Efficient Bioremediation of Environmentally Persistent Contaminants with Nanomaterial-Fungus Framework

PI: Susie Dai, Texas A&M University

Co PI: Dr. Joshua Yuan, Texas A&M University

Dr. Greg Lowry, Carneigie Mellon Univeristy

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The problem and solution

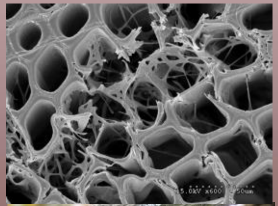
The Problem:

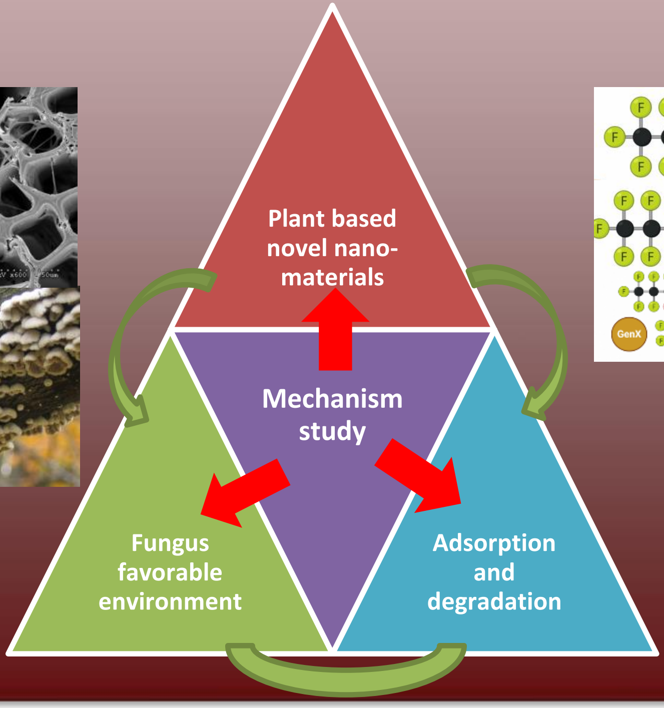
1) No sustainable technology to remediate PFAS
2) PFAS bioremediation approaches need improvement
   - PFAS bioavailability/toxicity are double-edged swords to the remediation efficiency.
   - Slow growth and PFAS degradation rate
   - Need for continuous nutrient supply for organisms
   - Degradation mechanisms and products are not elucidated

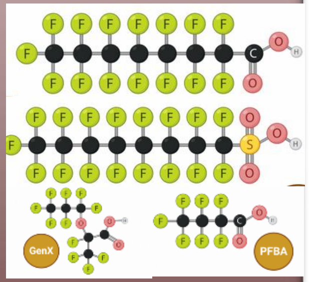
Our Solution:

❖ "Efficient Bioremediation of Environmentally Persistent Contaminants with Nanomaterial-Fungus Framework"

❖ Integrating material science/engineering/fungal biology/informatics to address the challenges







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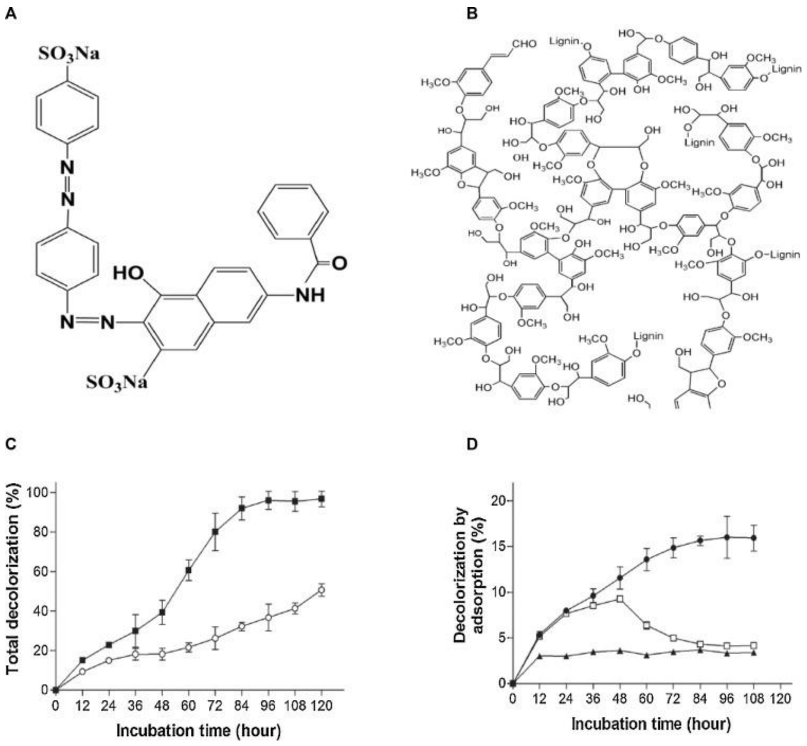
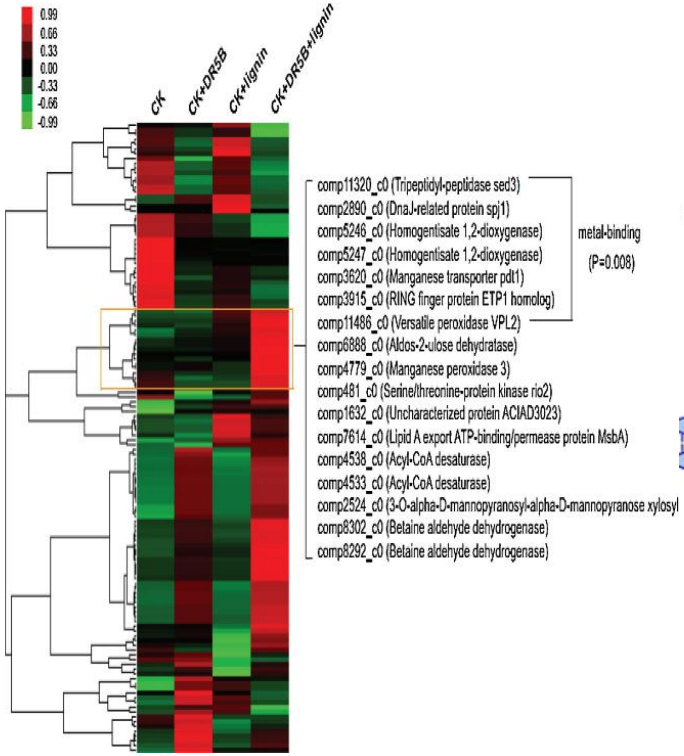
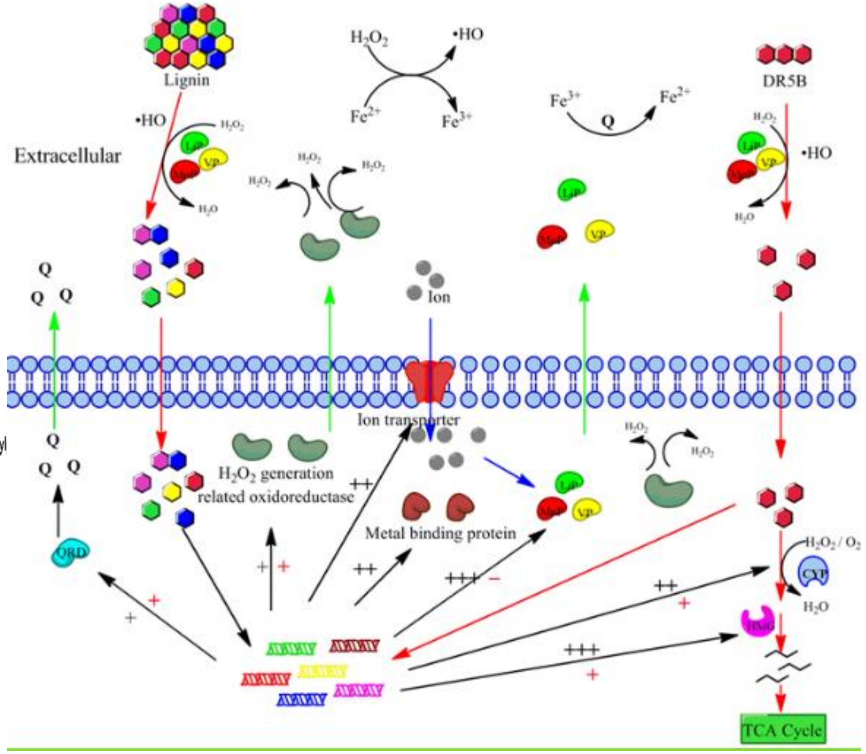
Rational







