

Biodegradation of CNT-polymer nanocomposites

The Influence of CNTs

Howard Fairbrother

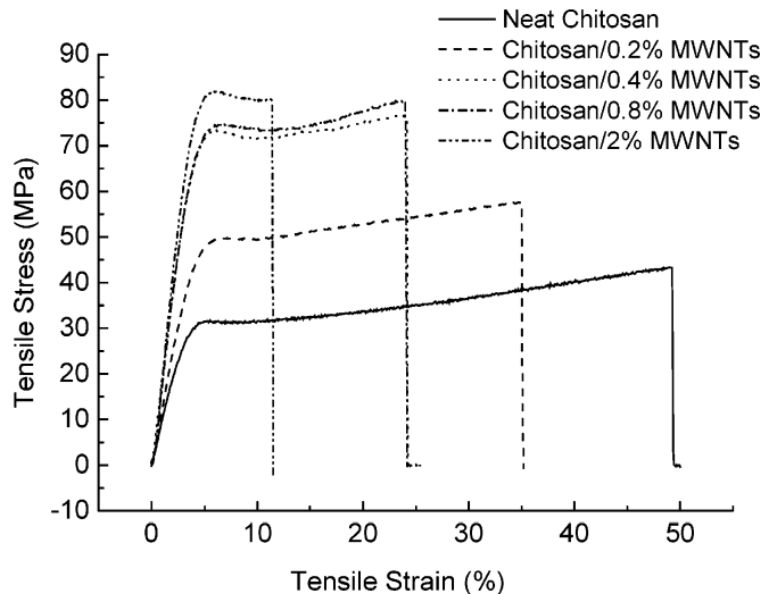
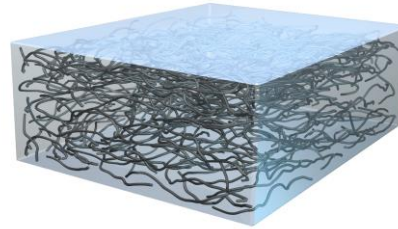
Department of Chemistry

Johns Hopkins University



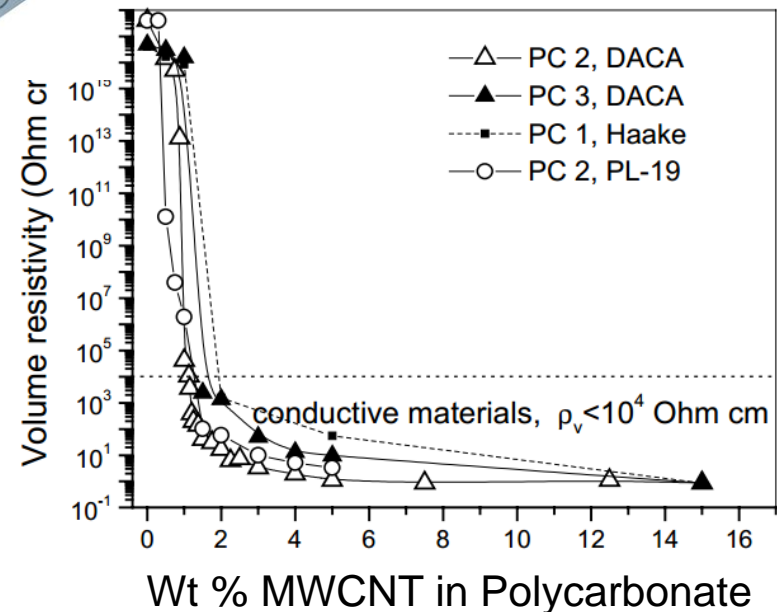
Why add CNTs to Polymers ?

Structural Properties¹



Chitosan:
Poor Properties,
Limited Usability

Functional Properties²



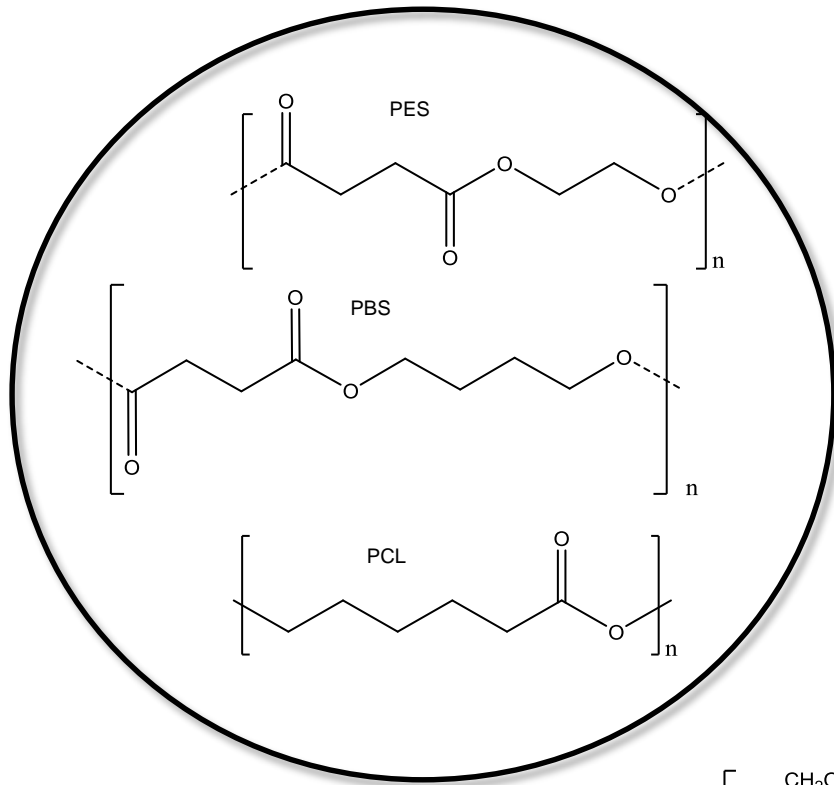
Polycarbonate:
Property Enhancement,
Multifunctional

1) Wang et al., *Biomacromolecules*, **2005**, 6, 3607.
2) Potschke et al., *AIP Conf. Proc.* **2004**, 43, 3247.

