# Emerging microenvironmental approaches for enhanced bioremediation

Bioremediation - Expanding the Toolbox

Session III: Emerging Opportunities

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Microvi

# Presentation Outline

## Part I: Cometabolism

- Introduction to organic compounds as environmental contaminants
- Cometabolism is a promising bioremediation strategy
- Key technical challenges in cometabolism-based bioremediation

## Part II: Microenvironmental Engineering

- Introduction to microenvironmental engineering
- The application of a selected microenvironmental engineering approach for the bioremediation of chlorinated solvents

## Part III: Predictive Modeling & Future Directions

- Research trends in the applications of computational modeling
- Use of microbiomics to build functional models for enhanced bioremediation

# About Microvi Biotechnologies

Microvi works at the *intersection of materials science and biology* to discover, design and implement next-generation industrial bioprocesses, focusing on water purification, wastewater treatment and reuse, and the production of biobased chemicals.

Lack of Clean Drinking Water

Air Pollution

Petroleum Dependence

Climate Change

Environmental Degradation

Wasteful Technologies and Processes

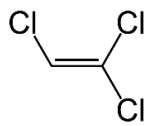
Outdated Infrastructure

Polluted Lakes and Rivers

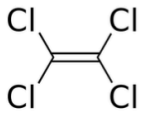
# Part I: Cometabolism

<u>Chlorinated Solvents (examples):</u>

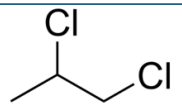
- Dichloromethane
- Chloroform
- Bromodichloromethane
- Dibromochloromethane
- Trichlorofluoromethane
- Carbon tetrachloride
- Dichloroethane
- Trichloroethane
- Tetrachloroethane
- Trichloropropane
- Chlorobenzene




Trichloroethylene (TCE)




Perchloroethylene (PCE)

