2021 ACS Green Chemistry & Engineering Conference

XT green

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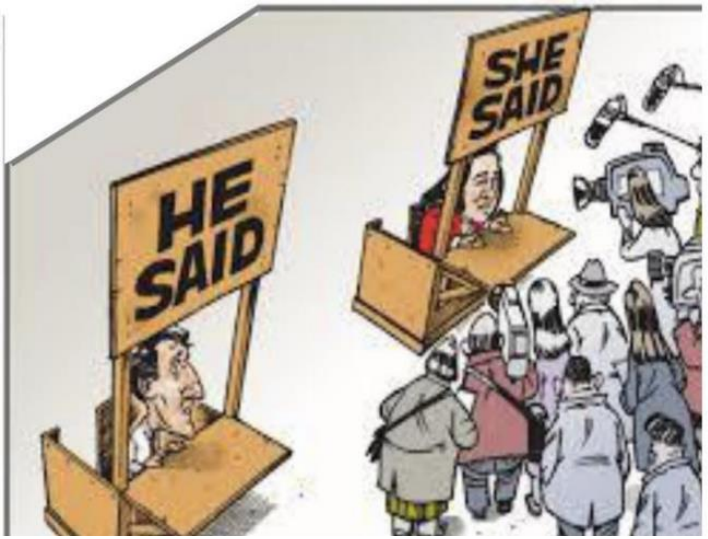


Disclaimer

All Information, Comments and Opinions are provided:

- As a representative of XT Green, and –
- NOT as a member/officer of the California Carpet Stewardship Advisory Committee, and --
- Not as a member of CARE, and --
- Not as part of Carpet Recycling Community

Presentation Outline

- Background on XT Green
- Short History of PFAS & Carpet Recycling
- XT Green's commitment to resolve its PFAS issue
- Unique challenges/opportunities to remove/treat PFAS due to patented aqueous-based carpet recycling technology
- PFAS Study Results: Support for UC Berkeley Green Team
- PFAS and the Future of XT Green

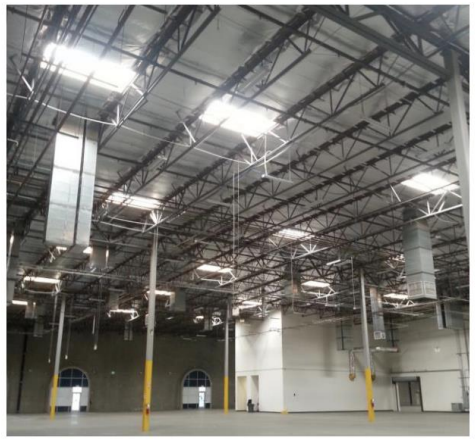
Background on XT Green

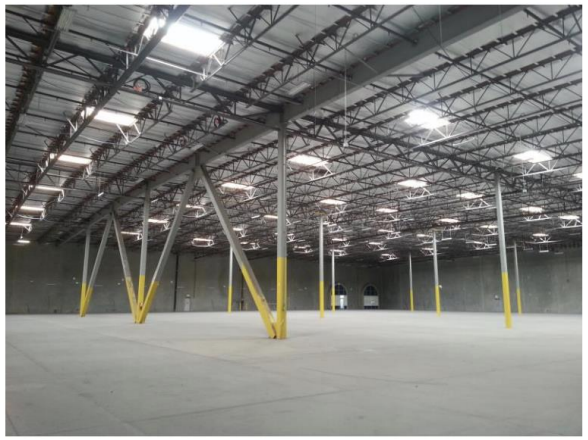
- XT Green created to develop and commercialize an advanced manufacturing technology to recover resources from post-consumer carpet (PCC)
- Funded by XT Green private investors + California incentives
- Focused on aqueous-based technology to meet these goals:
  - Produce highest-quality recycled output
  - Minimize/eliminate need to augment recovered product with virgin petroleum-based material
  - Maximize greenhouse gas emission reduction benefits and recycling rates
  - Protect employee health and the environment by eliminating particulate emissions
  - Create high-quality California green manufacturing jobs
- Developed process and tested equipment in two pilot plants