The fungal degradation of organic dye was significantly enhanced when lignin, the natural fungal substrate was added into the culture media

Genomic and molecular mechanisms for efficient biodegradation of aromatic dye, Sun et al, 2016
Enhancement of Environmental Hazard Degradation in the Presence of Lignin: a Proteomics Study, Sun et al, 2016

Technical Approach

Aim. 1: Design NFF for Chemical Adsorption and Fungal Cultivation

Aim 2: Molecular Mechanism Study of Remediation Efficiency

Aim. 3: Coupling Key Enzymes Identified in Aim 2 to NFF

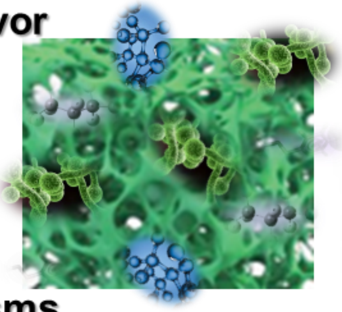
Specific Aims

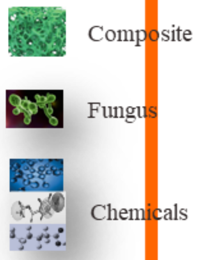
How material modification can improve chemical adsorption and favor fungal growth?

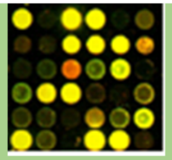
What are the molecular and systems mechanisms of NFF efficiency?

How key genes and enzymes can further improve remediation efficiency?