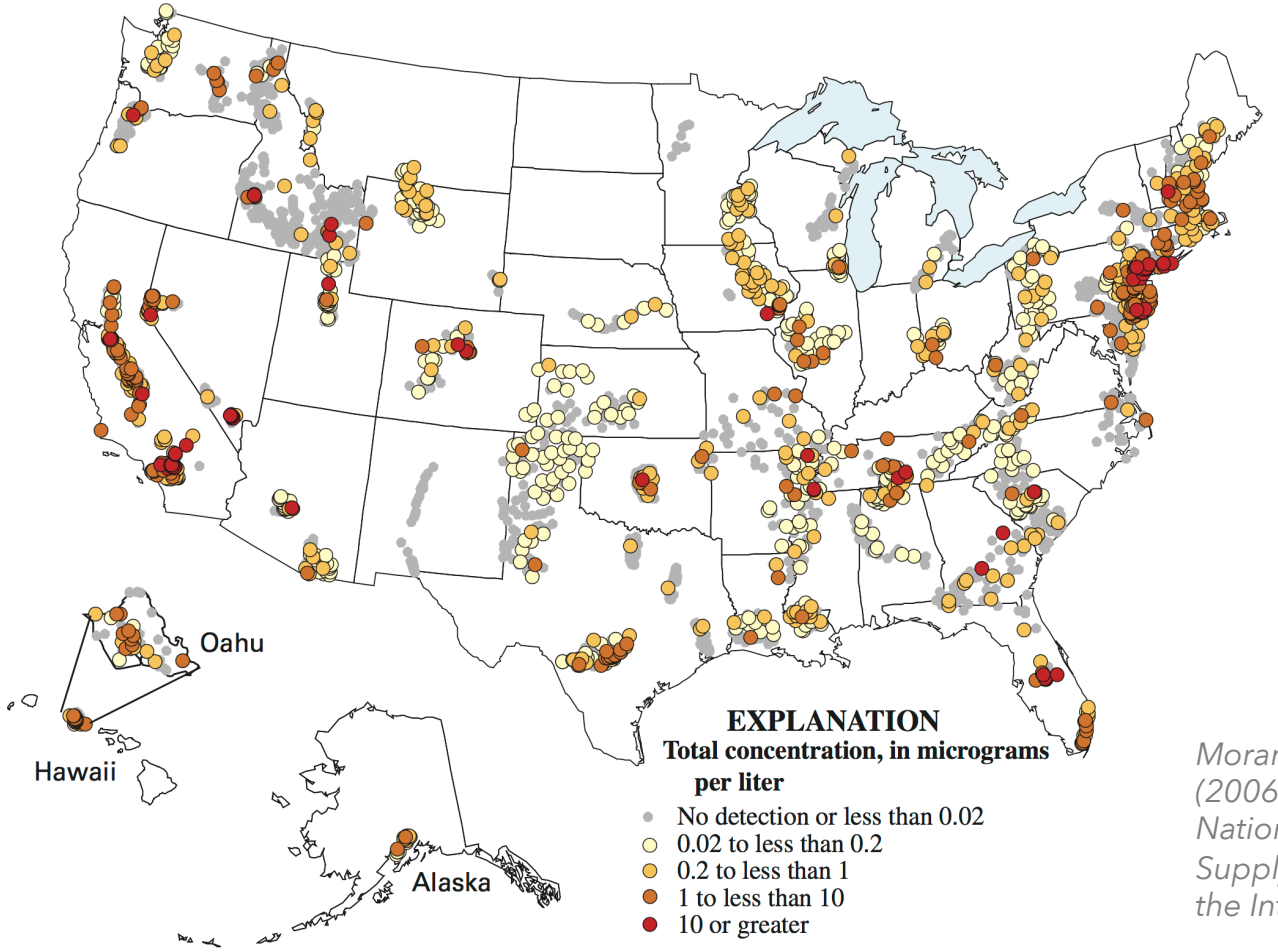



1,2-dichloropropane

- N-Nitrosodimethylamine (NDMA)
- Polychlorinated biphenyls (PCBs)
- Polycyclic aromatic hydrocarbons (PAHs)
- Methyl tert-butyl ether (MTBE)
- 2,4,6-trinitrotoluene (TNT)
- 1,4-dioxane
- Dieldrin
- Nitroaromatic compounds
- 2,2-bis(p-chlorophenyl)-1,1-dichloroethylene) (DDE)
- Pentachlorophenol (PCP)

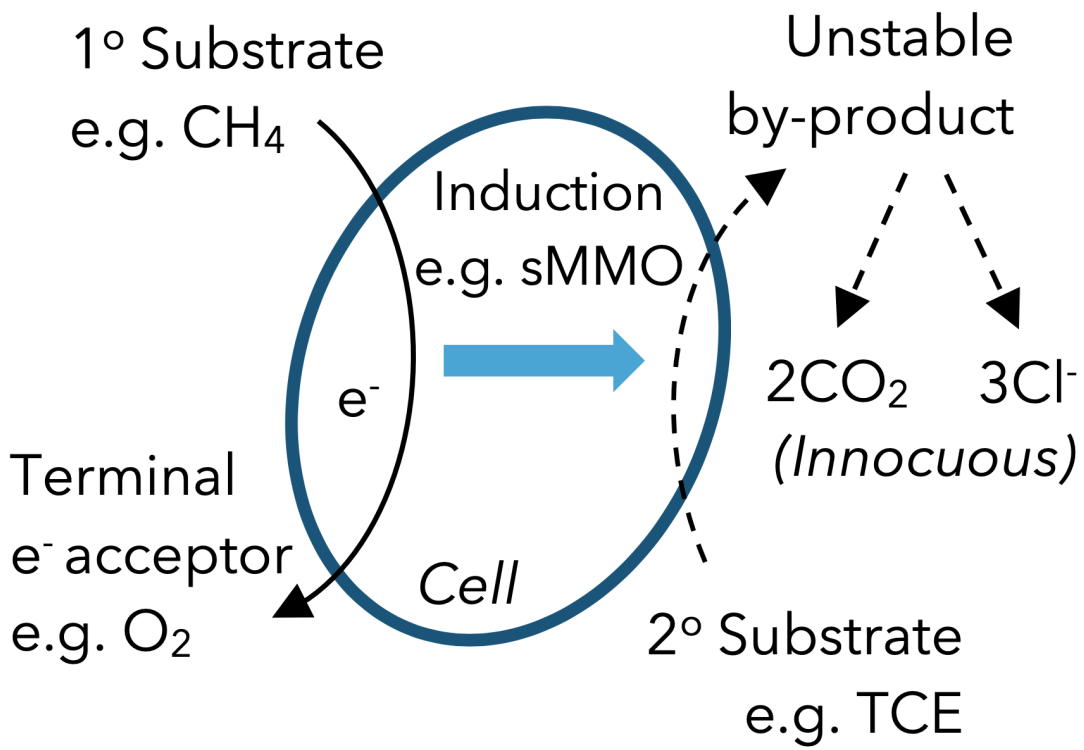
- BTEX (benzene, toluene, ethylbenzene, xylenes)
- Pyrene
- Atrazine
- Creosote
- Propylene
- Chlordane
- Aldrin
- Benzidine
- Acrolein
- Endosulfan
- Naphthalene