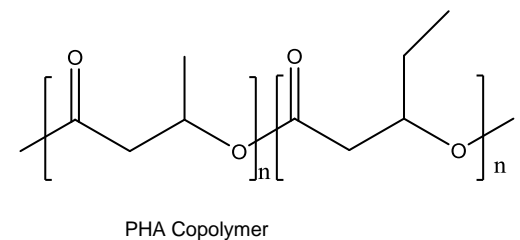
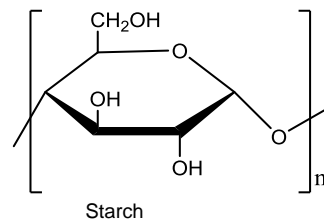
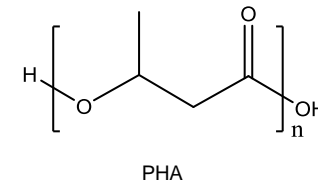
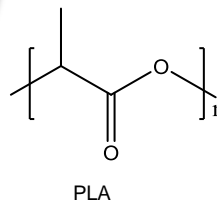
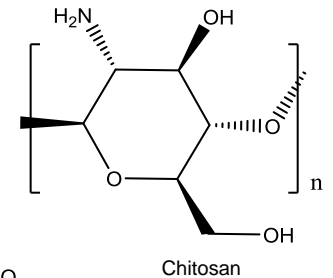
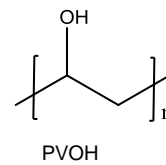
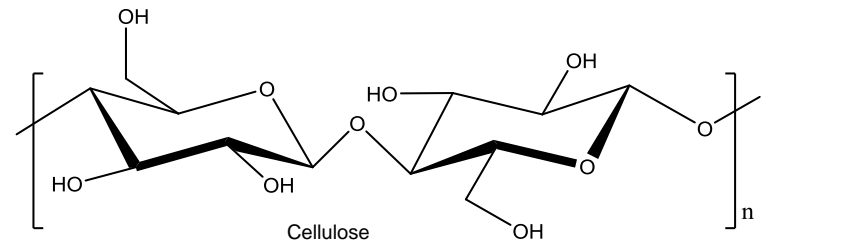
Biodegradable Polymers

Often cheap but without CNTs, poor properties can preclude the use of these polymers in products

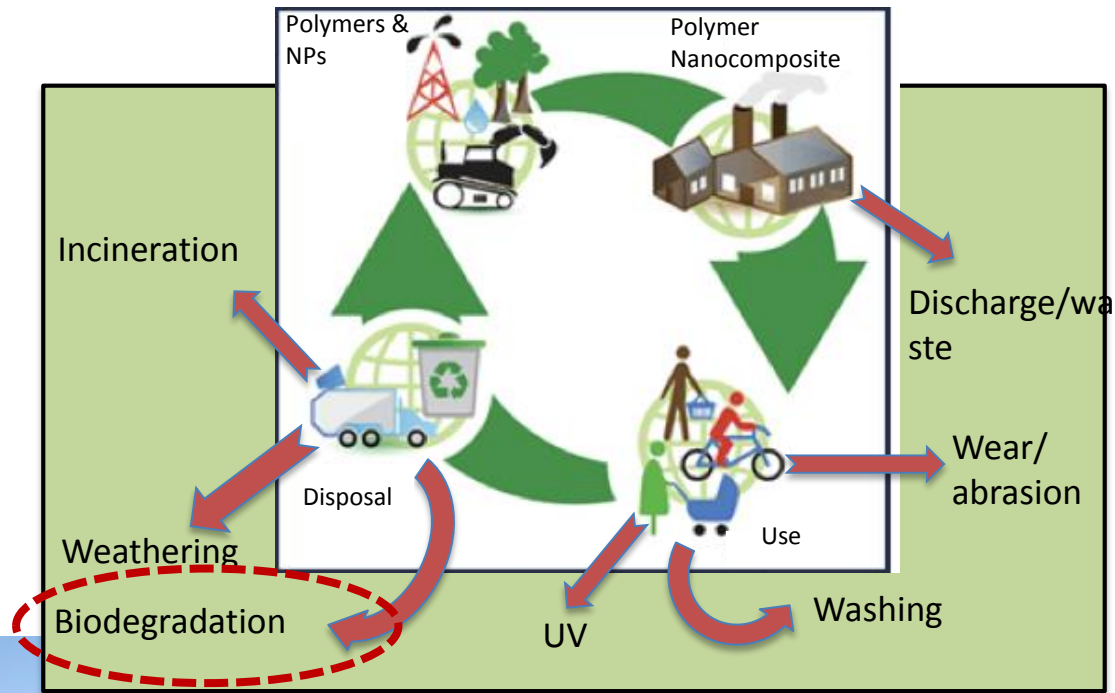
Synthetically Derived



Bio-Derived



Life Cycle Perspective



Motivation

If the polymer matrix is biodegradable:

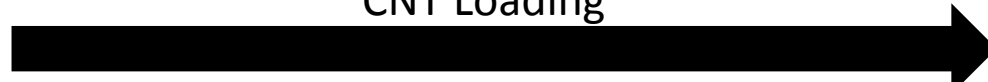
- How does the presence of CNTs impact the biodegradability?
- Does biodegradation lead to CNT release?