More Background on XT Green

- Awarded two U.S. and one Canadian patents
- Recognized as an "advanced manufacturing technology" by the State of California.
- Overcame major obstacles including switching power companies and a world-wide pandemic. Last obstacle –

PFAS contamination in post-consumer carpet





Short History of PFAS & Carpet Recycling

- 1986: PFAS first used as stain repellant in carpet
- 2002: Carpet America Recovery Effort (CARE) created through MOU between Carpet Industry & EPA
- 2008: Under pressure from EPA, Carpet Industry committed to replacing long-chained PFAS with short-chain PFAS
- 2011: First carpet stewardship act in U.S. passed in California. CARE appointed as Stewardship Organization
- 2017: Healthy Building Network publishes “Eliminating Toxics in Carpet” lists 44 chemical types including PFAS
- 2018: DTSC publishes discussion draft of Product Profile for PFAS in Carpet and Rugs, includes “end-of-life” concerns

- 2018: California Carpet Stewardship Advisory Committee
- CARE submits 2018-2022 Carpet Stewardship Plan to CalRecycle, no mention of PFAS
- CARE issues guidelines for “In/on ground application of PCC” requires PFAS testing but no guidance regarding results
- 2019: Advisory Committee requests CARE to address PFAS concerns. CARE declines as there are “no specific guidelines or requirements for the use of post-consumer carpet”
- 2019: XT Green requests $10K grant for analytical work to determine levels of PFAS in PCC. CARE denies request.

California Carpet Stewardship Advisory Committee

"Much" of the Carpet Recycling World →

California Carpet Stewardship Program run by Georgia Carpet Industry:

- 2016 – Present: Lawsuit against Georgia Carpet Industry for Drinking Water Contamination in Alabama
  - 90% of all carpet in the world manufactured in Dalton GA
  - Carpet Industry negotiated with EPA to allow short-chain PFAS
  - Industrial discharge sent to Dalton WWTP. PFAS passes through to –
  - Conasauga River – One of the most bio-diverse rivers in the world, more species than all rivers in Europe combined. PFAS present.
  - Drinking water source for many cities in Georgia and Alabama
- Lawsuit Timeline
  - 2016: Gadsen AL sues 30 carpet companies including Shaw & Mohawk for contaminating drinking water supply with PFAS
  - 2017: Centre AL joins because of PFAS drinking water contamination
  - 2019: Carpet Industry tries to change venue to Georgia. Blames Dalton WWTP for not treating "forever chemical." Alabama denies venue change.
  - 2020: Carpet Industry petitions U.S. Supreme Court to change venue
  - January 2021: Supreme Court refuses to take case. Stays in Alabama
- While carpet industry spends $$$ to fight lawsuits, Alabama cities have installed PFAS treatment for $5 million to provide safe drinking water for citizens.
- But it's all not all PFAS "heads in the sand… denial" …

Companies & Organizations Requiring PFAS-Free Carpet

XT Green's commitment to resolve its PFAS issue

Personal Background with "Legacy Chemicals" --

Liability & Moral Responsibility Doesn't Require Regulations

- Hired by California Aerospace company named #1 Superfund site to address extensive chlorinated solvent groundwater contamination.
- Grew an environmental engineering company from 10 to 450 employees to investigate and remediate contaminated industrial sites across the U.S.

  Left company when focus changed to expert testimony defense of toxic chemical polluters
- Extensive knowledge of the "forever chemical" DDT and the life of Rachel Carson whose book "Silent Spring" resulted in the banning of DDT in 1972 --

  DDT legacy continues with 2021 discovery of 65,000 + DDT drums off California coast and health problems in grand-daughters of women exposed to DDT in the 60's
- Plus … Fiduciary responsibility to XT Green Investor

Sign on truck: "DDT POWERFUL INSECTICIDE, HARMLESS TO HUMANS"

