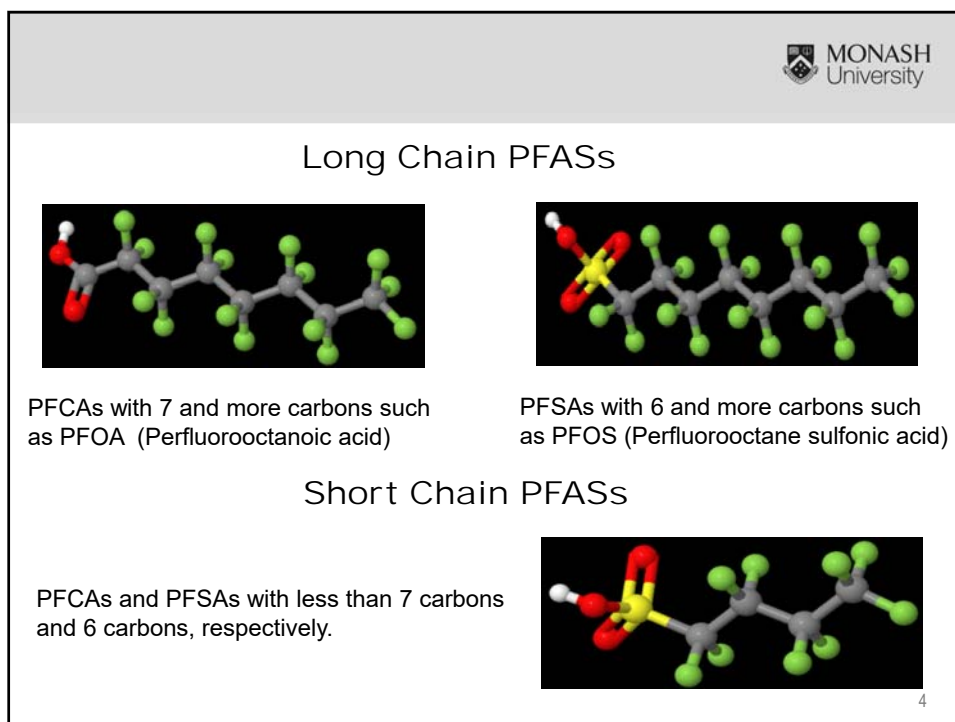
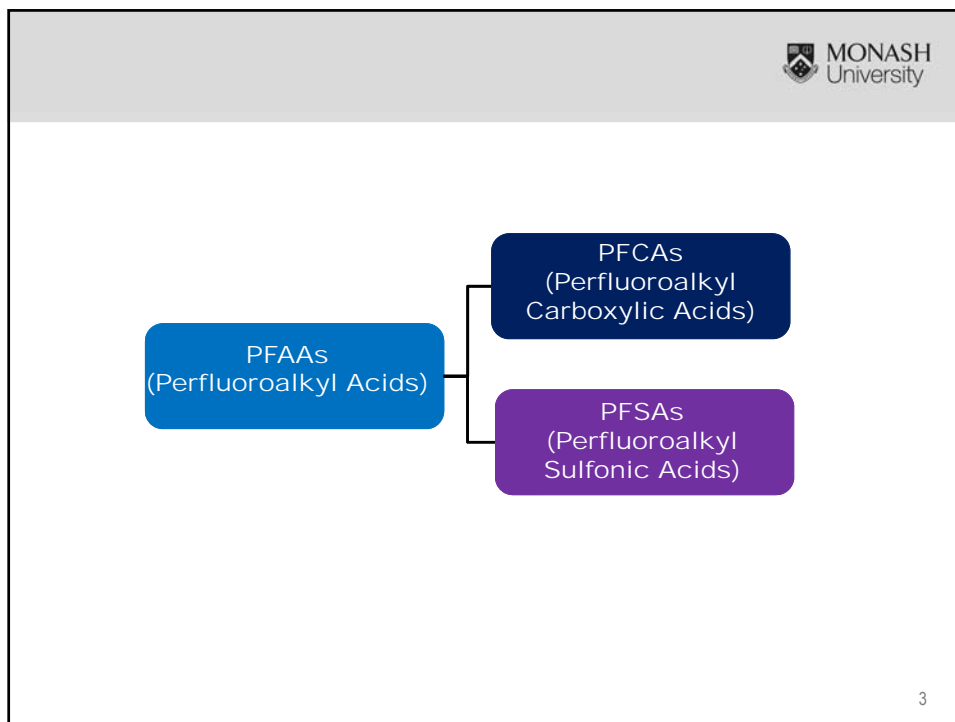


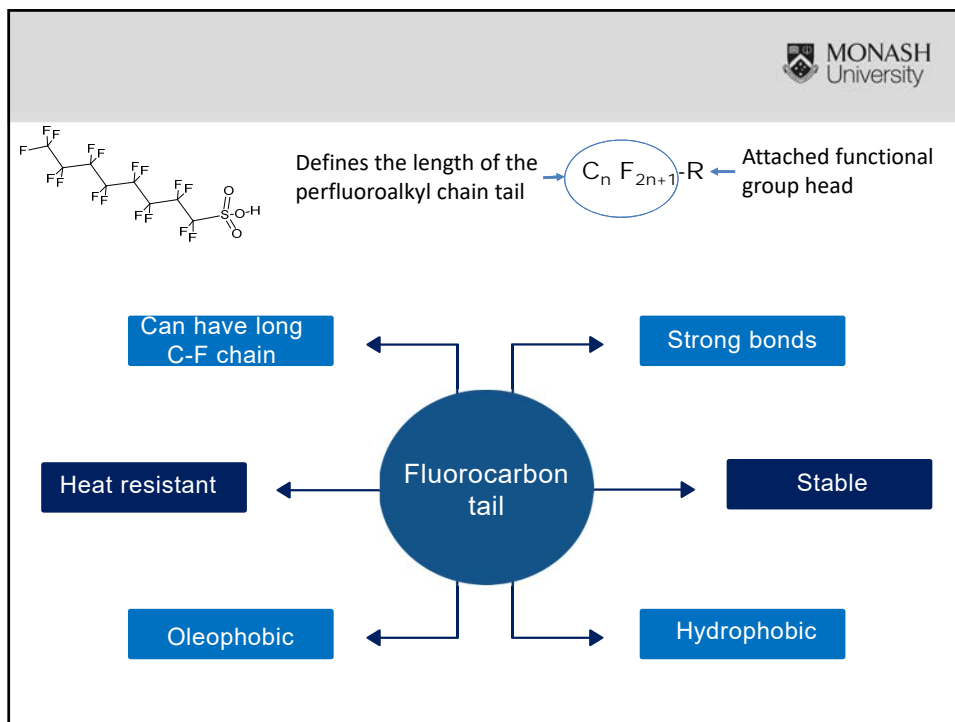
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**Why should we be  
Concerned?**