Synthesis of CNT Composites

Solution Blending



CNT Loading

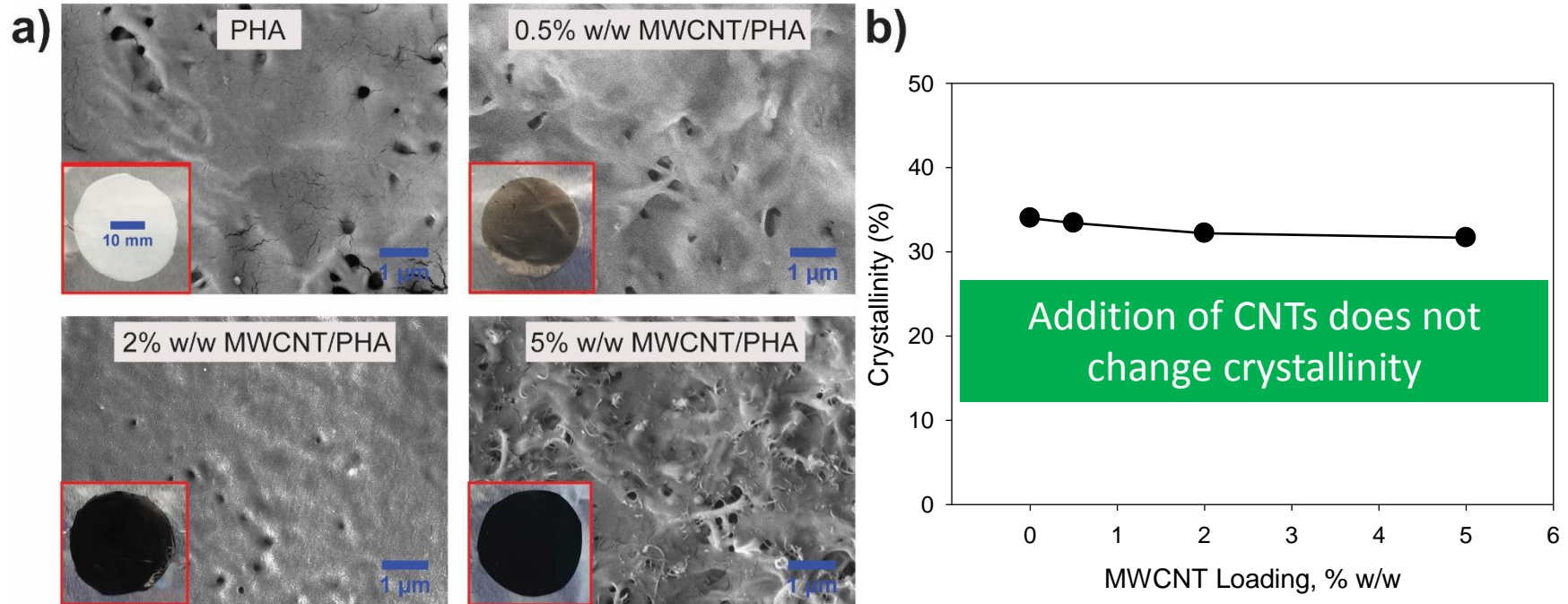


Influence of CNTs on Polymer Biodegradation

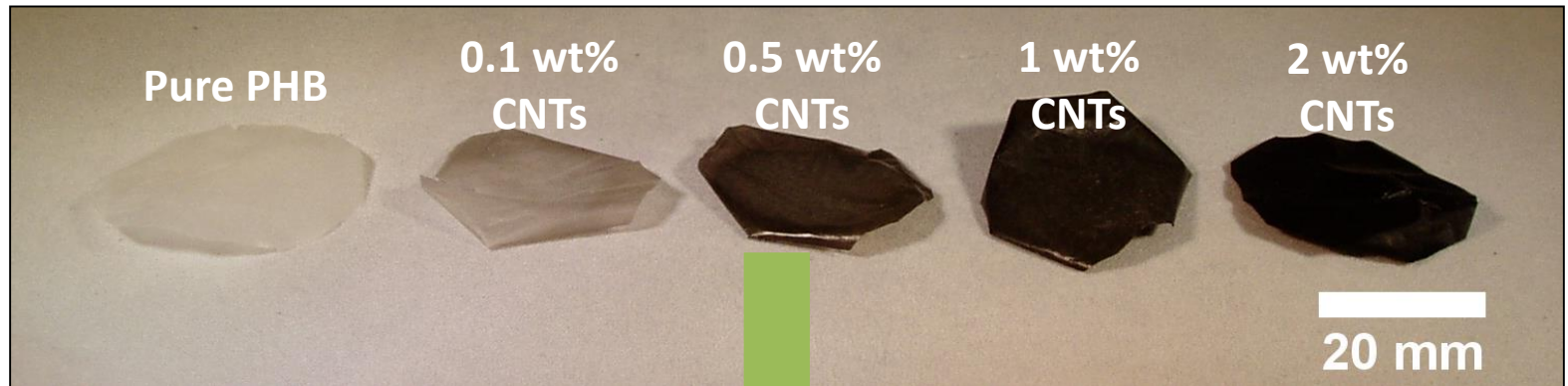
Two Case Studies:

1. PCL/Single Culture
2. PHA/Mixed Culture

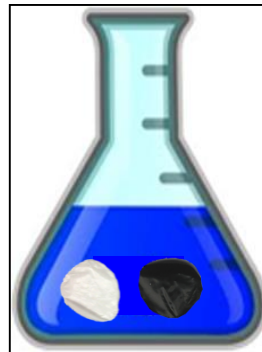
Characterization: Does the Inclusion of CNTs Change Crystallinity?



Experimental Approach



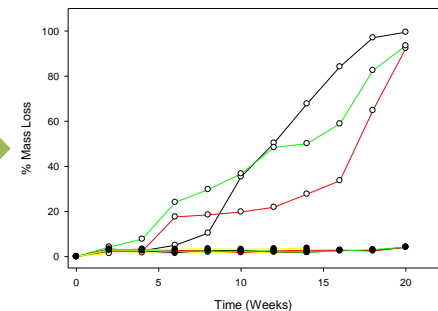
Add
&
Incubate



Microorganism

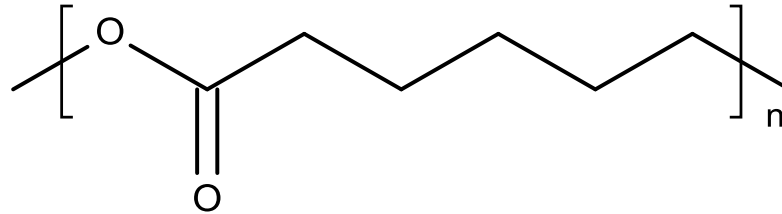
Remove
&
Weigh

Measure
%Mass Loss



One end of the spectrum:

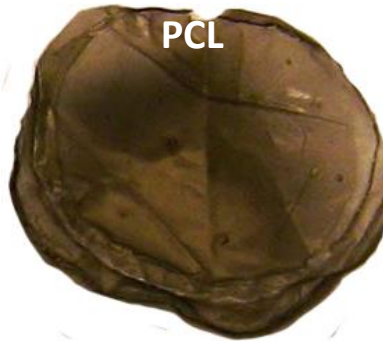
Polycaprolactone (PCL) – CNT Composites



PCL



**0.1 wt.% O-MWNT in
PCL**



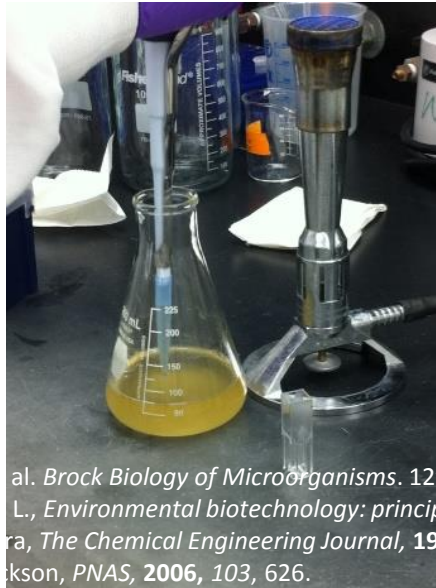
**2 wt.% O-MWNT in
PCL**



Microorganism

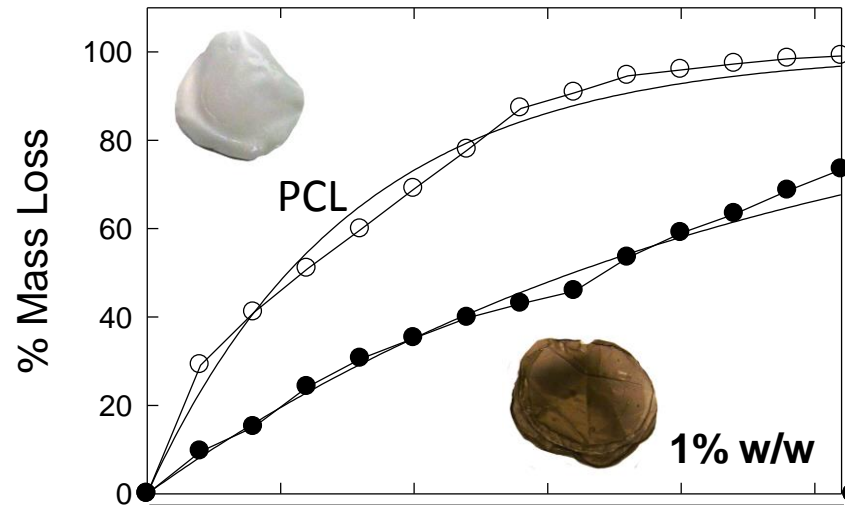
Single Culture

- *Pseudomonas aeruginosa*¹
- Model, gram negative microorganism commonly found in soil