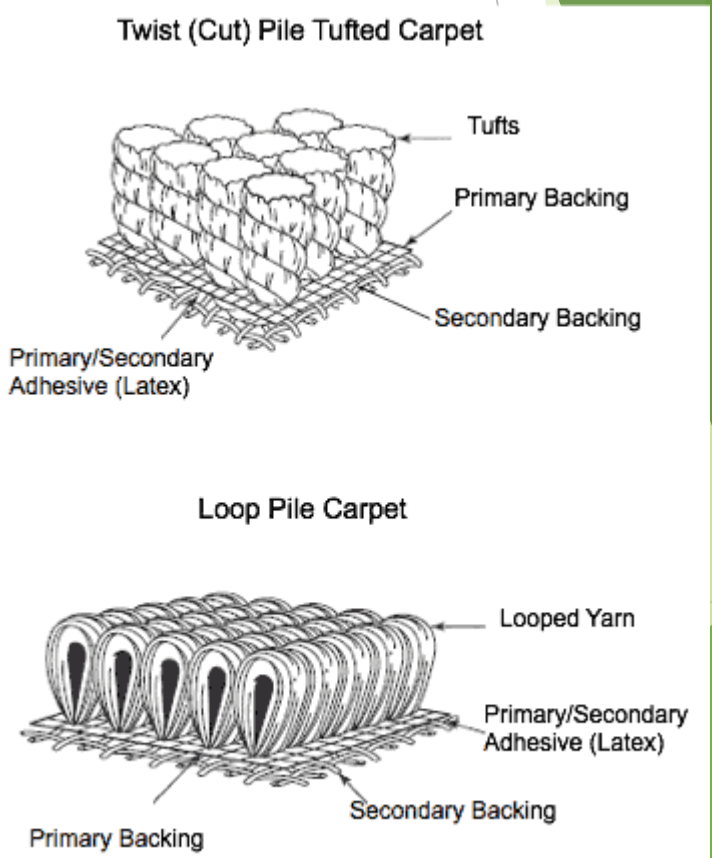
Unique challenges/opportunities to remove/treat PFAS due to XT Green aqueous-based technology

- Challenge #1: Carpet is Designed to Stay Together

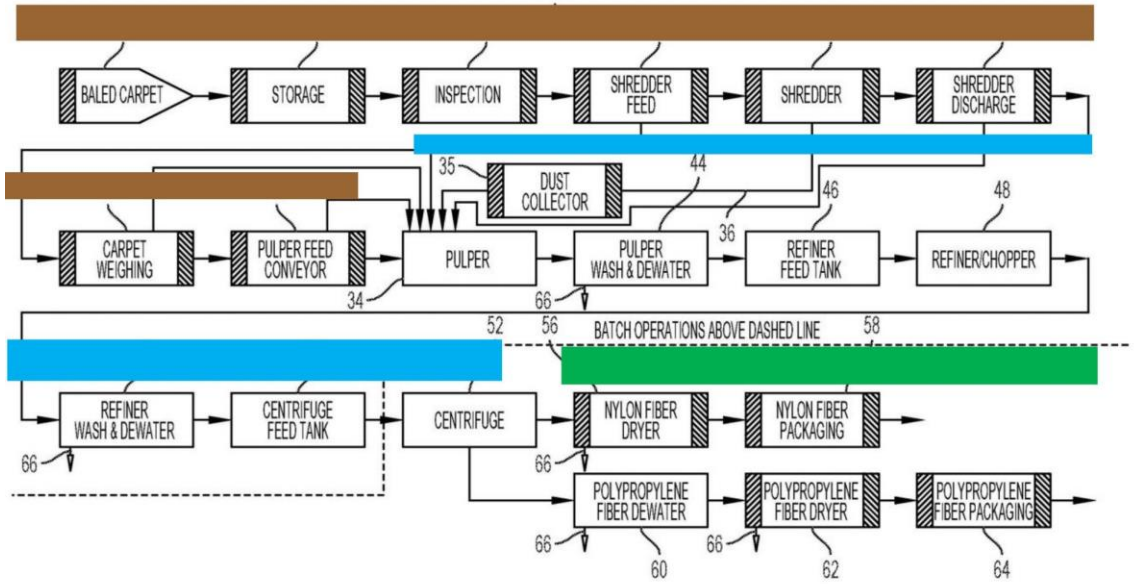
- Components of Carpet, e.g. Nylon Residential
  - Face Fiber 40%
  - Polypropylene from Backing 15%
  - Rest of Backing: Latex & Calcium Carbonate* 45%