- ✓ PERVASIVE
- ✓ PERSISTENT
- ✓ BIOACCUMULATIVE
- ✓ ADVERSE HEALTH EFFECTS
- ✓ SCARCITY OF INFORMATION  
IN LITERATURE
- ✓ INCOMPLETE REGULATORY  
STRUCTURE






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### PFASs concentrations in landfill leachates (from Bouazza, 2021)

PFAS	Australia	Victoria	Germany	China	Canada	USA
	Concentrations (ng/L)					
*PFHxA	73-25000	110-7740	2509	146-4430	670-2500	3560-8300
*PFHpA	18-4400	40-1700	280	75-5830	240-690	1060-6500
**PFBS	NA	40-23000	1356	1600-41600	44-190	2200-3150
^PFOA	17-7500	90-3120	926	281-214000	300-1500	2200-4800
^^PFOS	13-2700	20-1200	235	1150-6020	220-4400	390-557
^^PFHxS	56-16000	30-2410	178	ND-479	85-540	2250-4100

\*short-chain PFCA; \*\*short-chain PFSA; ^ long-chain PFCA; ^^long-chain PFSA


Bouazza, A. (2021). Interaction between PFASs and geosynthetic liners: current status and the way forward. *Geosynthetics International*, 28(2), 214-223



### PFASs concentrations in historic landfill leachates

Landfill Operations	1920s-1990s Propp et al. (2021)	1982-1993 Huset et al. (2021)	1964-1995 Gallen et al. (2016)	1930s-1990s Hepburn et al. (2019)	2019 Simmons (2019)	2021 Bouazza (2021)
Country/state	Canada	USA	Australia	Australia	Vic	Germany
Landfills No	20	1	6	7		NA
Samples No	48	2	7	8		NA
Concentrations (ng/L)						
*PFHxA	670	360	260	46	110-7740	2509
*PFHpA	270	170	94	22	40-1700	280
**PFBS	710	390	250	16	40-23000	1356
^PFOA	850	490	170	74	90-3120	926
^^PFOS	2800	91	13000	71	20-1200	235
^^PFHxS	1300	200	72	35	30-2410	178

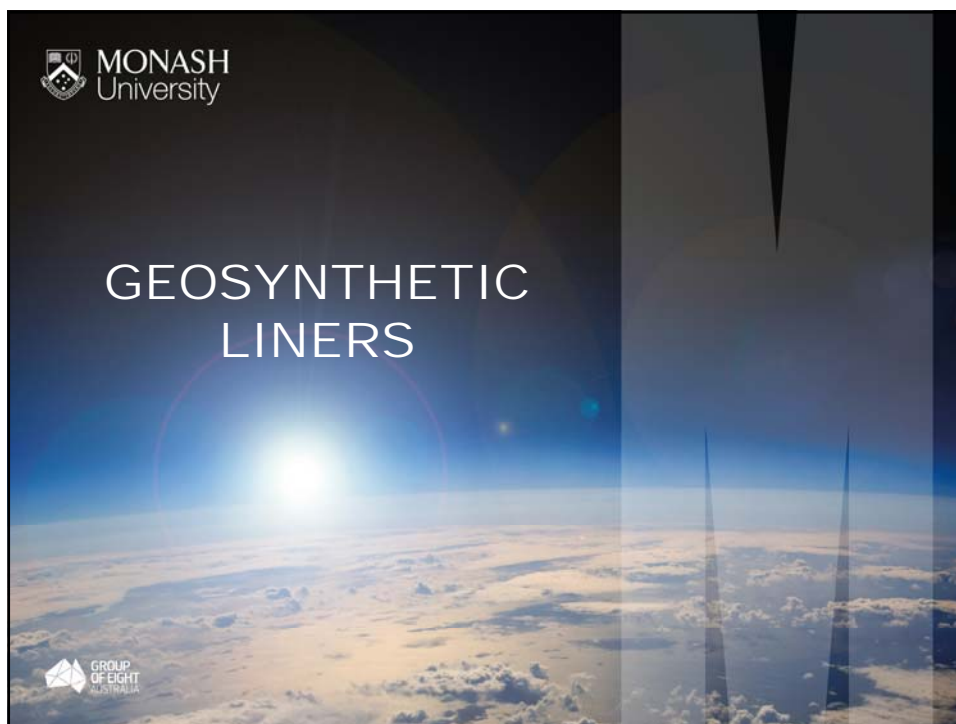
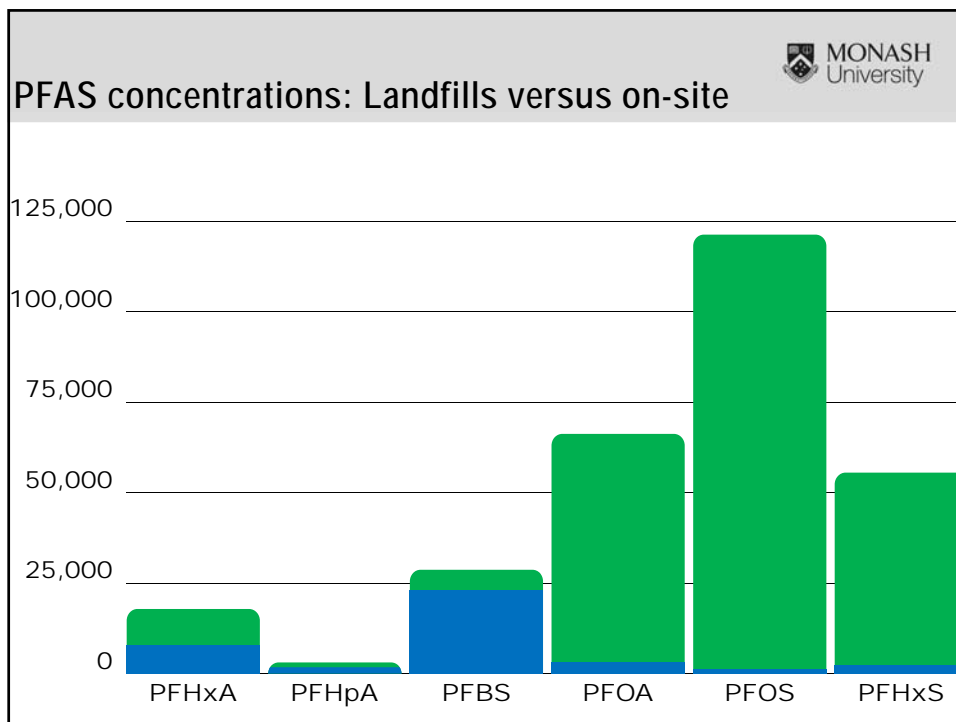
\*short-chain PFCA; \*\*short-chain PFSA; ^ long-chain PFCA; ^^long-chain PFSA 7