# Widespread occurrence of volatile organic compounds (VOCs) in drinking water




*Moran, M. J., Hamilton, P. A., & Zogorski, J. S. (2006). Volatile Organic Compounds in the Nation's Ground Water and Drinking-water Supply Wells: A Summary. US Department of the Interior, US Geological Survey.*

# Introduction to aerobic cometabolism




- Cometabolism involves the degradation of a secondary substrate when a general enzyme is induced by a primary substrate.
- Some contaminants may only be effectively degraded through cometabolism
- Cometabolism may offer faster and more efficient degradation than other pathways
- Cometabolism may consolidate the biodegradation of different compounds

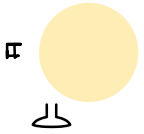
*sMMO: soluble methane monooxygenase*

*TCE: trichloroethylene*

# Technical challenges in the application of cometabolism for bioremediation

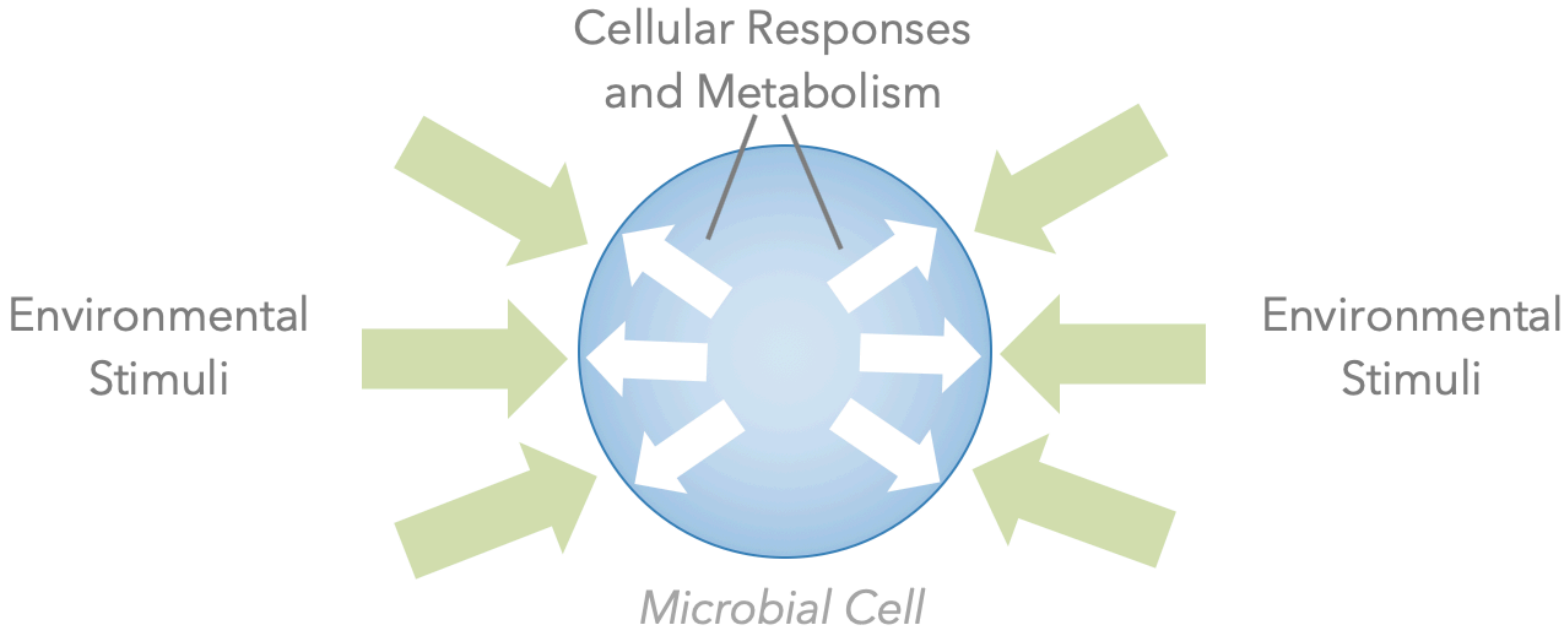
Lack of control over the microbial consortia due to the reliance on indigenous organisms in the bioreactor or treatment zone

The bioavailability of gaseous and/or sparingly soluble primary substrates is rate-limiting, leading to unpredictable induction kinetics