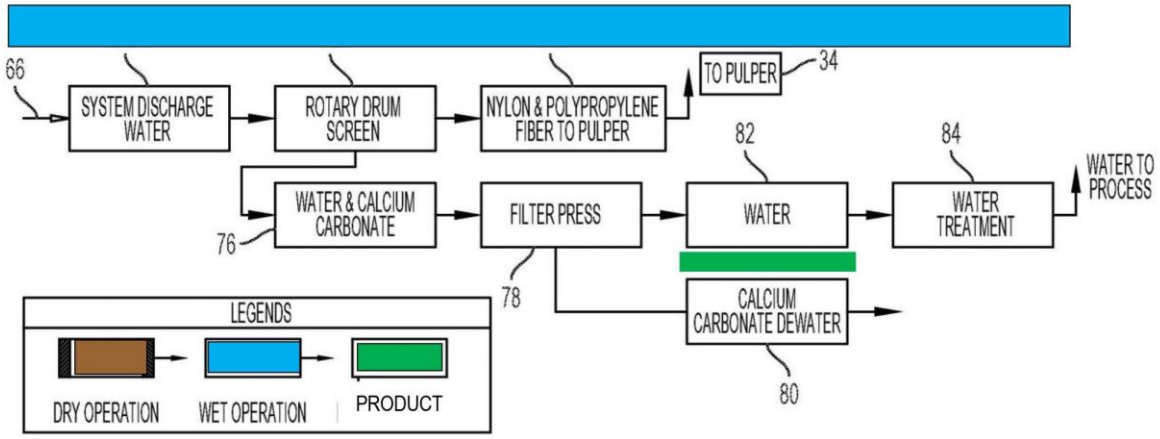
  "Post-Consumer Carpet Calcium Carbonate (PC4)"

  PFAS added to carpet either in the production of fiber or applied to the entire carpet during manufacturing



Where does PFAS go? First need to understand process* (It will be quick, promise)





* Detailed information available in Patent Documents including: Advanced Manufacturing System to Recycle Carpet #US2020/0156082A1 May 21, 2020

"Advanced Manufacturing System to Recycle Carpet"

(patents in U.S. and Canada)

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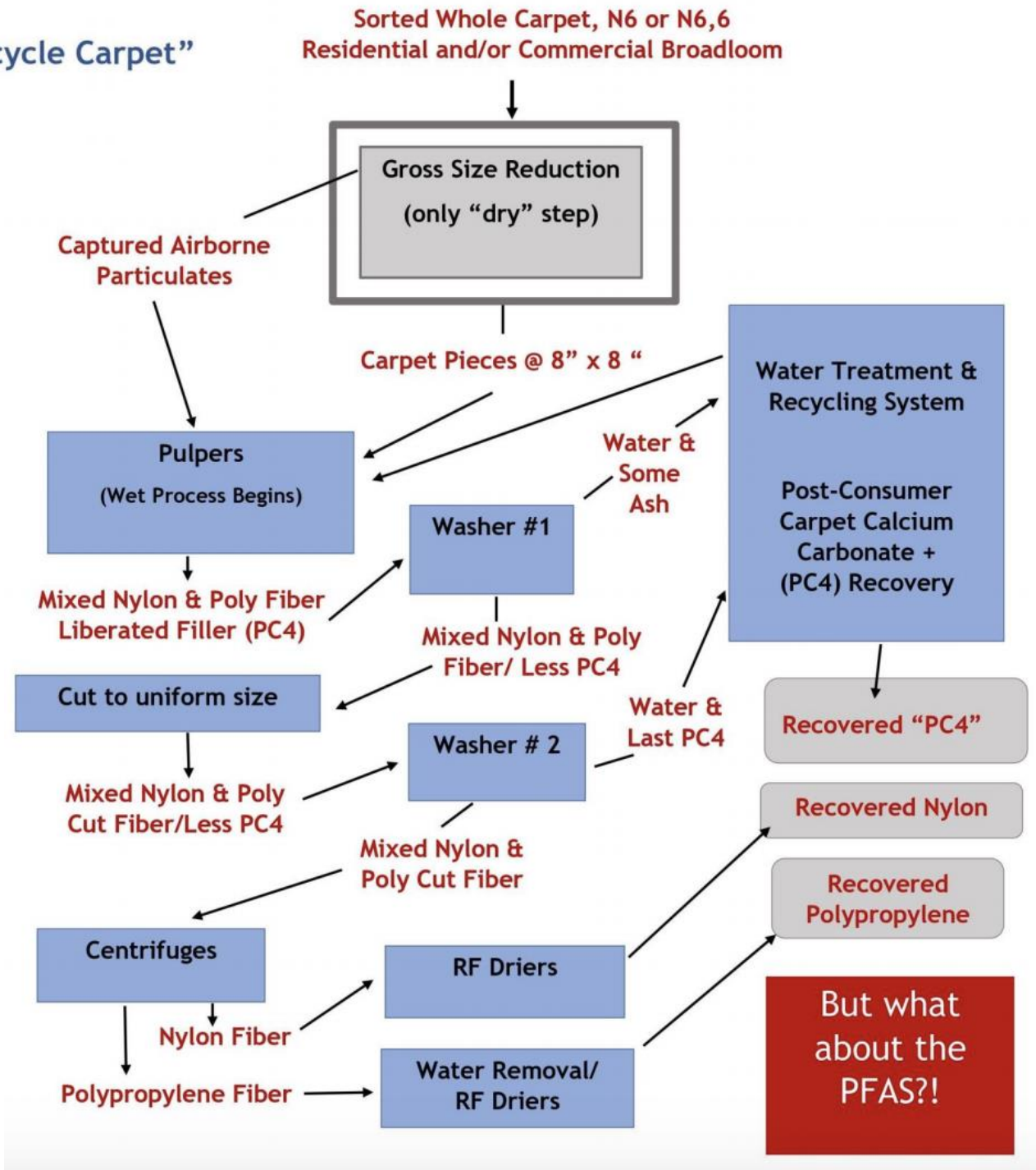