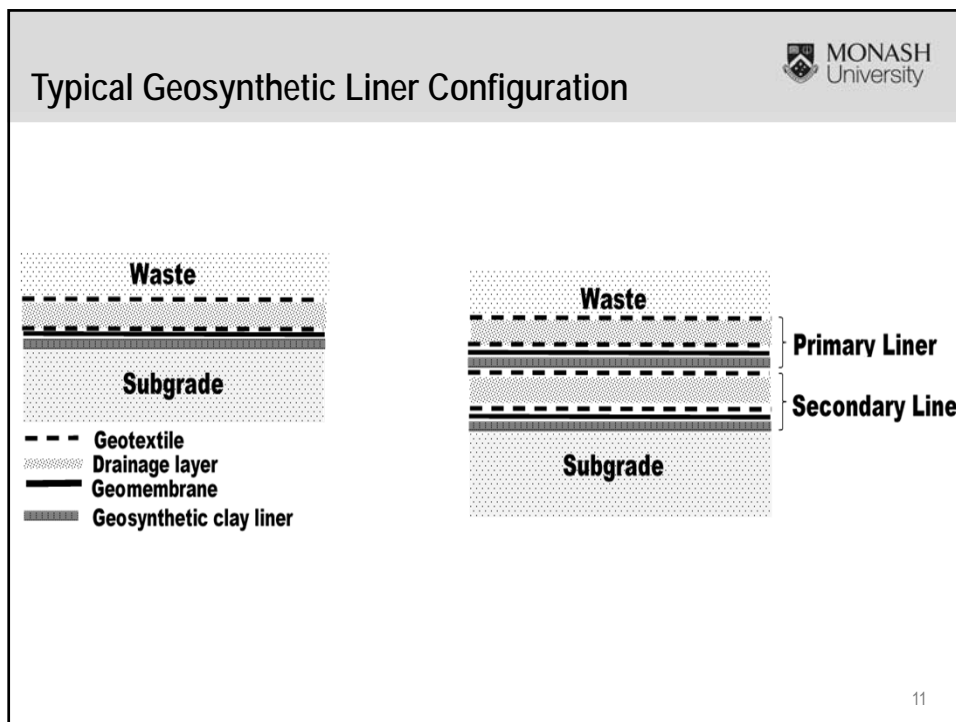


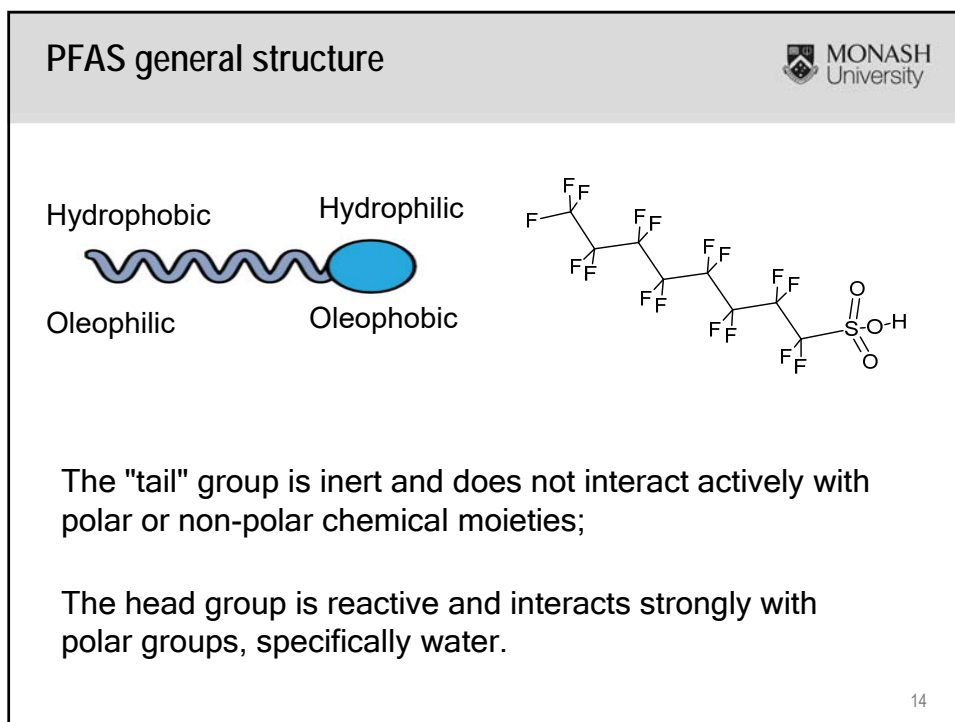
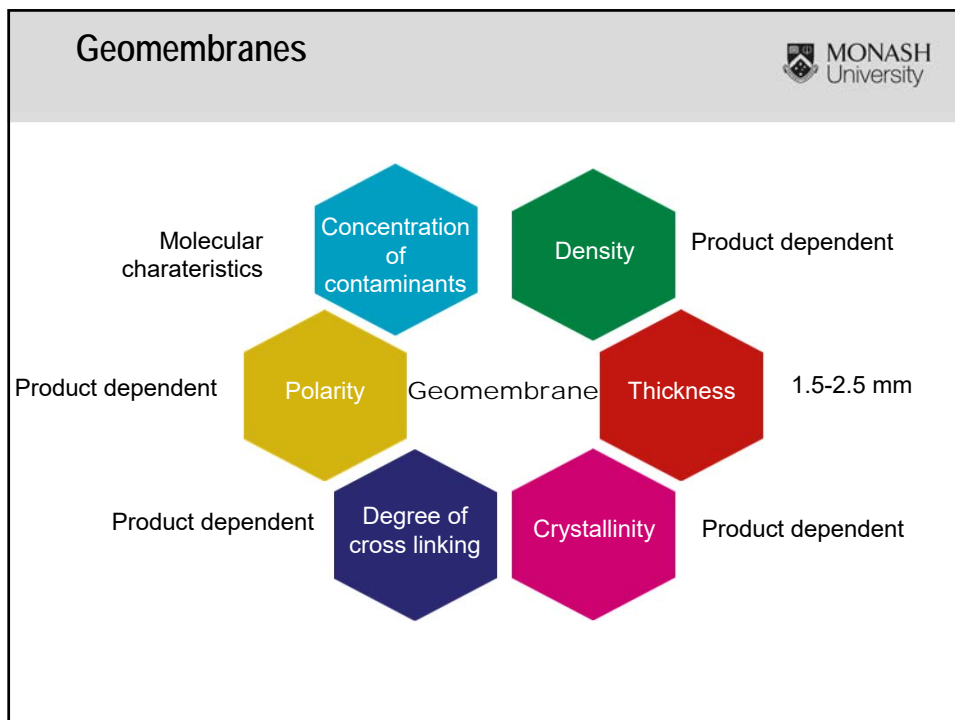
### Occurrence of PFASs in various aqueous environments at airports and fire training facilities (from Bouazza, 2020)