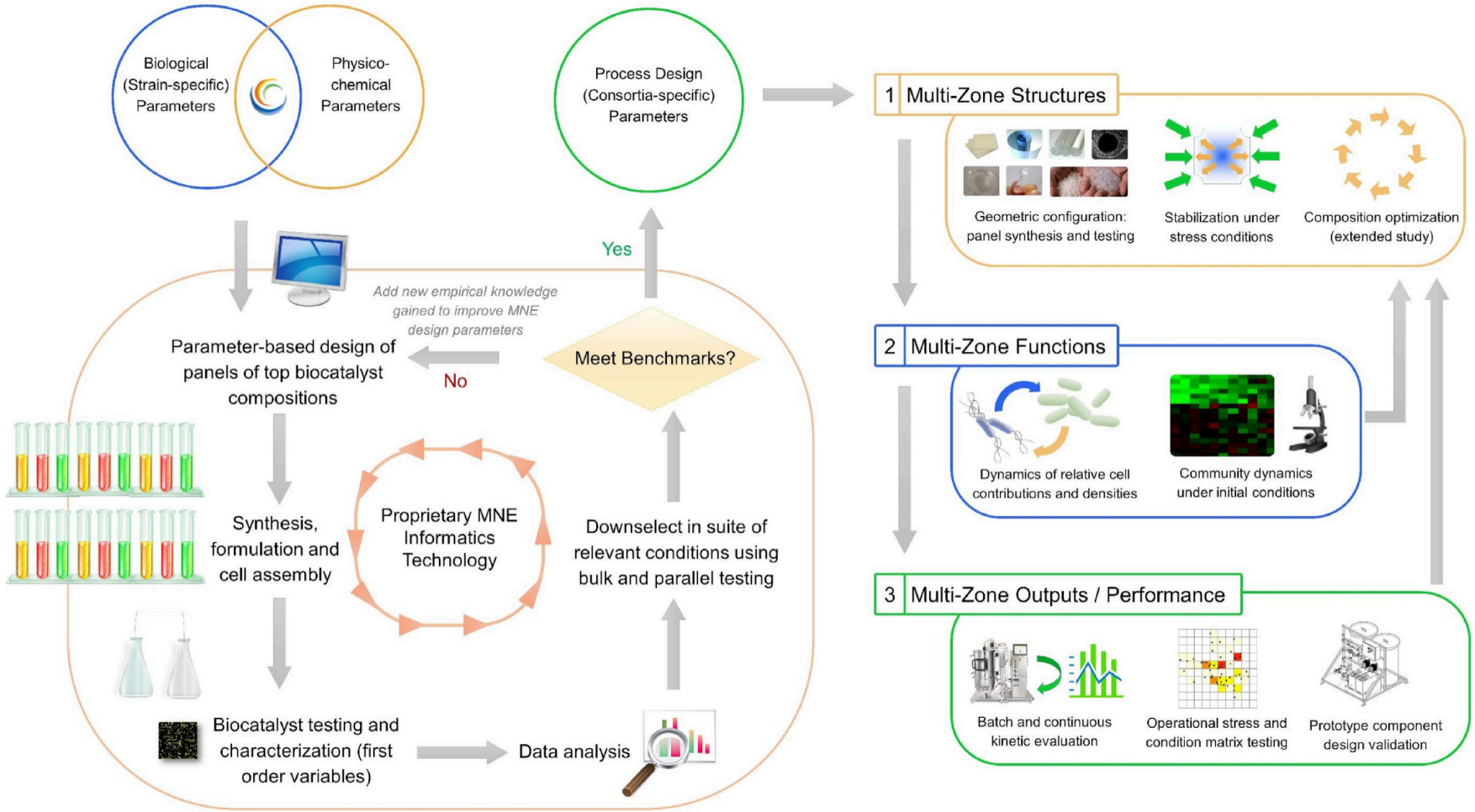


Slow-growing target organisms for cometabolism can lead to long startup periods, instability, and competitive inhibition.