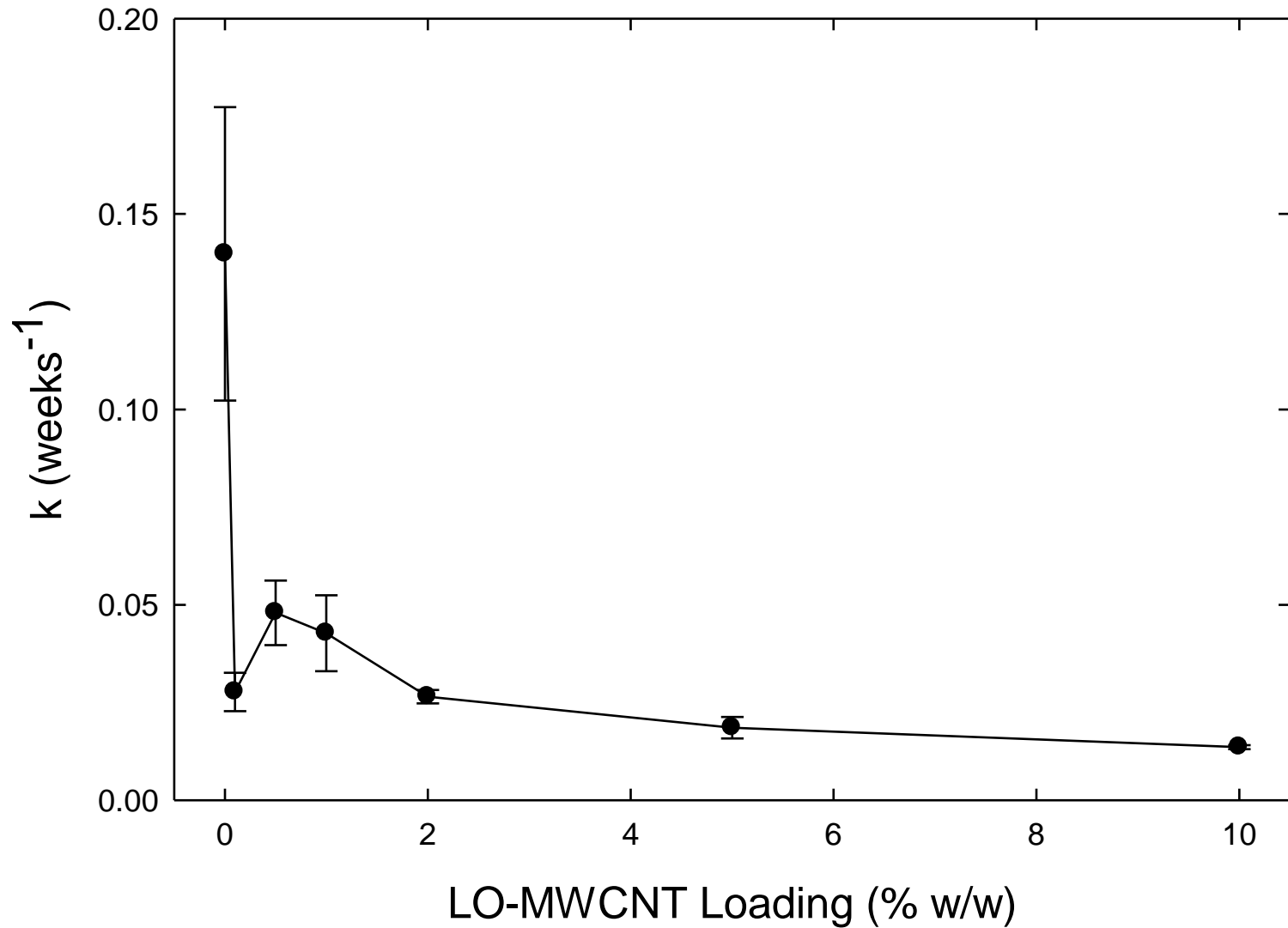


al. *Brock Biology of Microorganisms*. 12th ed. L., *Environmental biotechnology: principles and applications*, *The Chemical Engineering Journal*, 1987, 1987, 1987. Jackson, *PNAS*, 2006, 103, 626.

Biodegradation: CNT Content Matters

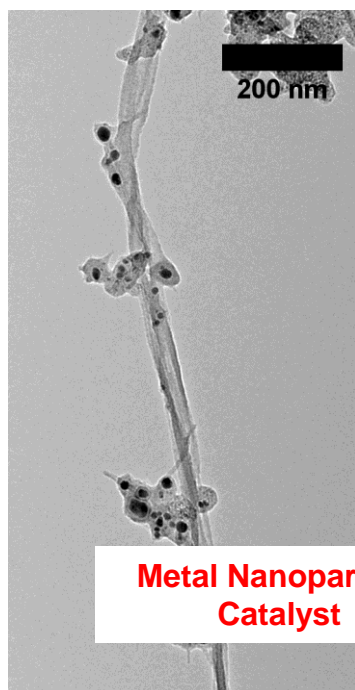


CNT Content Matters



Does Biodegradation of the Polymer
Nanocomposite Lead to CNT Release?

Detection of SWNTs at environmentally relevant concentrations by monitoring residual trace metal catalysts using single particle ICP-MS



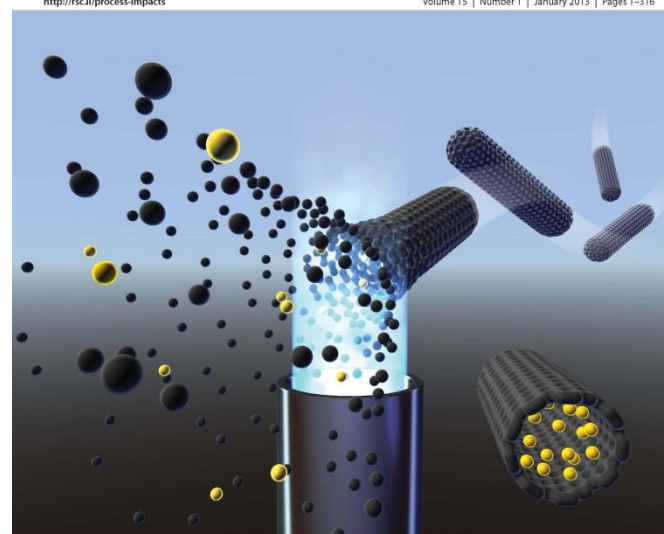
**Metal Nanoparticle
Catalyst**

Environmental Science Processes & Impacts

Formerly Journal of Environmental Monitoring

<http://rsc.li/process-impacts>

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Themed issue: Anthropogenic nanoparticles in the environment