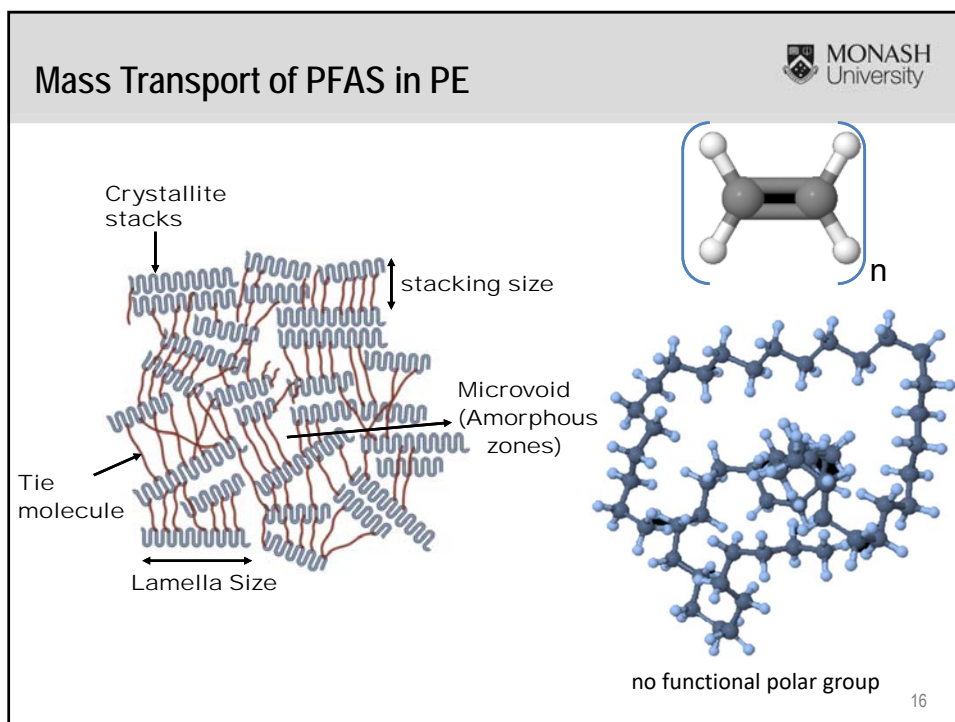
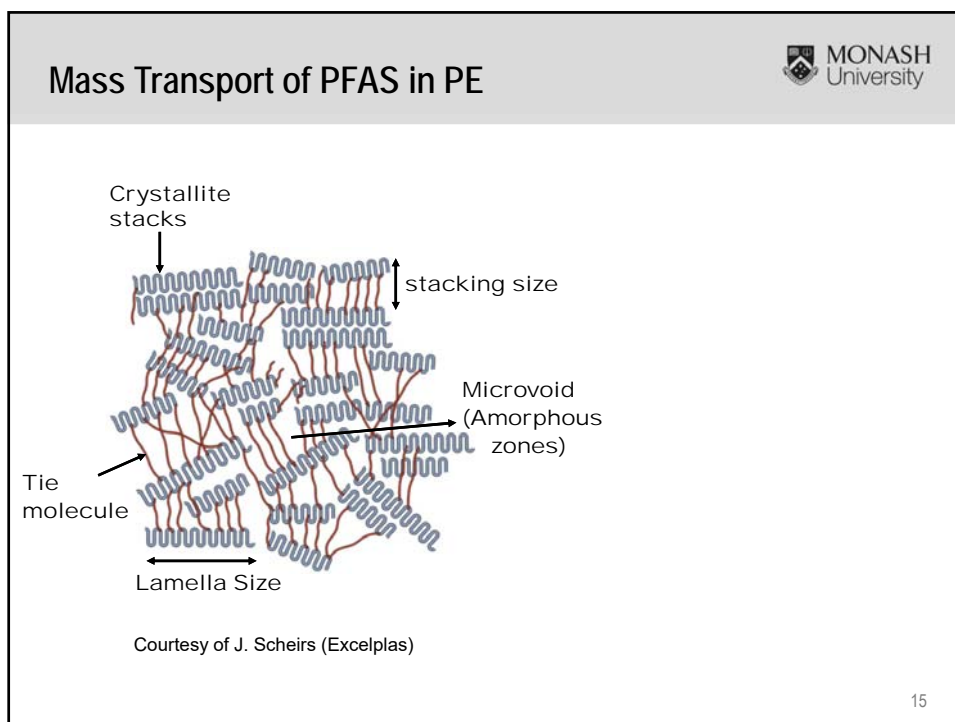
PFAS	Australia				France		USA
	Concentration (ng/L)						
	Site 1 <sup>a</sup>	Site2 <sup>b</sup>	Site3 <sup>c</sup>	Site 4 <sup>a</sup>	Loc 1 <sup>d</sup>	Loc 2 <sup>d</sup>	Site 1 <sup>a</sup>
*PFHxA	NA	2,500-3,400	NA	NA	293,040	689,260	140,500
*PFHpA	NA	200-570	NA	NA	60,192	143,792	185,575
**PFBS	NA	550-2,000	NA	NA	204,440	57,312	56,025
^PFOA	600,000-1,700,000	660-2,660	1,140,000-1,360,000	63,000	62,016	120,592	79,500
^^PFOS	3,600,000-9,700,000	90,000-550,000	5,830-12,500,000	240,000	1,907,840	1,376,980	32,750
^^PFHxS	NA	22,000-62,000	NA	560,000	559,973	211,640	184,000