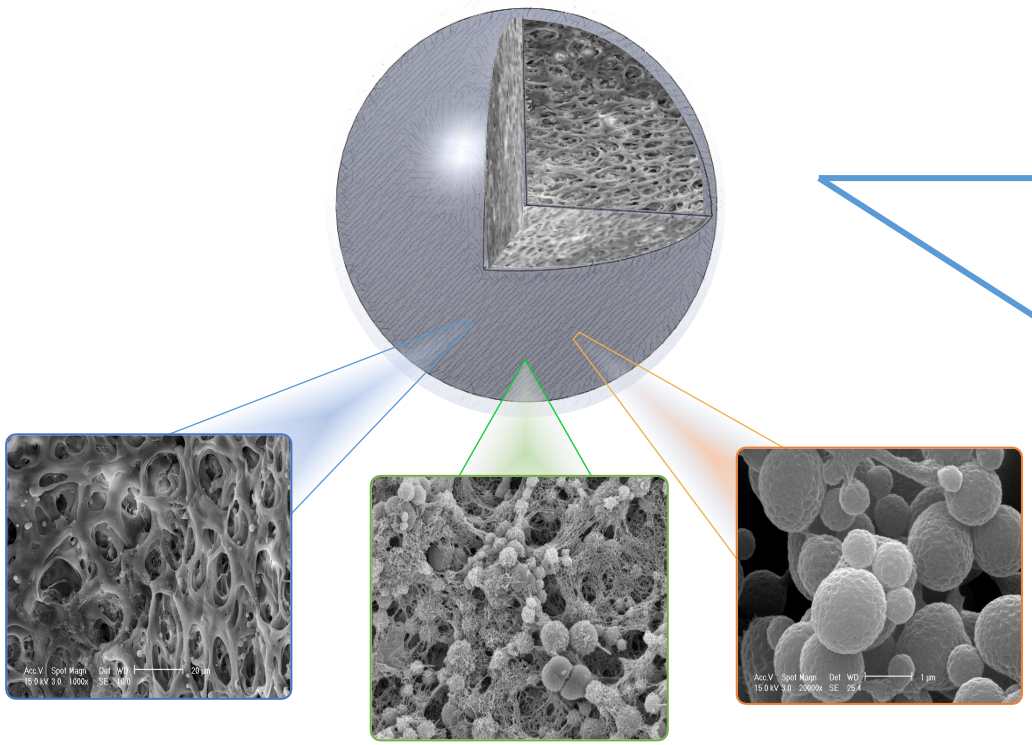
# Part II:
# Microenvironmental Engineering

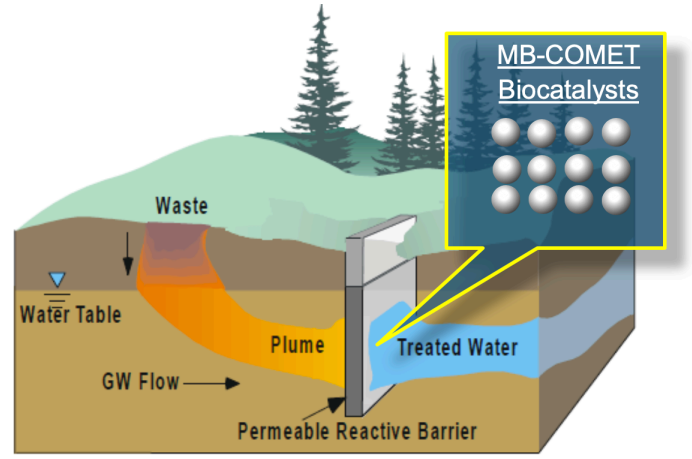


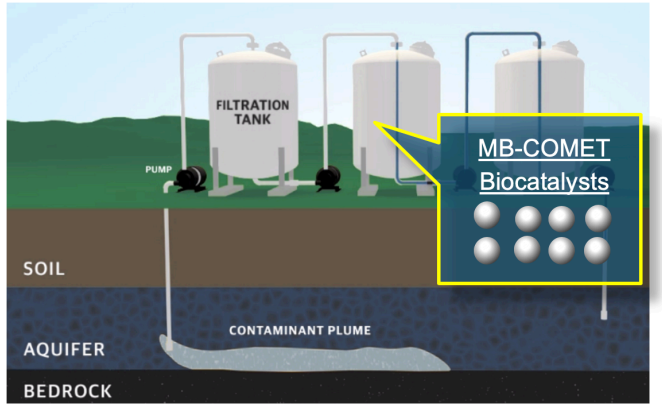
# Microvi's MicroNiche Engineering (MNE) Platform