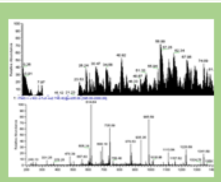
Biological Questions



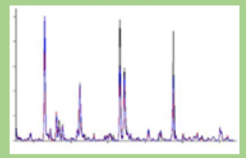




Transcriptomics

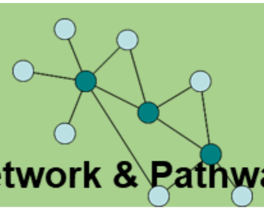


Proteomics

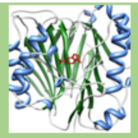


Metabolites Profiling

Bioinformatics



Network & Pathway



Enzyme Function Analysis & Verification

Synergizing NFF & Enzyme Treatment

Systems Biology Approach

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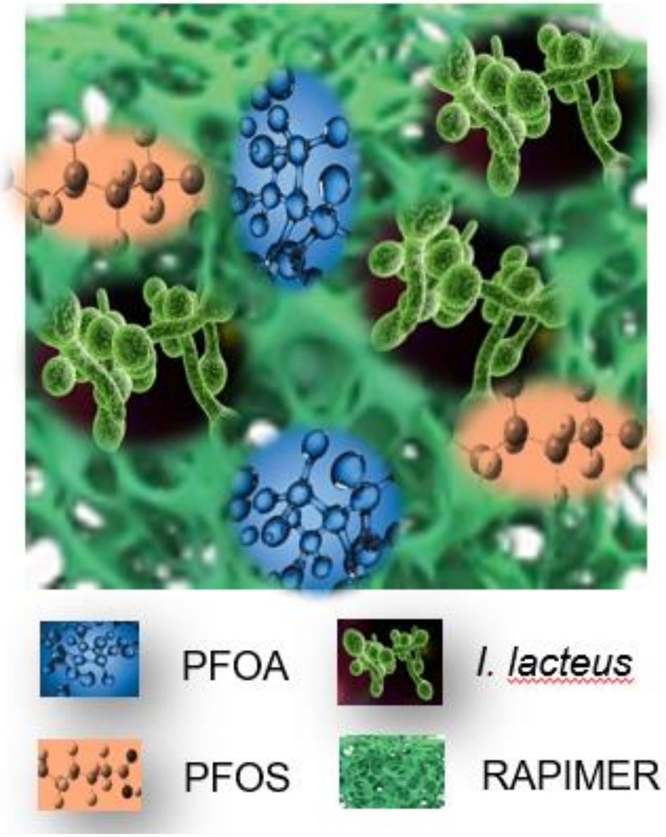
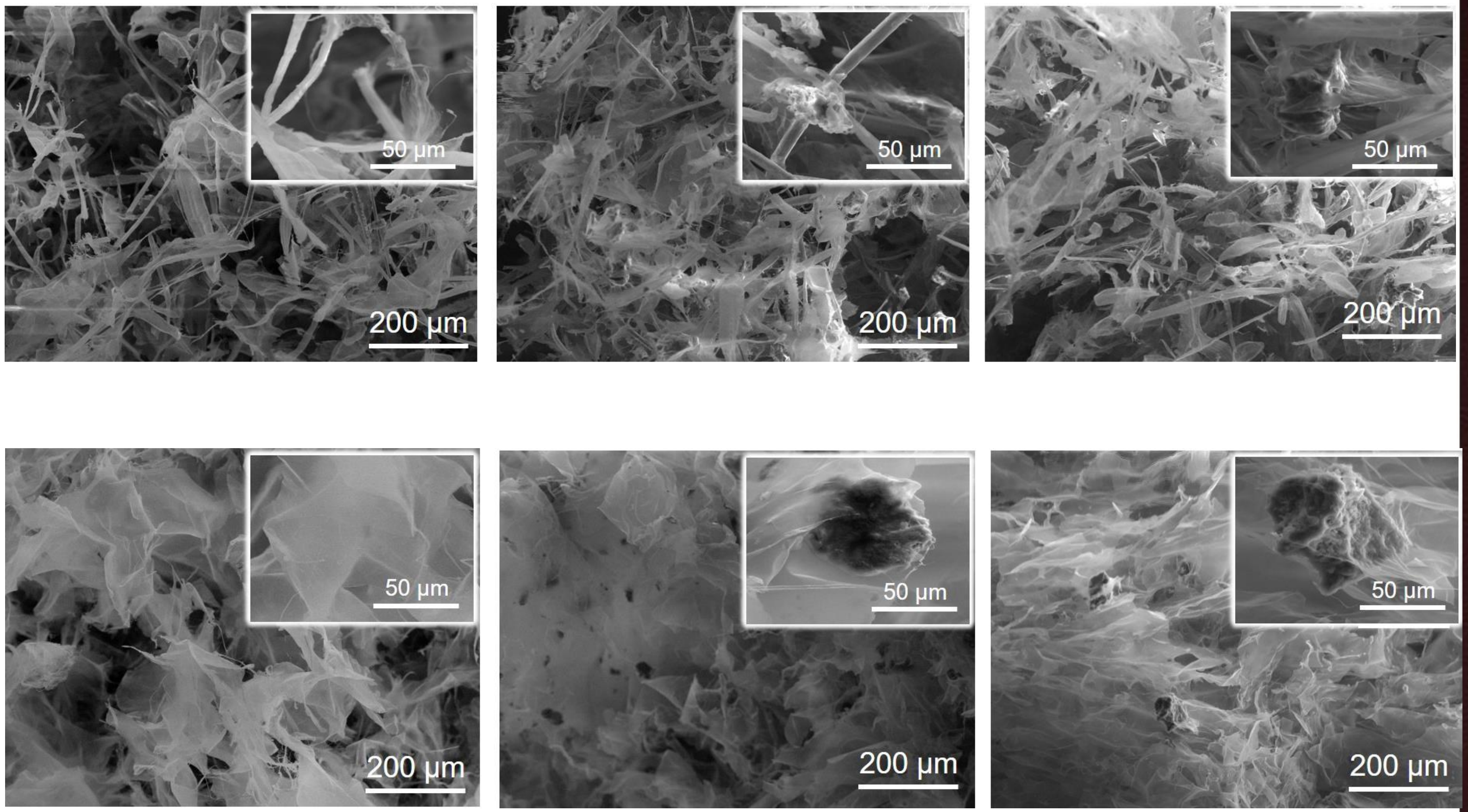
Aim 1





Renewable Artificial Plant for In-Situ Microbial Environmental Remediation (RAPIMER)

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Li et al, submitted

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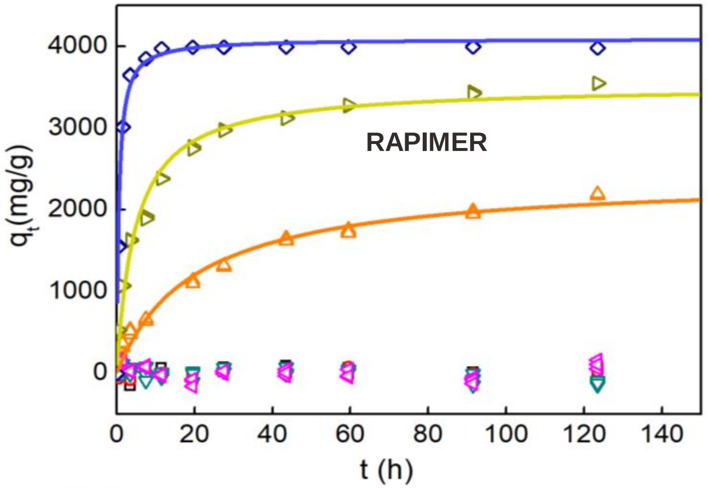