a= military airport base b= firetraining ground at airport; c= Civilian airport; d=fire training facility; NA=Not available 8












Mass Transport of PFAS in PE 


### Current Evidence from Literature

- Long-Chain PFAS**

HDPE sampling containers showed irreversible adsorption of long-chain PFAS to their surface.
- Short-Chain PFAS**

remained in solution due to their high solubility. Adsorption into HDPE almost non-existent
- U.S TRB**

use of XLPE (high-density cross-linked polyethylene) tanks to store AFFF due to superior stress cracking resistance and chemical performance

Mass Transport of PFAS in PE 

### Current Evidence from Literature

- Long-Chain PFAS** (Battista et al. 2020)

Diffusion through 0.1 mm LLDPE, 483 days at 23°C

PFAS:  $D_g = 2.5 \times 10^{-17} \text{ m}^2/\text{s}$

PFOS:  $D_g = 4.0 \times 10^{-17} \text{ m}^2/\text{s}$

$C_{\text{PFAS}} = 19800000 \text{ ng/l}$

$C_{\text{PFOS}} = 22700000 \text{ ng/l}$

## Geosynthetic Clay Liners

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Fibres

Upper Geotextile (cover)

Bentonite

Lower Geotextile (Carrier)

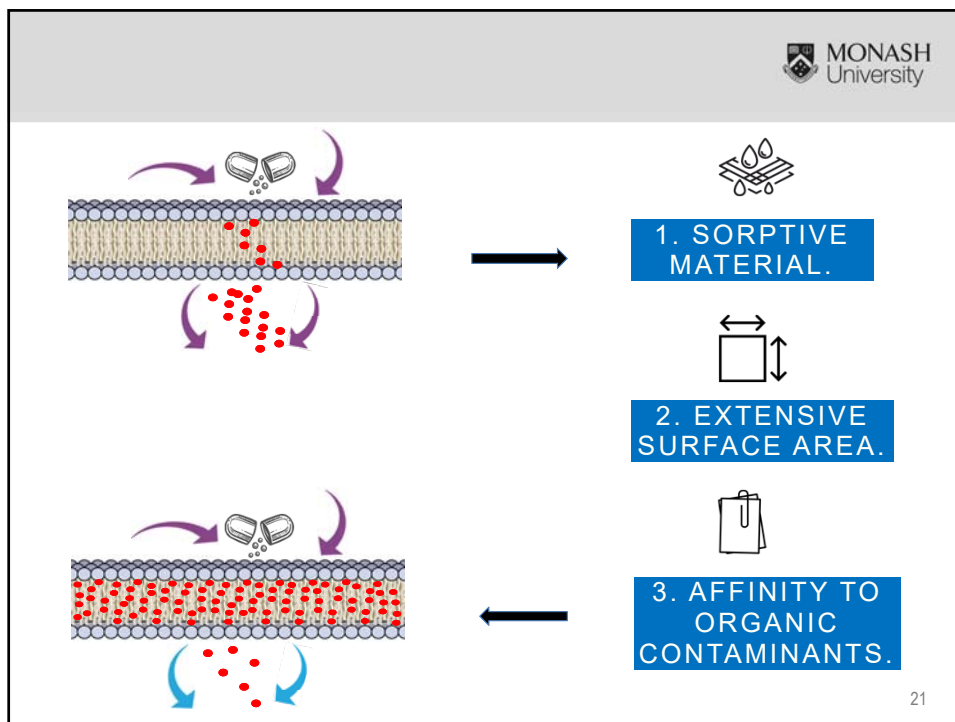
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## GCLs Hydraulic Conductivity

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### Current State of Knowledge

WHAT WE KNOW	WHAT WE DON'T KNOW
<ul style="list-style-type: none"> <li>Extended wealth of information on GCL chemical compatibility</li> <li>Bentonite has low sorption capacity to organic pollutants</li> <li>Organic pollutants can affect bentonite structure</li> </ul>	<ul style="list-style-type: none"> <li>Compatibility with PFAS substances in aqueous solutions.</li> </ul>



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### GCLs Hydraulic Conductivity