ISSN 2050-7887

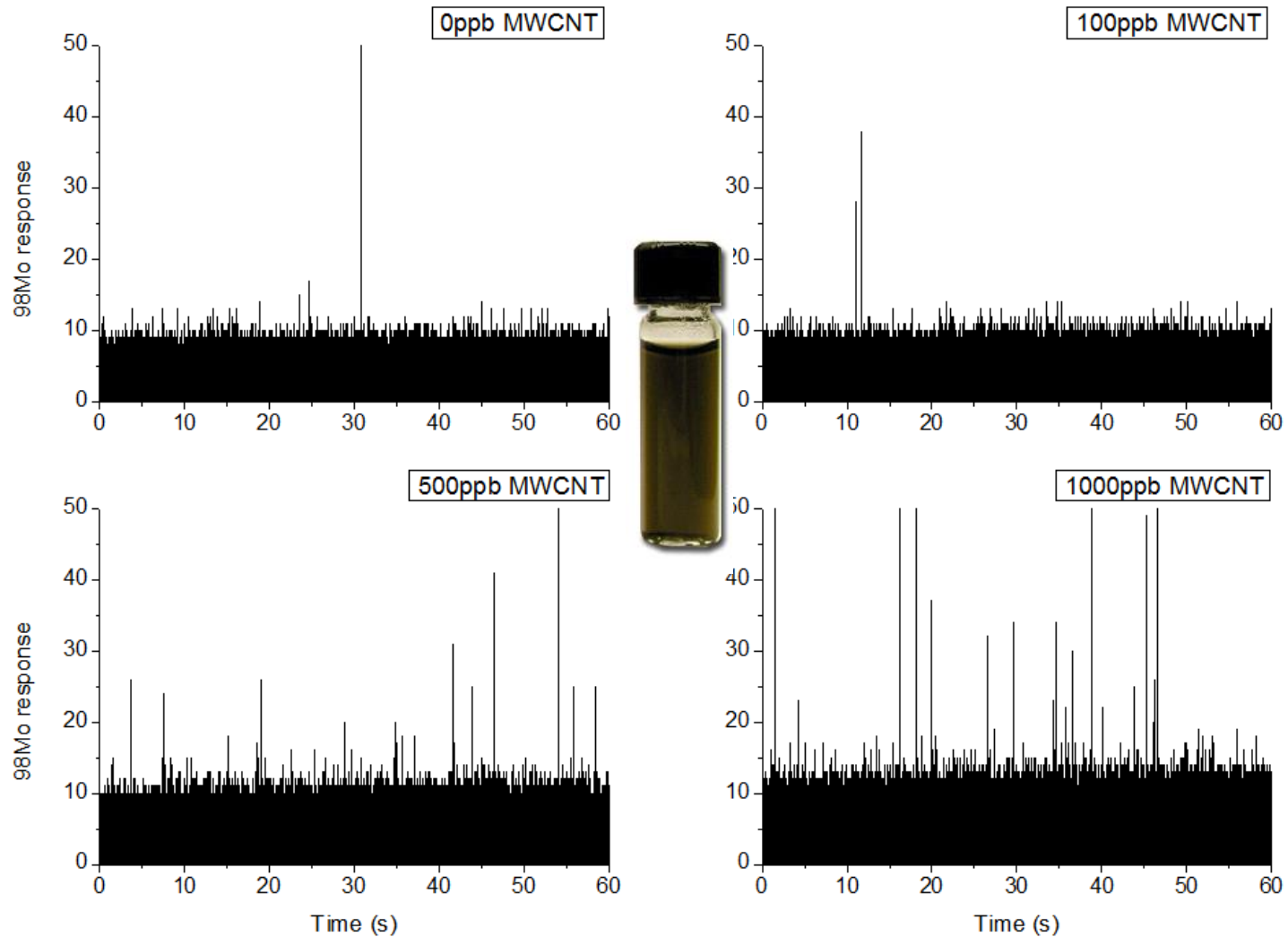
RSC Publishing

PAPER
James F. Ranville et al.
Detection of single walled carbon nanotubes by monitoring embedded metals

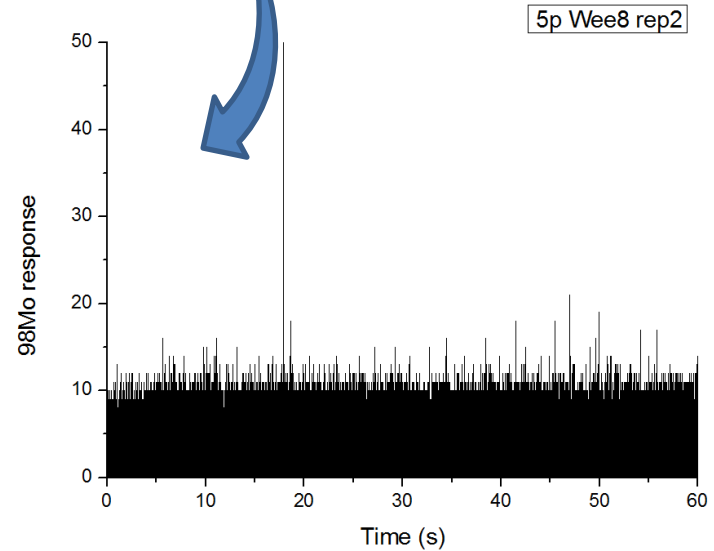
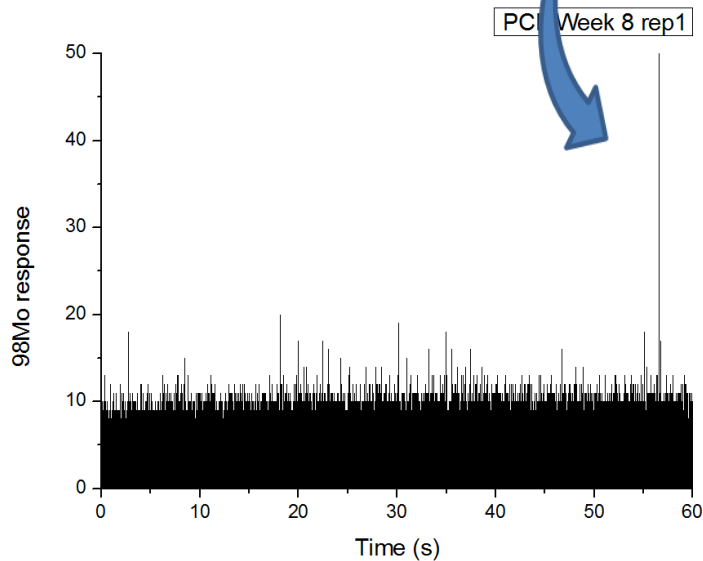
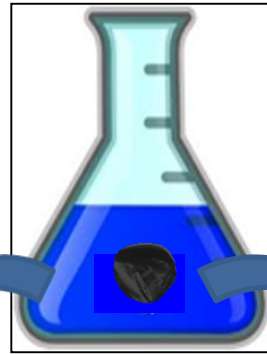