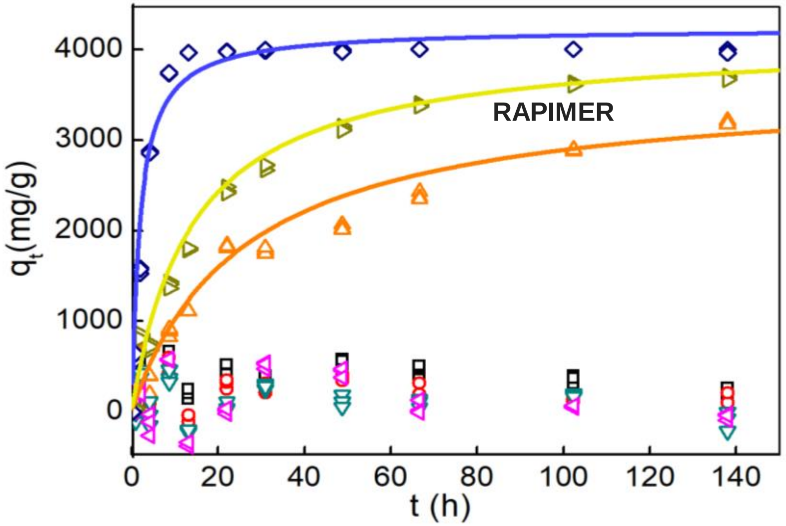

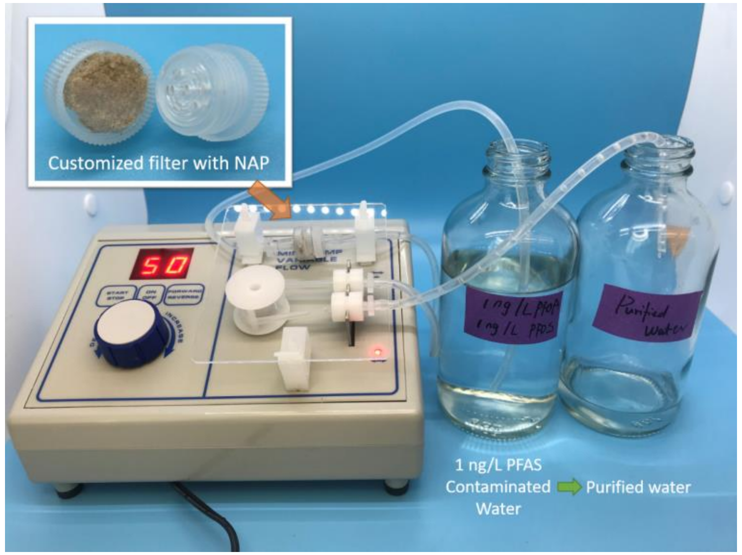

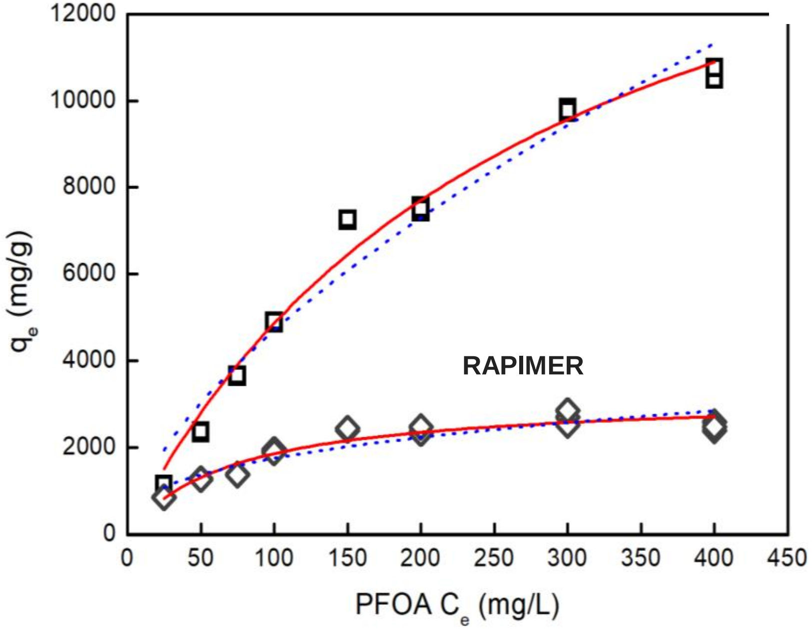

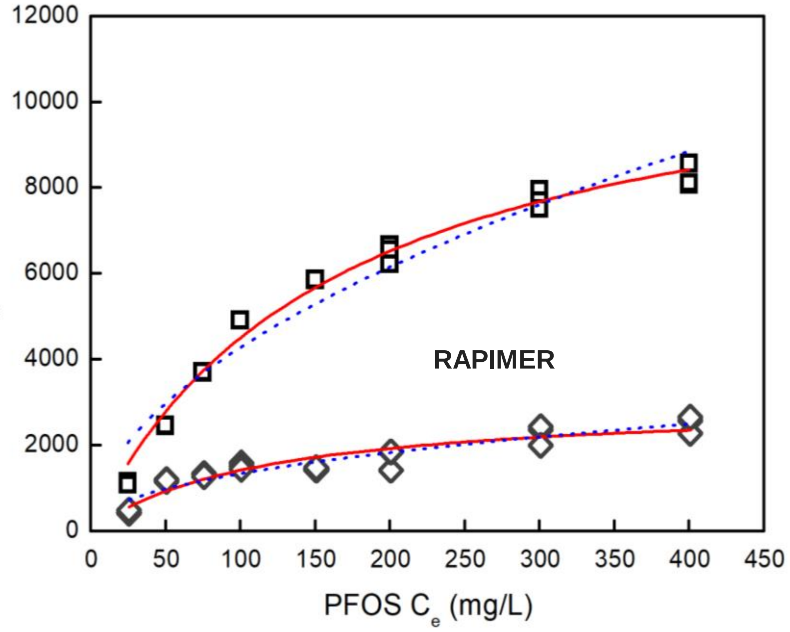

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Li et al, submitted