How much PFAS is in Post-Consumer Carpet (PCC)?

		R16A	R26A	R366A	R466A	C16A	C166A
PF Type	# of Carbons	Target variable quantities are shown in ng/kg (parts/trillion)					
PFBA	4	7800	15000	30000	8200	ND	9100
PFBS	4	5400	9900	6200	ND	ND	ND
PFPeA	5	ND	ND	ND	11000	ND	24000
PFHxA	6	ND	4900	ND	23000	11000	71000
PFHpA	7	ND	ND	ND	51000	6000	110000
6:2 FTS	8	ND	ND	ND	ND	ND	ND
PFOA	8	ND	ND	ND	34000	5700	77000
PFOS	8	ND	ND	ND	ND	ND	ND

- PCC collection facility: Multiple samples randomly pulled from multiple bales with Residential & Commercial PCC
- Researched literature for most likely PFAS in PCC
- Analyses done by PFAS-certified Weck Laboratories
  - PFAS removed through leaching protocol
  - LCMS analyses done by Triple-Quadrupole Mass Spectrometers
- CA Water Board levels (RLs) requiring water systems to be removed from service: 10 ppt for PFOA and 40 ppt for PFOS
- How does that relate to PCC? TBD but, of concern in landfills & in recycled content returning to circular economy

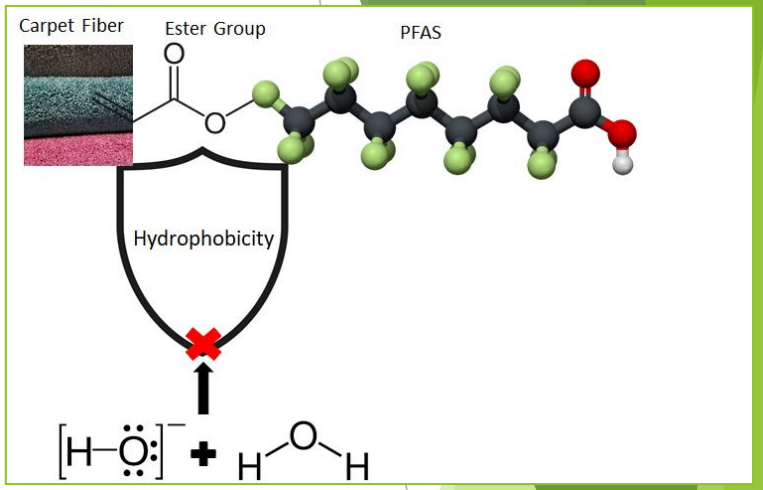
What will happen to the PFAS in the XT Green facility?