2050-7887 (2013)15:1;1-4

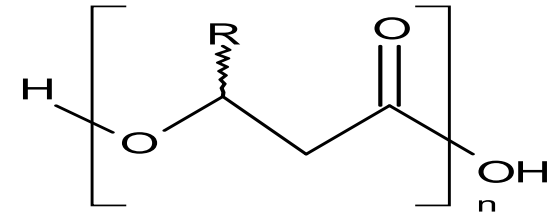
Using Mo to Detect MWCNTs



No Measureable ($< 200 \mu\text{g/L}$) MWCNT Release During Biodegradation

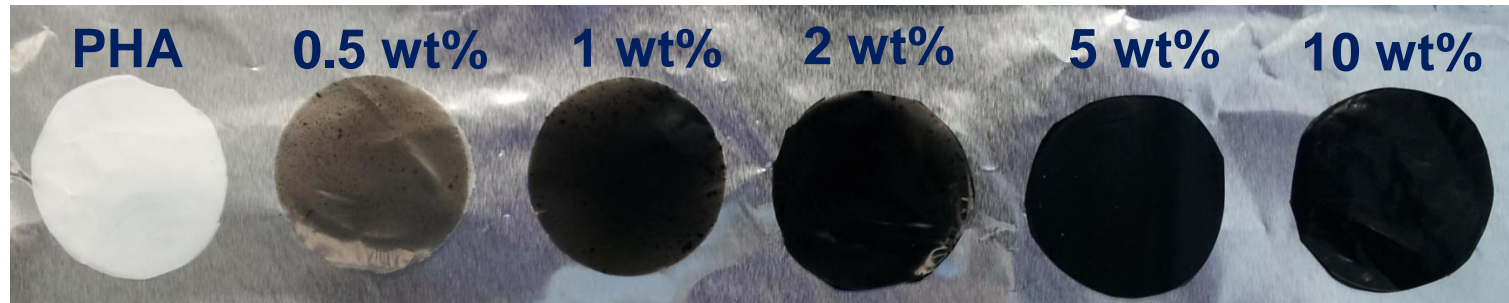


The Other end of the Spectrum: Polyhydroxyalkanoates (Bio-polymer)



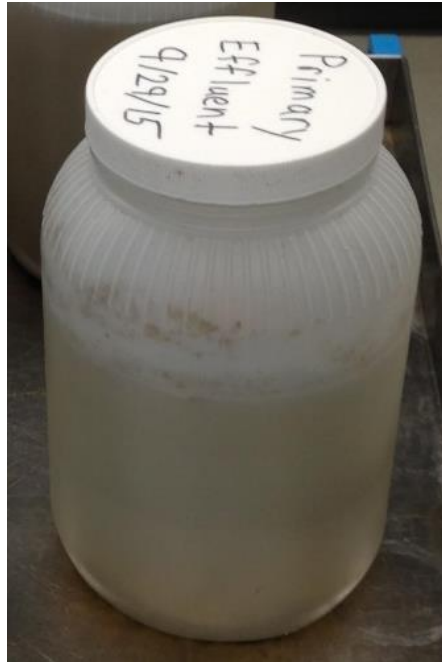
Rapidly Biodegraded

- Biodegradation studies using primary effluent (mixed culture)
- Pristine MWCNTs



Microorganism

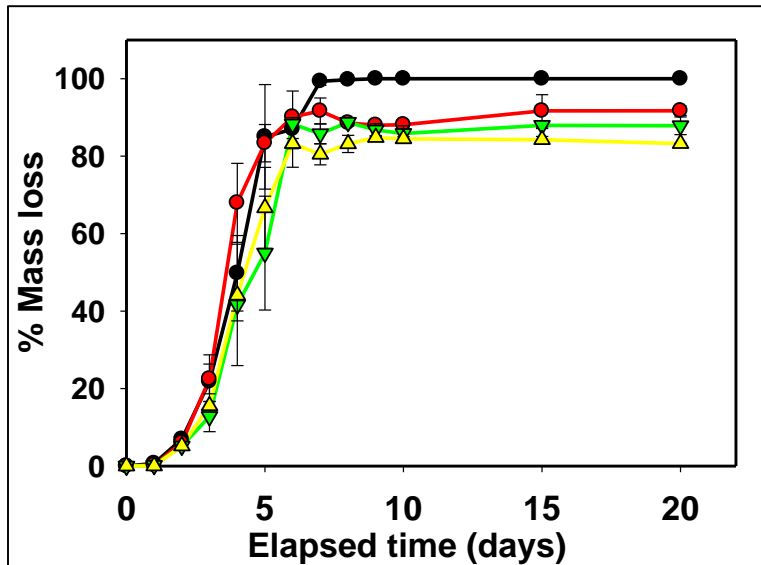
Mixed Culture



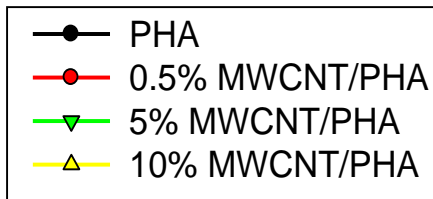
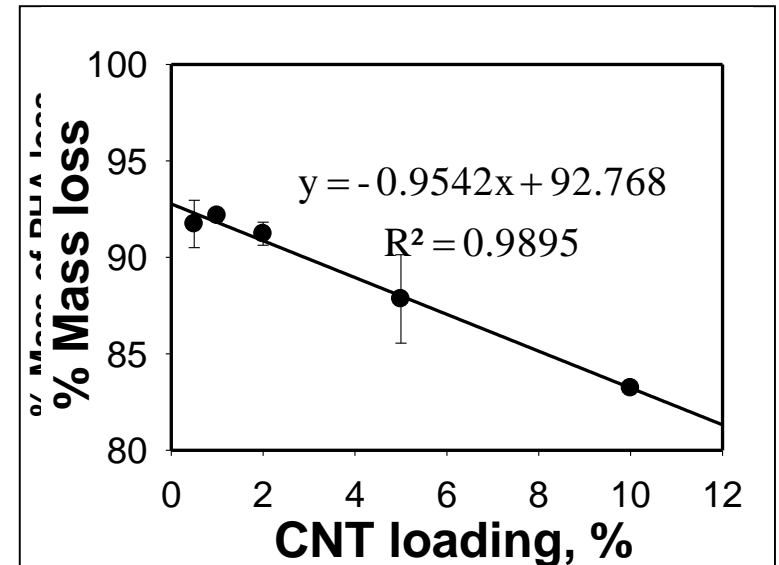
Aerobic: Primary effluent
(wastewater after settling of
solids)⁴