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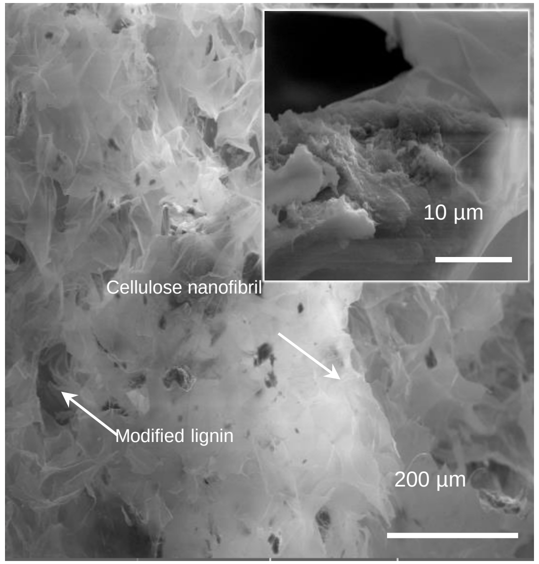
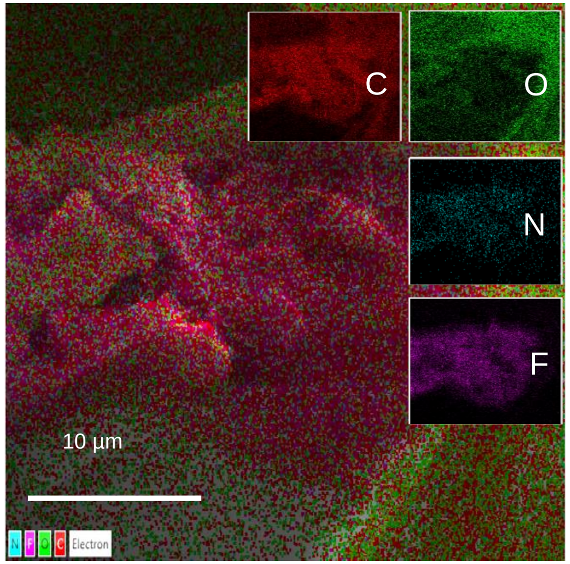
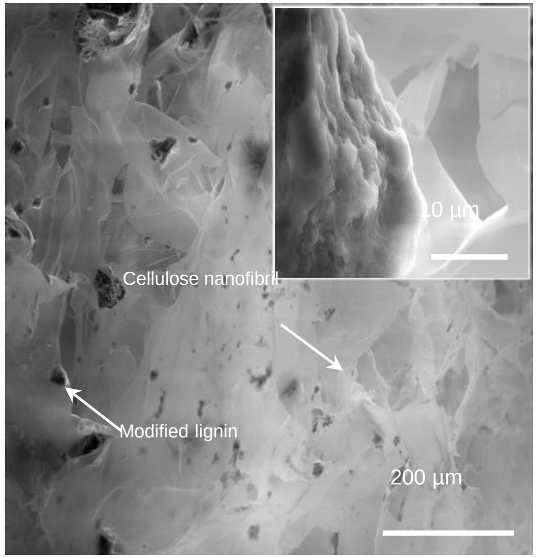
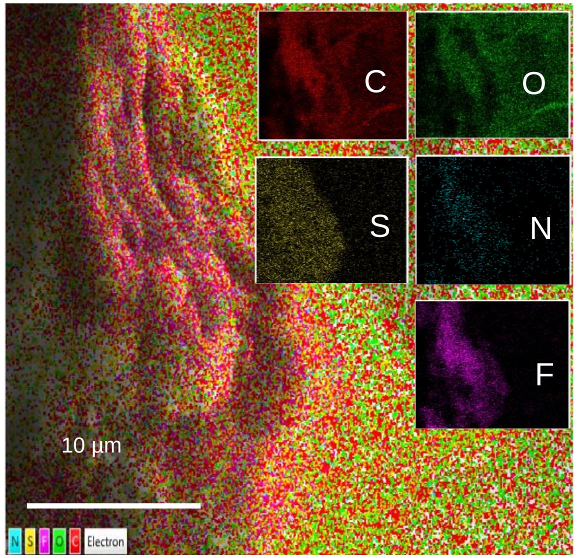
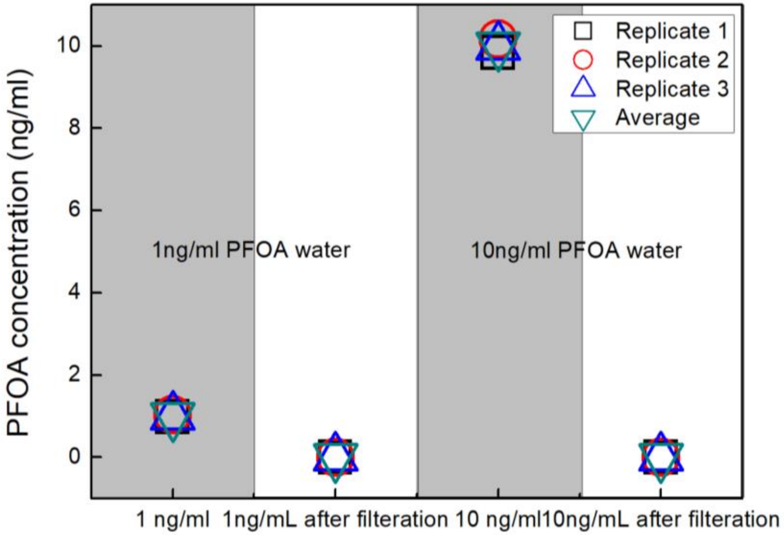
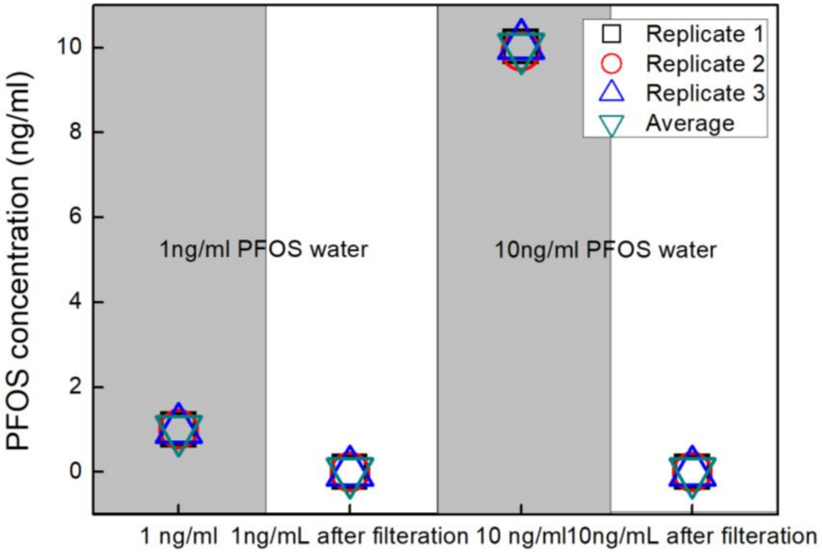