# The application of microenvironmental engineering for flexible implementation goals



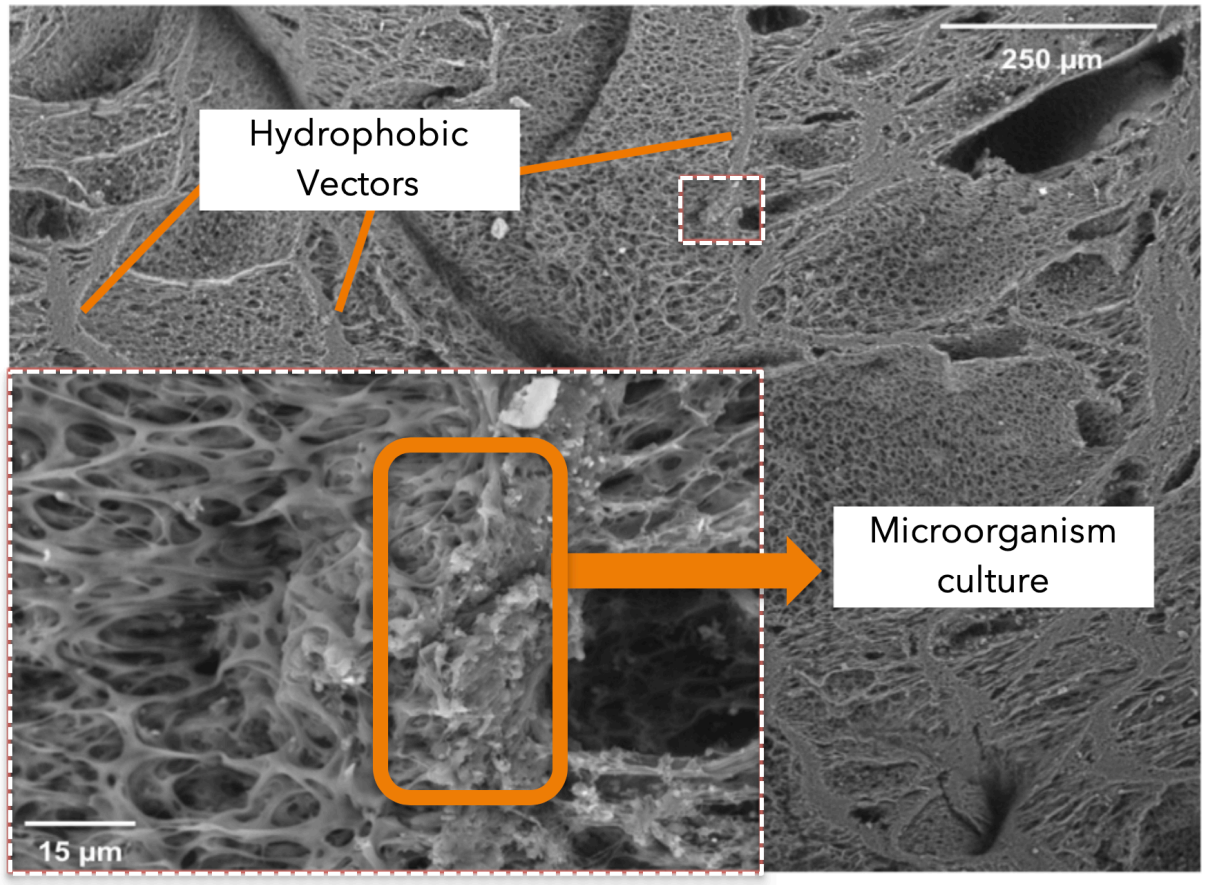


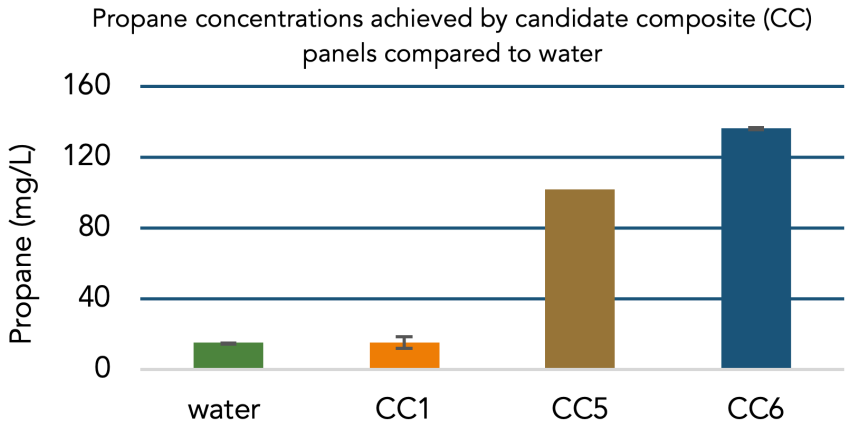



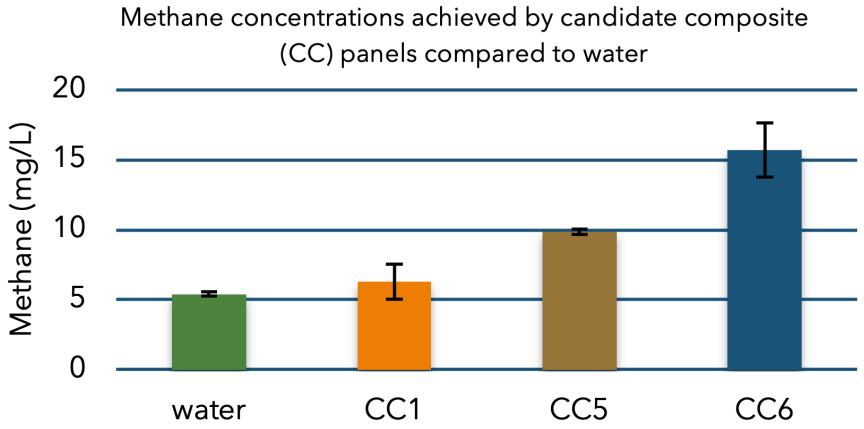

*MB-COMET: Microvi biocatalysts developed for enhanced cometabolism.*

*Supported by NIEHS SBIR/STTR (Contract 2R44ES024670)*

# Design of composite materials for reducing rate-limiting bottlenecks in aerobic cometabolism

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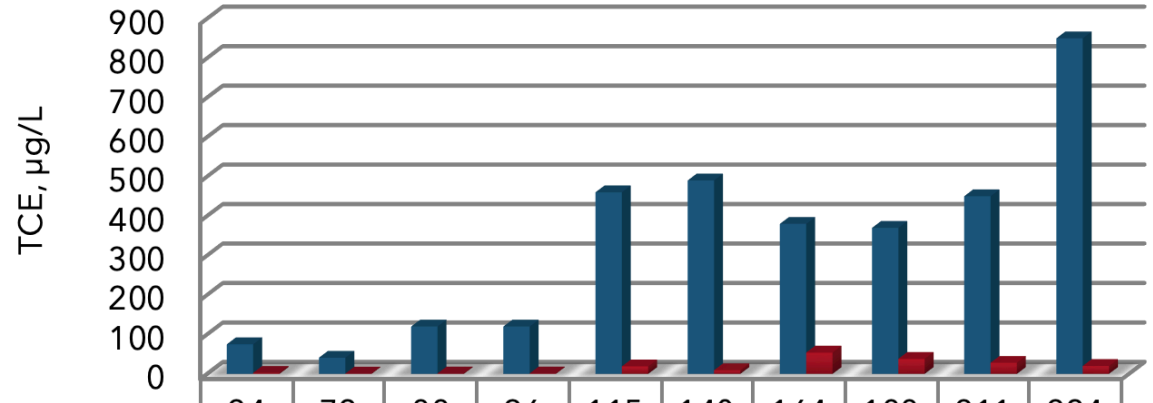