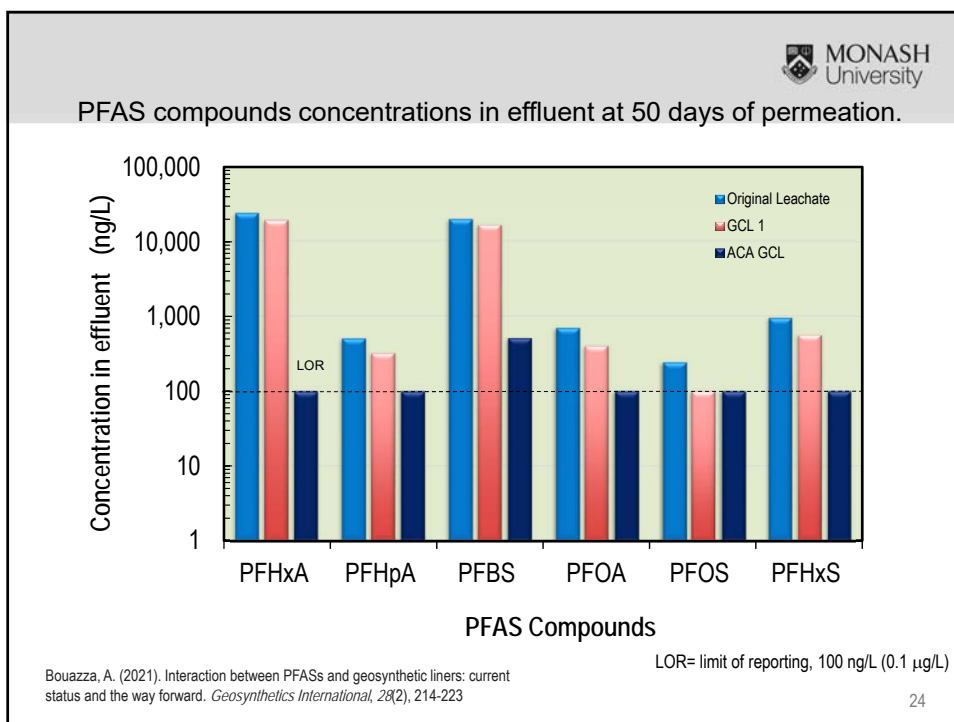
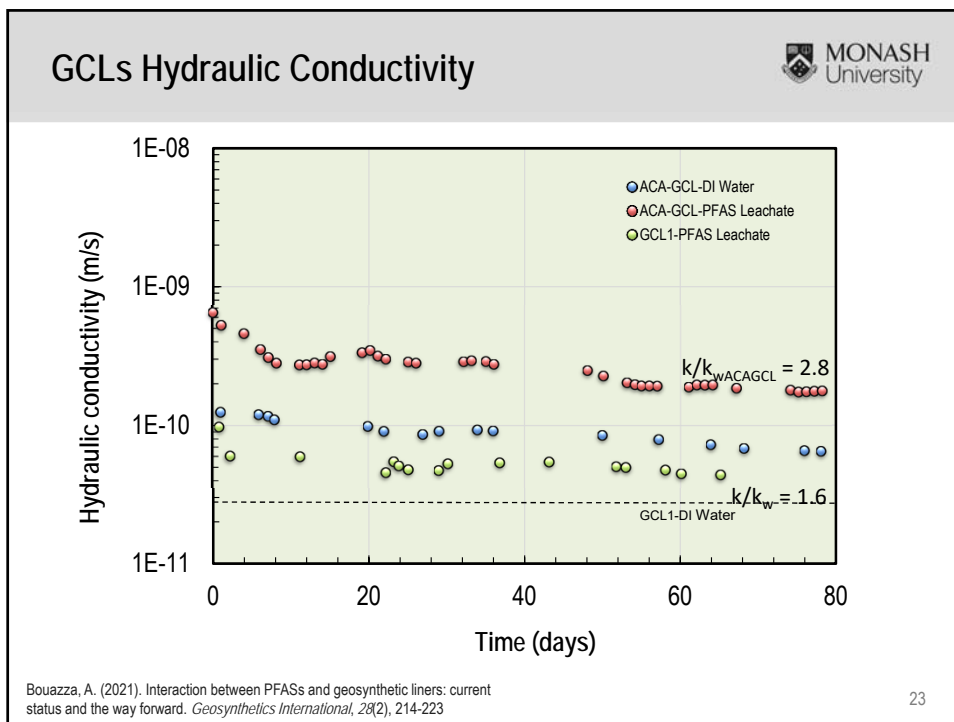
PFAS compounds concentrations as measured in landfill leachate  
(from Bouazza, 2020, Gates et al. 2020).