10 µm
Cellulose nanofibril
Modified lignin
200 µm


C
O
N
F
10 µm
Electron

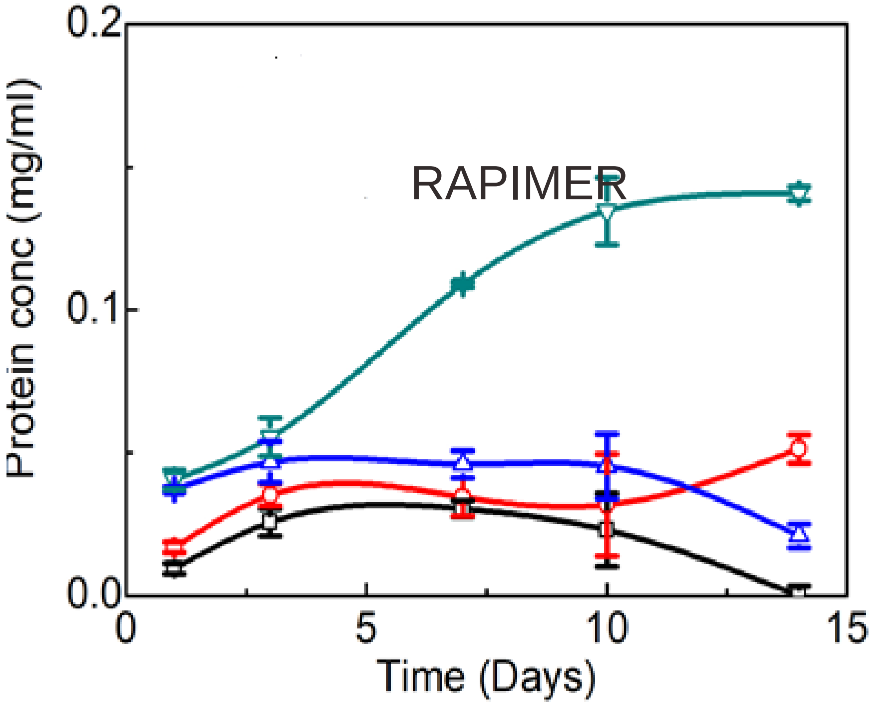

10 µm
Cellulose nanofibril
Modified lignin
200 µm

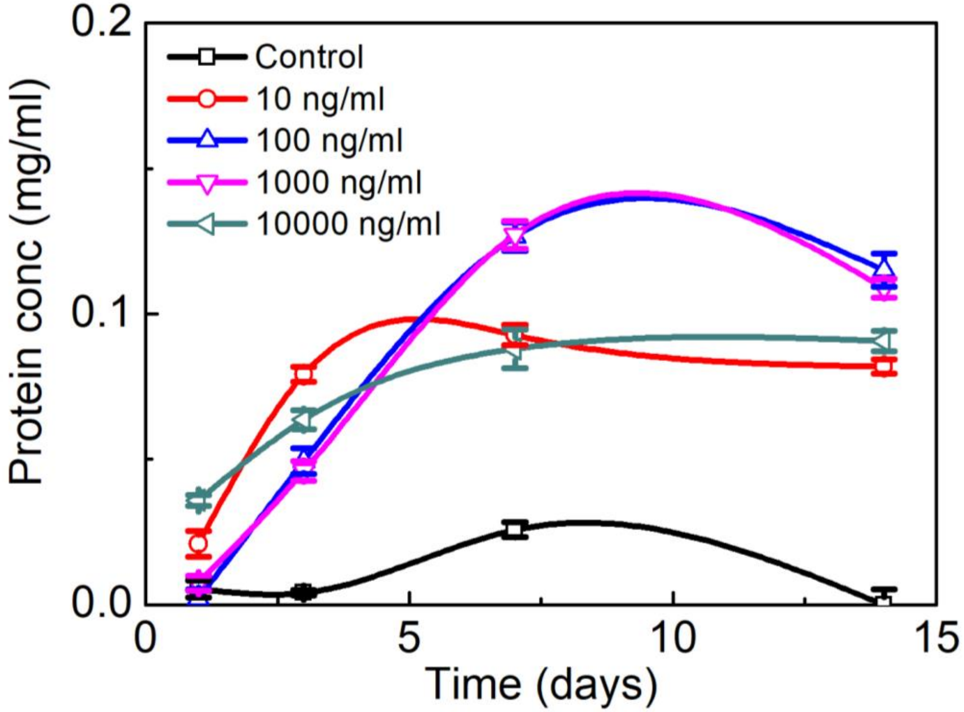

C
O
S
N
F
10 µm
Electron

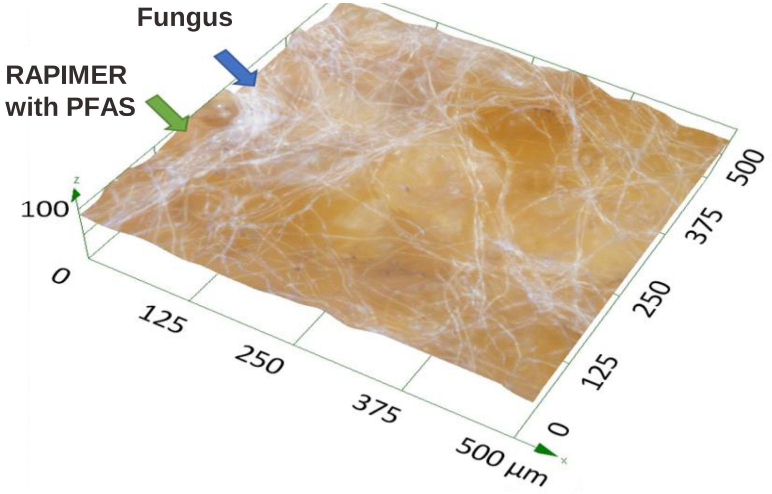

PFOA concentration (ng/ml)
Replicate 1
Replicate 2
Replicate 3
Average
1ng/ml PFOA water
10ng/ml PFOA water
0
2
4
6
8
10
1 ng/ml
1ng/mL after filteration
10 ng/ml
10ng/mL after filteration