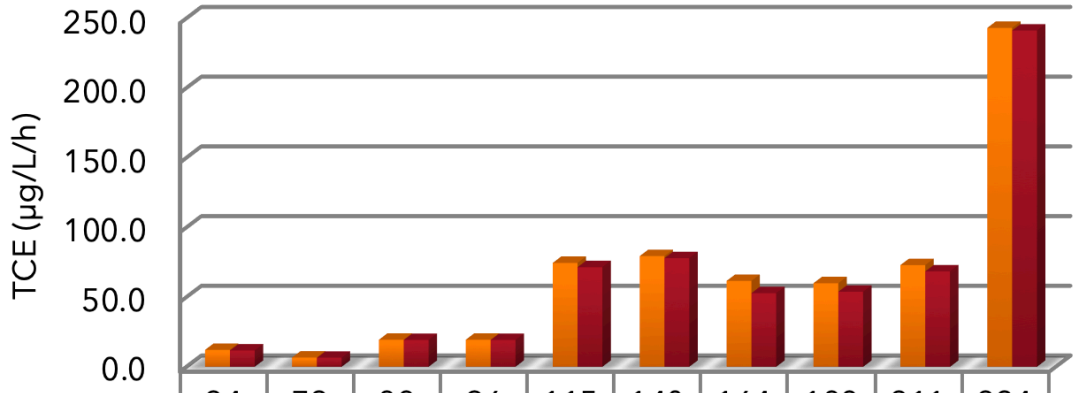
# Development of a continuous-flow prototype for the degradation of trichloroethylene (TCE)

TCE degradation under continuous flow conditions




| | 24 | 73 | 88 | 96 | 115 | 140 | 164 | 188 | 211 | 234 |
|---|---|---|---|---|---|---|---|---|---|---|
| TCE, INF | 75 | 41 | 120 | 120 | 460 | 490 | 380 | 370 | 450 | 850 |
| TCE, EFF | 2.6 | 0.88 | 1 | 1.1 | 19 | 9.1 | 54 | 38 | 28 | 20 |