Mass Loss of MWCNT/PHA Nanocomposites

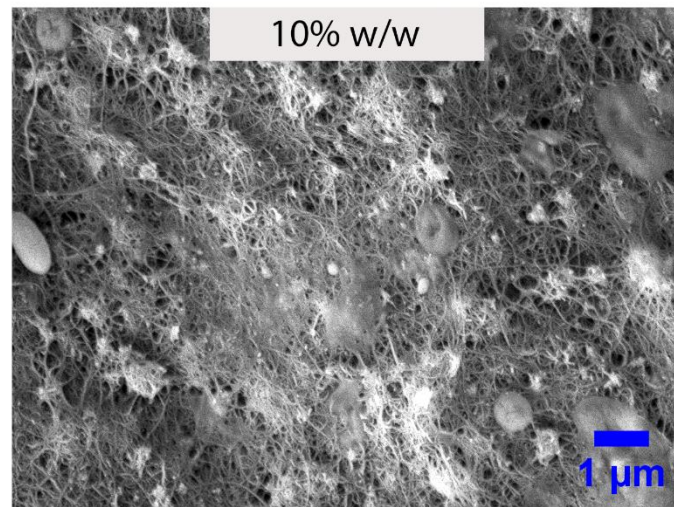
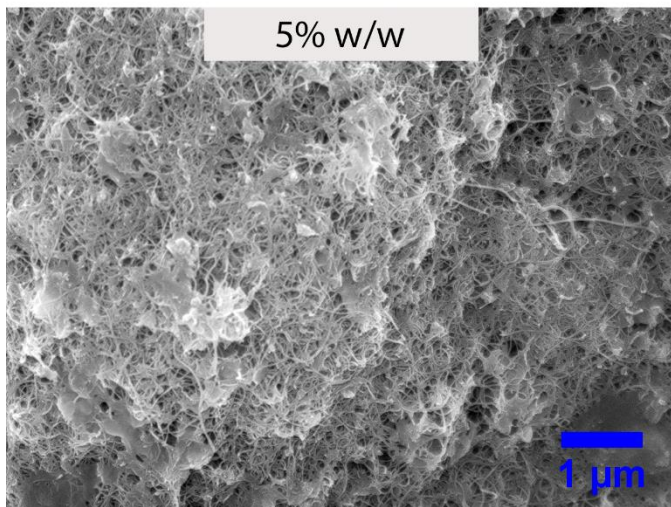
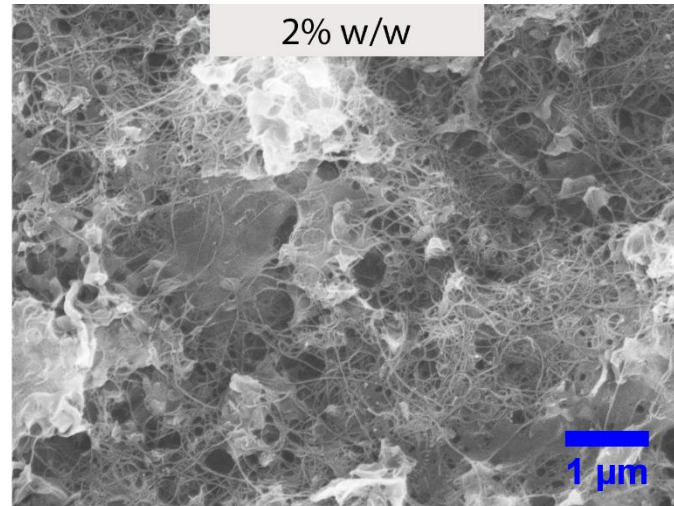
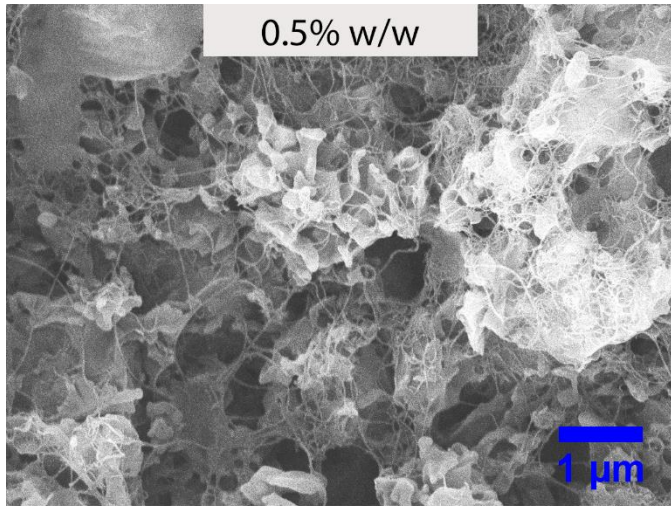
% mass loss entire nanocomposite



% mass loss polymer matrix



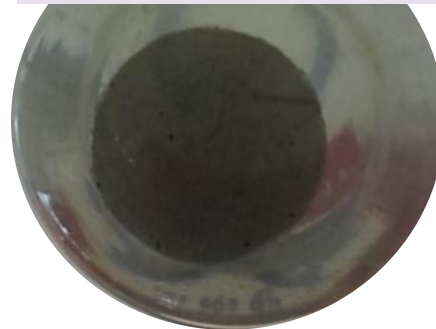
Nanocomposites at the End of Biodegradation



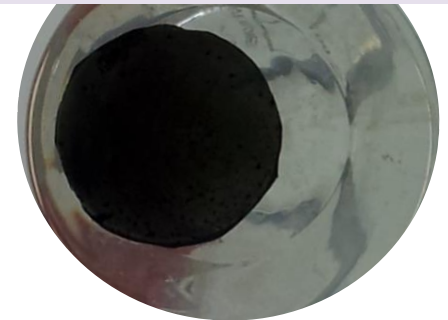
Physical Transformation of Nanocomposites

Despite >90% mass loss, all CNT/PNCs of varied CNT loading remained intact after biodegradation in mixed culture.