PFOS concentration (ng/ml)
Replicate 1
Replicate 2
Replicate 3
Average
1ng/ml PFOS water
10ng/ml PFOS water
0
2
4
6
8
10
1 ng/ml
1ng/mL after filteration
10 ng/ml
10ng/mL after filteration

Aim 2

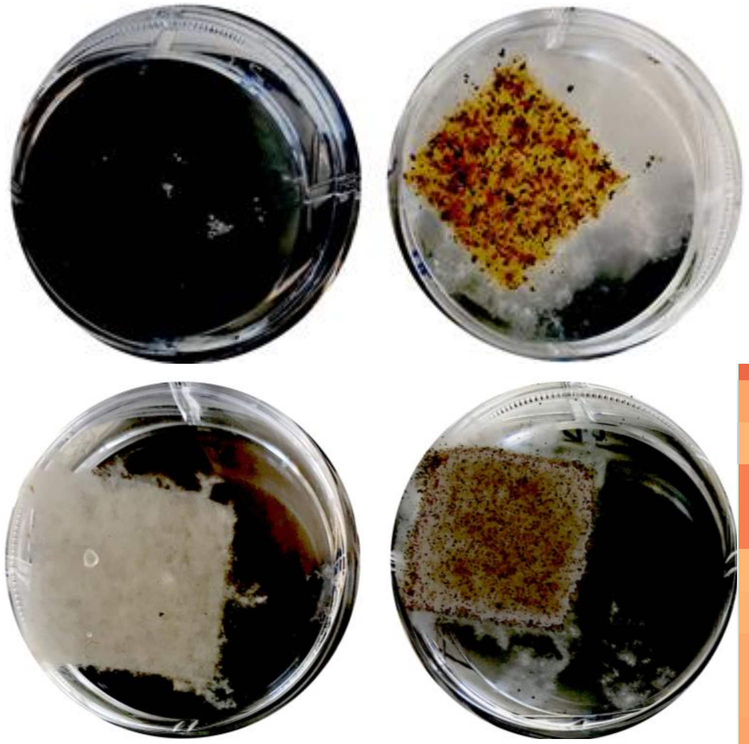




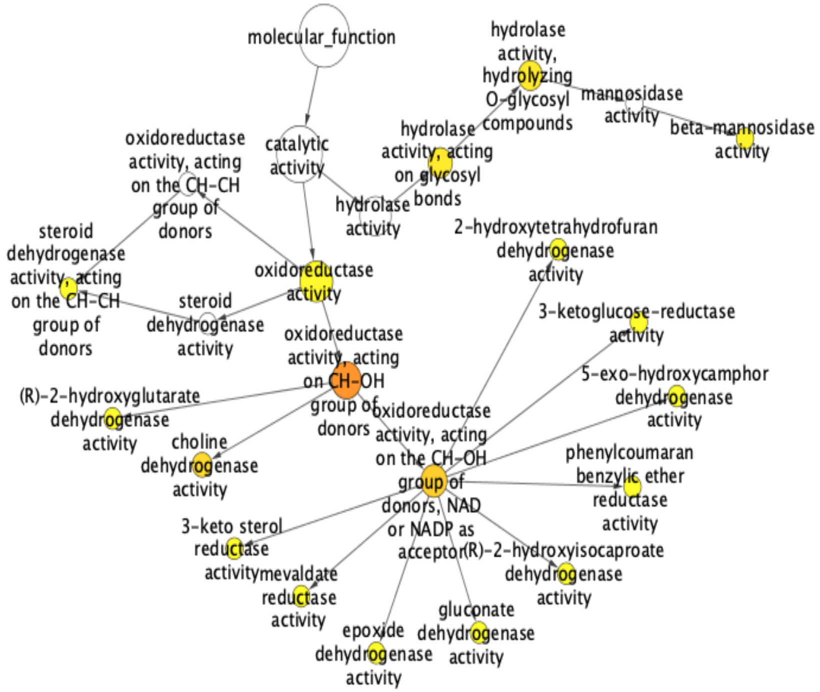


- RAPIMER sustains fungal growth without external carbon source
- RAPIMER can adsorb large amounts of PFAS
- Non-targeted PFAS analysis can help elucidate degradation products