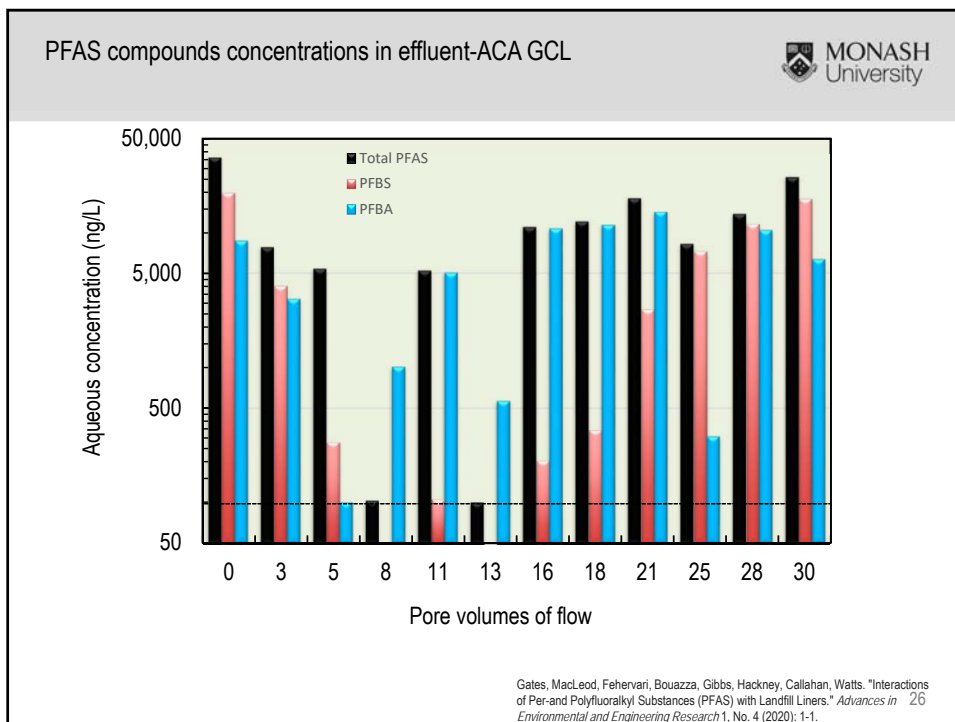
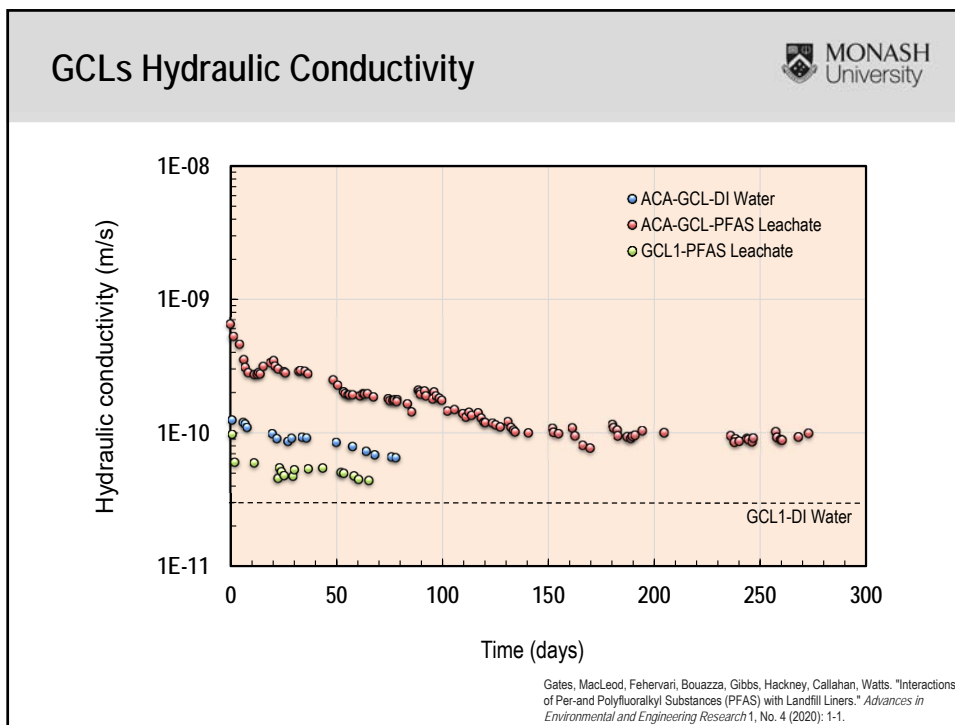
PFAS compounds	PFHxA	PFHpA	PFBS	PFOA	PFOS	PFHxS
Concentration (ng/L)*	23,600	500	19,600	690	240	940
Molecular weight (g/mol)**	314	364	300	414	500	400
Solubility (g/L)**	21.70	4.20	46.20-56.60	3.40-9.50	0.52-0.57	2.30
Dissociation constant, pKa**	-0.13	-0.15	-6.00 to -5.00	-0.16 to -2.6	-6.00 to -2.60	-6.00 to -5.00

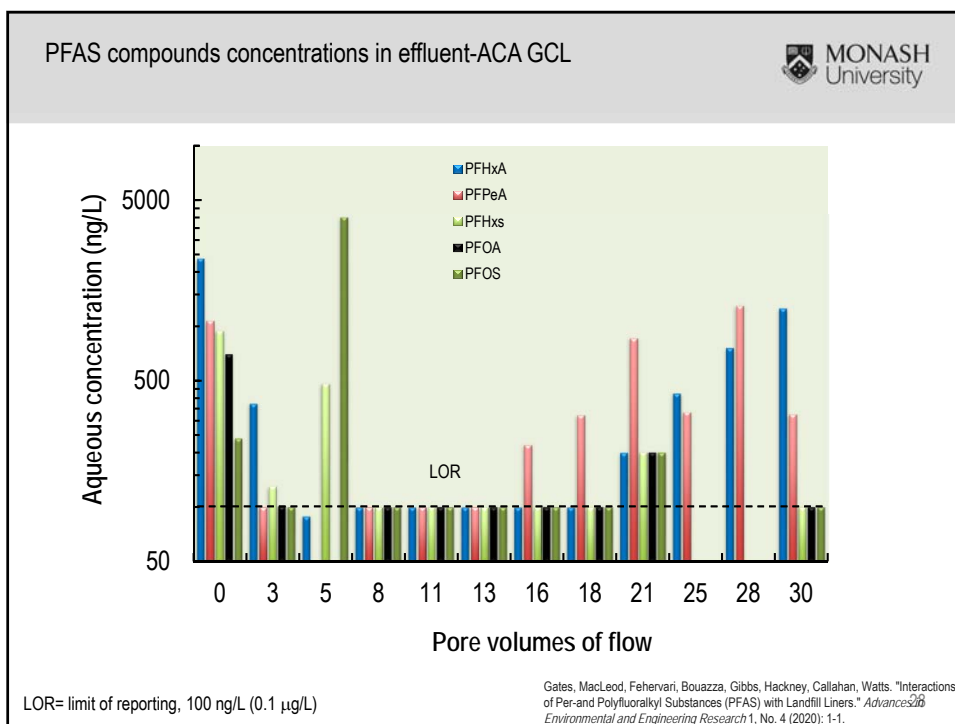
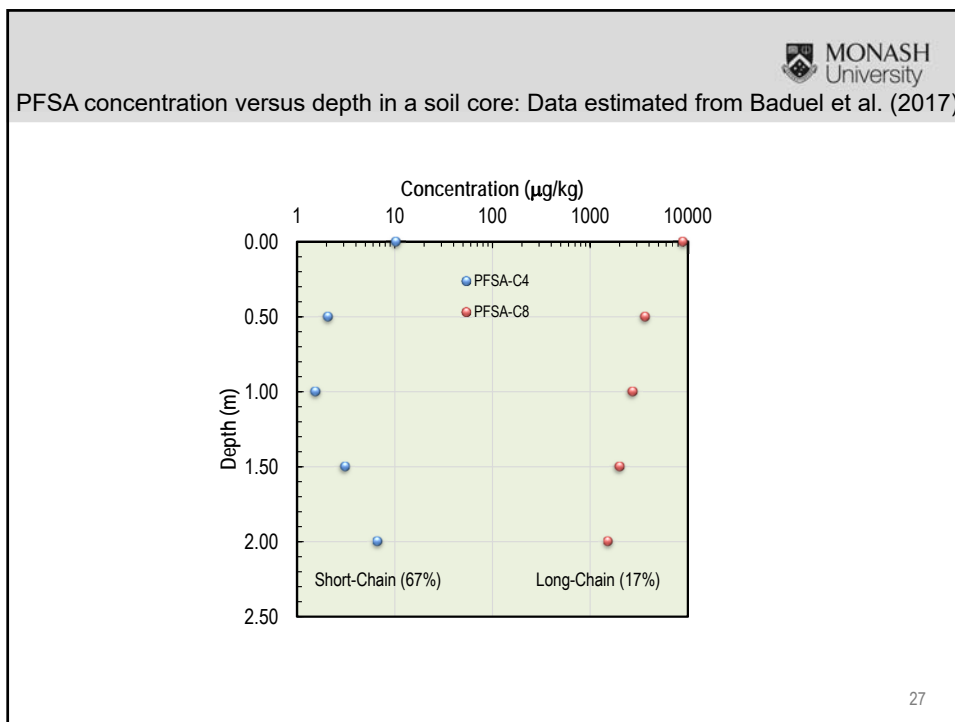
Bouazza, A. (2021). Interaction between PFASs and geosynthetic liners: current status and the way forward. *Geosynthetics International*, 28(2), 214-223