- Simulated XT Green aquatic-based process using fiber produced from XT Green pilot plant
- Hoping XT Green's carpet recycling technology would result in PFAS going into process water for removal but ...
- Round 1 of testing: It stays in the fiber
- Considered abandoning project due to PFAS until --

	Sample ID	C166A	C166B	
	Material Type	Commercial Nylon 66	Commercial Nylon 66	
	Process State	Incoming	Post-Process Solids	Post-Process Water
PF Type	# of Carbons	Target variable quantities are shown in ppt		
PFBA	4	9100	ND	ND
PFBS	4	ND	ND	ND
PFPeA	5	24000	ND	0.0011
PFHxA	6	71000	10000	0.0036
PFHpA	7	110000	17000	0.0041
6:2 FTS	8	ND	ND	ND
PFOA	8	77000	15	0.0017
PFOS	8	ND	ND	ND

Support from UC Berkeley Greener Solutions Team

- DTSC Simone Balan referral to UCB Thomas McKeag and “Greener Solutions” students investigating PFAS in carpet
- Work conducted by Ned Antell, Ph.D student
- Round #2 of testing:
  - Determine if strong base in aqueous solution can release the PFAS from the XT Green carpet fiber
- Strong base inadequate to remove PFAS from Fiber:
  - Result likely due to shielding of the ester bond by the PFAS hydrophobic tail due to inadequate distance between the 2+ non-fluorinated carbons separating ester bond from the hydrophobic tail

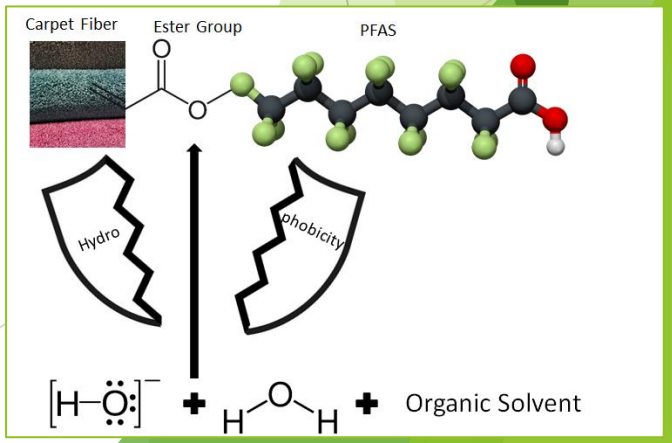


PFAS	# of Carbons	Extracted from Fiber (ppt)	2M NaOH/water	1 M NaOH/water	2 M NaOH in water, Sonicated
PFBA	4	NA	ND	ND	ND
PFBS	4	NA	ND	ND	ND
PFPeA	5	143000	ND	ND	ND
PFHxA	6	257,100	ND	ND	ND
PFHpA	7	49,000	ND	ND	ND
6:2 FTS	8	8,804,400	ND	ND	ND
PFOA	8	125,000	ND	ND	ND
PFOS	8	83,800	ND	ND	ND

- Round #3 of testing:
  - Determine if strong base in aqueous solution plus organic solvents can release the PFAS from the XT Green fiber
  - Five organic solvent candidates reduced to four after consultation with nylon fiber manufacturer

PFAS	# of Carbons	PFAS in fiber (ppt)	2 M NaOH + 50% Solvent #1 (ppt)	2 M NaOH + 50% Solvent #2 (ppt)	2 M NaOH + 50% Solvent #3 (ppt)	2 M NaOH + 50% Solvent #4 (ppt)
PFBA	4	ND	158,925	355,200	620,550	591,524
PFBS	4	ND	0	0	0	0
PFPeA	5	143000	0	0	0	0
PFHxA	6	257,100	141,788	129,150	107,175	160,088
PFHxSaAm	6	Surprise!	601,088	537,638	503,325	3,498,975
PFHpA	7	49,000	136,838	135,113	136,575	131,438
6:2 FTS	8	8,804,400	0	0	0	0
PFOA	8	125,000	96,150	99,750	96,524	91,050
PFOS	8	83,800	8,676	129,375	140,888	209,738