RAPIMER



RAPIMER.PFAS	
5.52	Cellulose 1,4−beta−cellobiosidase
4.71	Mannan endo−1,4−beta−mannosidase
5.60	Hexosyltransferases
4.41	GMC oxidoreductase family
3.98	Glycoside hydrolase, family 5
4.29	Metallopeptidase
2.38	Thioredoxin
3.41	GMC oxidoreductase family
4.47	Endo−1,4−beta−xylanase
3.36	Acylglycerone−phosphate reductase
2.99	Cellulose−binding domain, fungal
4.07	Flavonol reductase/cinnamoyl−CoA reductase
4.11	Voltage−gated shaker−like K+ channel, subunit beta/
2.95	Reductases with broad range of substrate specificitie
3.09	Function unknown
3.24	Glycerol 2−dehydrogenase (NADP+)
3.23	Beta−glucosidase
3.43	Glycoside hydrolase, family 5
3.05	With NAD(+) or NADP(+) as acceptor
2.95	60s ribosomal protein L23
2.72	Function unknown
2.55	Voltage−gated shaker−like K+ channel, subunit beta/KCNAB
2.14	Voltage−gated shaker−like K+ channel, subunit beta/KCNAB
2.50	Cytochrome P450 CYP4/CYP19/CYP26 subfamilies
2.57	Peptidyl−prolyl cis−trans isomerase



RAPIMER sustains the fungal growth on the PDA plate

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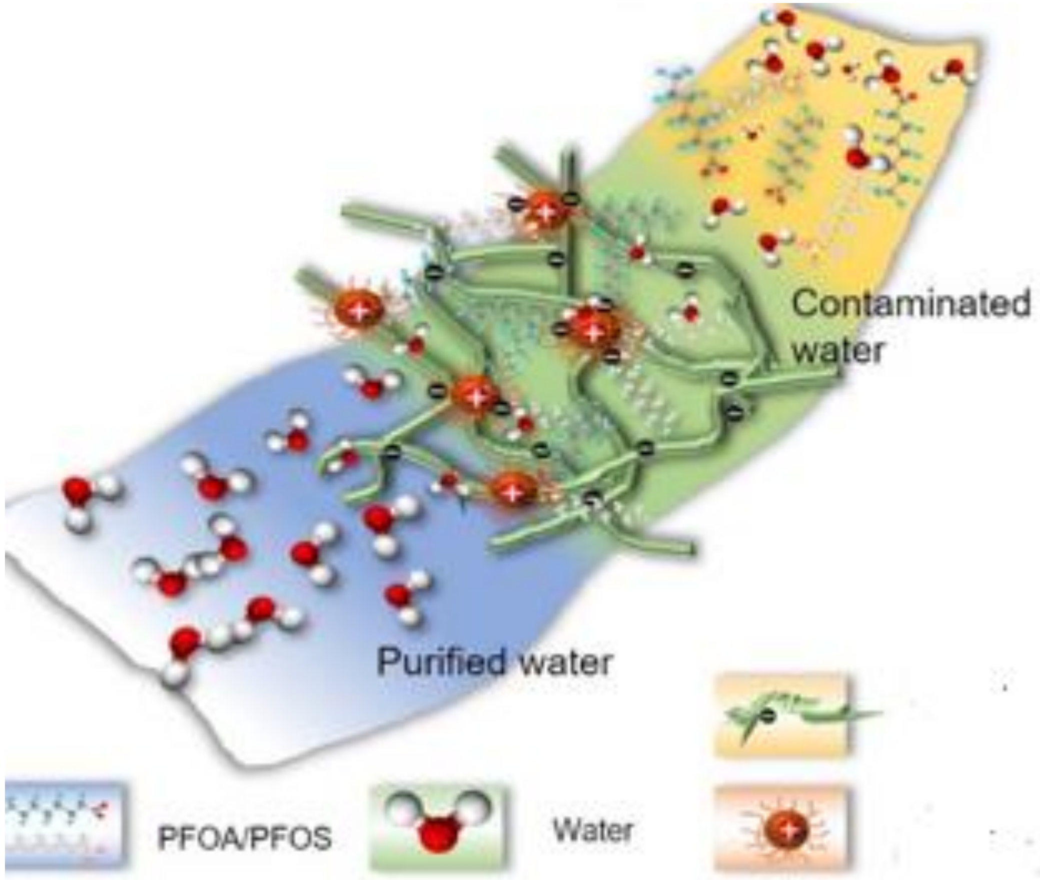
Summary

- The prototype of NFF-RAPIMER has been developed
- Highly efficient sorbent for PFAS and organic dye
- Sustains fungal growth as the carbon source and enables PFSA biotransformation
- The fungal *I. lacteus* strain degrades RAPIMER and PFAS, as revealed by the proteomics and metabolite analysis



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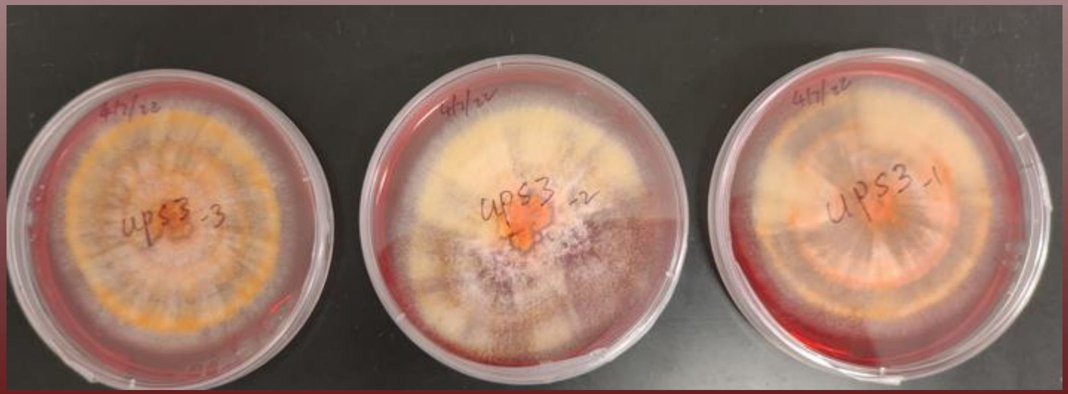
Future work

- Screen a large fungus library and identify PFAS tolerant fungi species
- Further optimize RAPIMER for larger scale applications and more matrices
- Non-targeted analysis for PFAS degradation products
- Proteomics for important genes and pathways



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  - Rachel Mole
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  - Dr. Rita Lopes

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