Gates, MacLeod, Fehervari, Bouazza, Gibbs, Hackney, Callahan, Watts. (2020) "Interactions of Per- and Polyfluoroalkyl Substances (PFAS) with Landfill Liners." *Advances in Environmental and Engineering Research* 1, No. 4: 1-1.

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## Fluorotelomer alcohols (FTOHs)

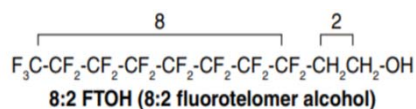


FTOHs are generated by abiotic and biological hydrolysis in landfills

- Low water solubilities and
- Dominant volatile PFAS measured in landfill gas

Concentrations in air at landfills (Ahrens, 2011, Weinberg, 2011, Wang, 2019)

- Canada: 93-98% of the  $\Sigma$ PFASs with 8:2 FTOH being the most present
- Germany: 75% in closed landfills, 92% in active landfills, 8:2 FTOH highest contributor
- China: 8:2 FTOH highest contributor ~75%

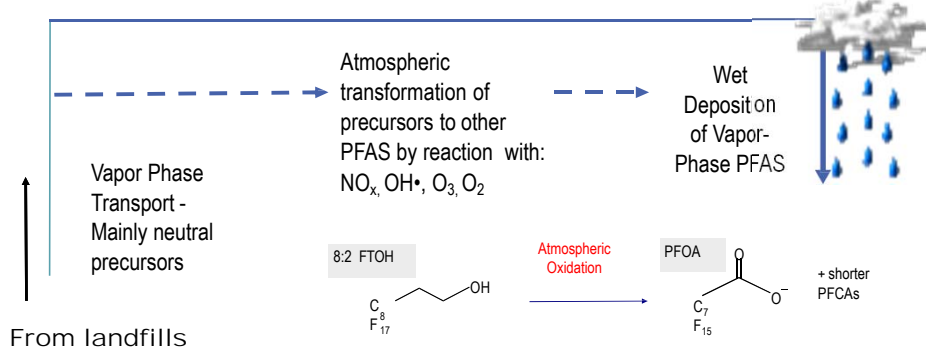


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## PFAS atmospheric fate and transport

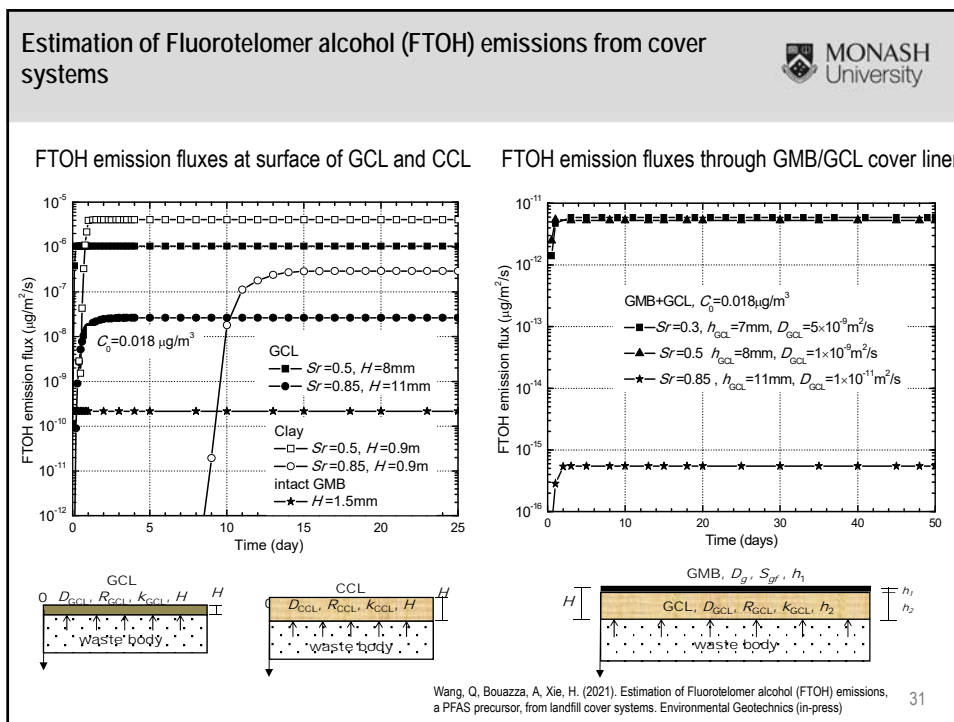


Long transport potential  
~20 days atmospheric lifetime (8:2 FTOH)



- Partially-fluorinated
- Non-fluorine atom (usually H or O) attached to at least one, but not all, of the carbons in the alkane chain
- Creates a "weak link" susceptible to biotic or abiotic degradation (becoming a perfluoroalkyl substance)

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## Concluding Remarks

Mobility

evaluation of the effectiveness of geosynthetic liner systems for containment of PFAS is very scarce

Differences

Important to differentiate between on-site repositories and landfills applications

Future

Gain better understanding of the PFASs complex chemistry



## Acknowledgments



Australian Research Council (ARC), Geofabrics Australasia,  
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The views expressed in this presentation are those of the  
presenter alone.

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**Thanks for  
attending!**

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for further questions or clarifications.