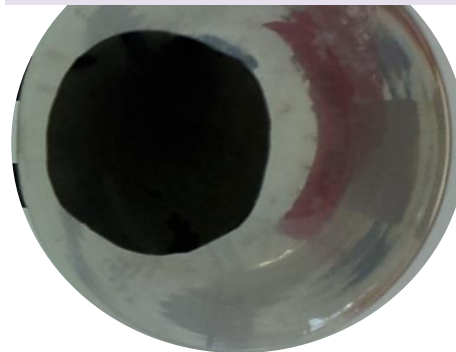
0.5% w/w
MWCNT/PHA



2% w/w
MWCNT/PHA



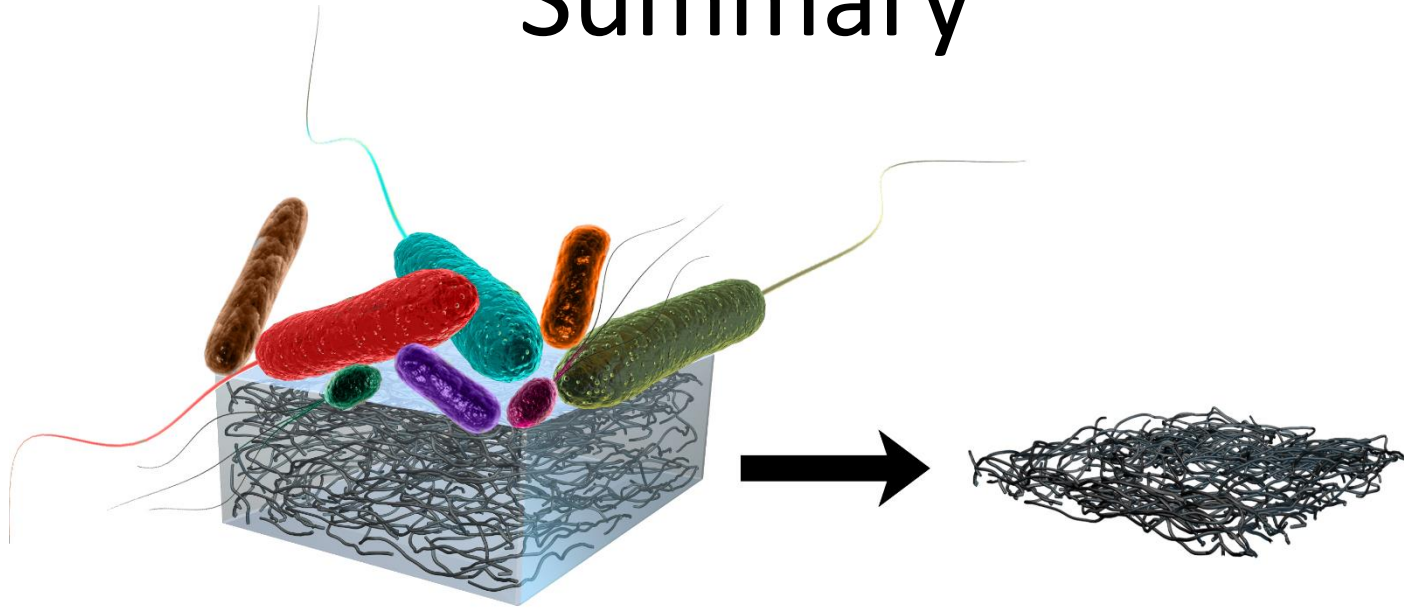
5% w/w
MWCNT/PHA



10% w/w
MWCNT/PHA

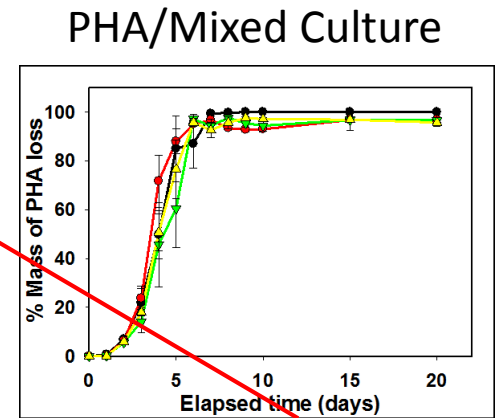
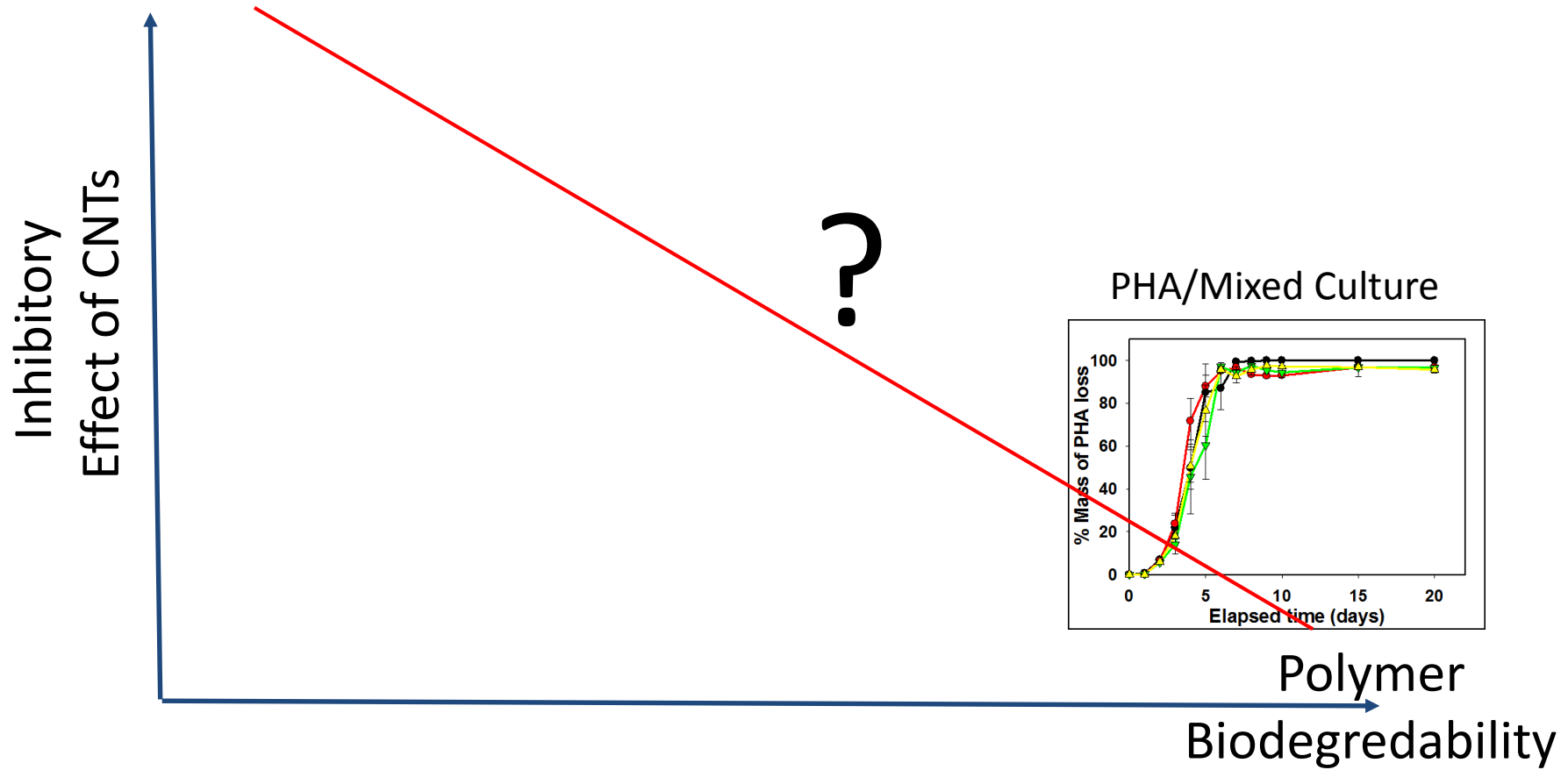


Summary



- Degradation of CNT polymer nanocomposite causes a compressed structure to form that still retains its basic shape
- No obvious release of CNTs even when $> 95\%$ mass loss is observed (strength of CNT-CNT interactions through London dispersion forces)

Conclusions



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JJ Wang