- Organic solvents improve removal of PFAS from carpet fiber, especially long chain PFAS
- Removal efficiencies different depending on organic solvent
- Precursors make up a large fraction of PFAS mass in carpet
- Need to expand measurement of PFAS beyond PFAAs for complete understanding of PFAS in carpet



Support from UC Berkeley Green Solutions Team (cont'd)

- Round #4 of testing:
  - Determine the residual PFAS in fiber and removal %
  - Determine the concentration of PFAS in the PC4

PFAS	# of Carbons	PFAS in fiber (ppt)	2 M NaOH + 50% Solvent #4 (ppt)	Residual PFAS in Treated Fiber (ppt)	% Removal
PFBA	4	ND	591,524	1020	>99
PFBS	4	ND	ND	ND	--
PFPeA	5	143000	ND	ND	--
PFHxA	6	257,100	160,088	1698	99
PFHxSaAm	6	Surprise!	3,498,975	ND	>99
PFHpA	7	49,000	131,438	2	>99
6:2 FtS	8	8,804,400	ND	ND	--
PFOA	8	125,000	91,050	1035	99
PFOS	8	83,800	209,738	630	>99

- Strong base in aqueous solution plus organic solvent #4 removes 99 to >99% of PFAS from carpet fiber
- Concentration of PFAS in PC4 similar to carpet fiber

PFAS	# of Carbons	PFAS in PC4 (ppt)	2 M NaOH + 50% Solvent #4 (ppt)	Residual PFAS in Treated PC4 (ppt)	% Removal
PFBA	4	265,920	TBD	TBD	TBD
PFBS	4	40,588	TBD	TBD	TBD
PFPeA	5	158,330	TBD	TBD	TBD
PFHxA	6	47,833	TBD	TBD	TBD
PFHxSaAm	6	2,695,133	TBD	TBD	TBD
PFHpA	7	38,830	TBD	TBD	TBD
6:2 FtS	8	ND	TBD	TBD	TBD
PFOA	8	46,535	TBD	TBD	TBD
PFOS	8	19,243	TBD	TBD	TBD
PFNA	9	46,368	TBD	TBD	TBD

Next Steps

Technology Development:

- Determine if strong base in aqueous solution plus organic solvents can remove PFAS from PC4
- Determine the residual PFAS in PC4 and removal
- Perform total oxidizable precursor assay on sample to quantify precursors without analytical standards
- Repeat experiments and compare results

Operational Data to support XT Green process system design:

- Determine reaction kinetics/optimal incubation times

Additional Action Items:

- Conduct preliminary economic impact to XT Green
- Secure guidance from regulatory agencies regarding acceptability of residual PFAS in fiber and PC4
- Discuss “level PFAS playing field” w/ CalRecycle & CARE
- Discuss preliminary results with recycled output buyers
- Continue discussions with PFAS removal/destruction vendors (including impact of organic solvents)

Conclusions: The PFAS Challenge & Future of XT Green

- Major Technical Challenges in Removing PFAS from PCC
- XT Green patented technology has potential to remove 99% of the PFAS from recovered carpet fiber (possibly PC4 too) for subsequent adsorption/destruction
- Role of CARE, CalRecycle and the California Carpet Stewardship Program in addressing PFAS in PCC?
- Must address acceptable PFAS residual in carpet recycled output vs. drinking water standards

Conclusions continued

- Need to compare risk of maintaining PFAS in circular economy vs. the risk of landfilling PCC. Does the risk change dependent on the use of the PCC recycled output?
- Do benefits of carpet recycling help outweigh these risks?
  - Between 3 – 4 billion pounds of PCC disposed annually
  - California has a recycling rate of 20+%
  - Rest of US sends +95% of PCC to landfills or burned
  - PFAS released through air emissions & landfill leachate pass-through at wastewater treatment plants
  - Major GHG emission reduction benefits from carpet recycling as recovered products replace virgin materials*

*XT Green's annual GHG emission reduction benefits would be equivalent to the carbon sequestered over 10 years by planting 2.5 million trees.

FINALLY … SHOULD XT GREEN CONTINUE THIS QUEST OR --

Should We Recycle Cardboard Boxes?

Questions? Concerns? … Solutions?

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Reclaiming Resources for a Greener Planet