TCE loading vs elimination capacity under continuous flow conditions

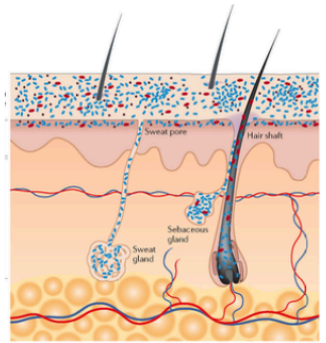



| | 24 | 73 | 88 | 96 | 115 | 140 | 164 | 188 | 211 | 234 |
|---|---|---|---|---|---|---|---|---|---|---|
| Loading | 12.2 | 6.6 | 19.4 | 19.4 | 74.6 | 79.4 | 61.6 | 60.0 | 72.9 | 243.1 |
| Elimination | 11.7 | 6.5 | 19.3 | 19.3 | 71.5 | 77.9 | 52.8 | 53.8 | 68.4 | 241.2 |

*Supported by NIEHS SBIR/STTR (Contract 2R44ES024670)*

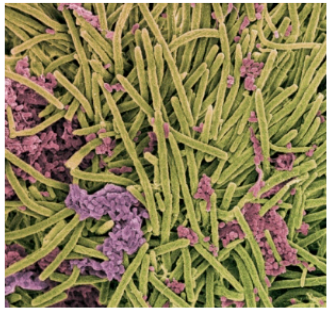
# Part III:

# Predictive Modeling & Future Directions




Human Skin

Human Gut



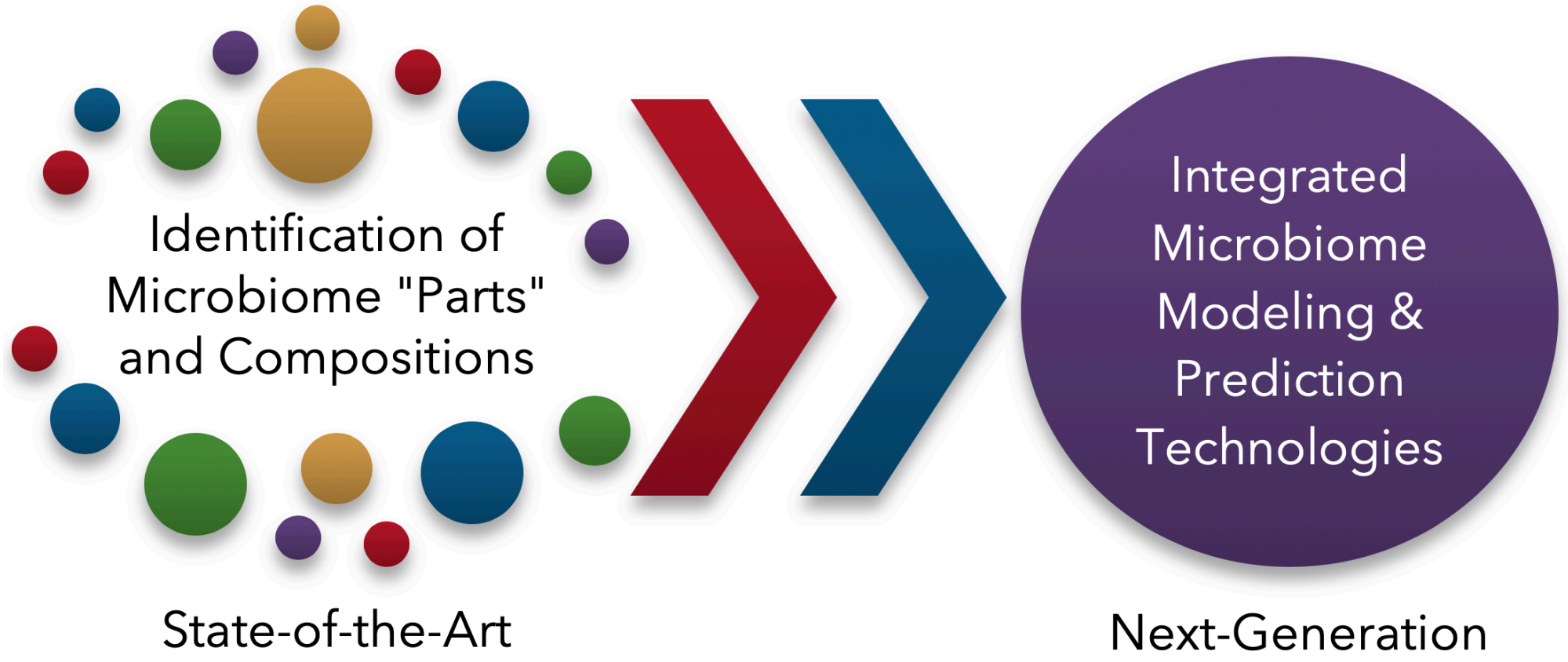
Human Mouth

Soil/Agriculture

Built Settings

*Bioremediation*

# Microbiome research today is shifting towards predictive computational models

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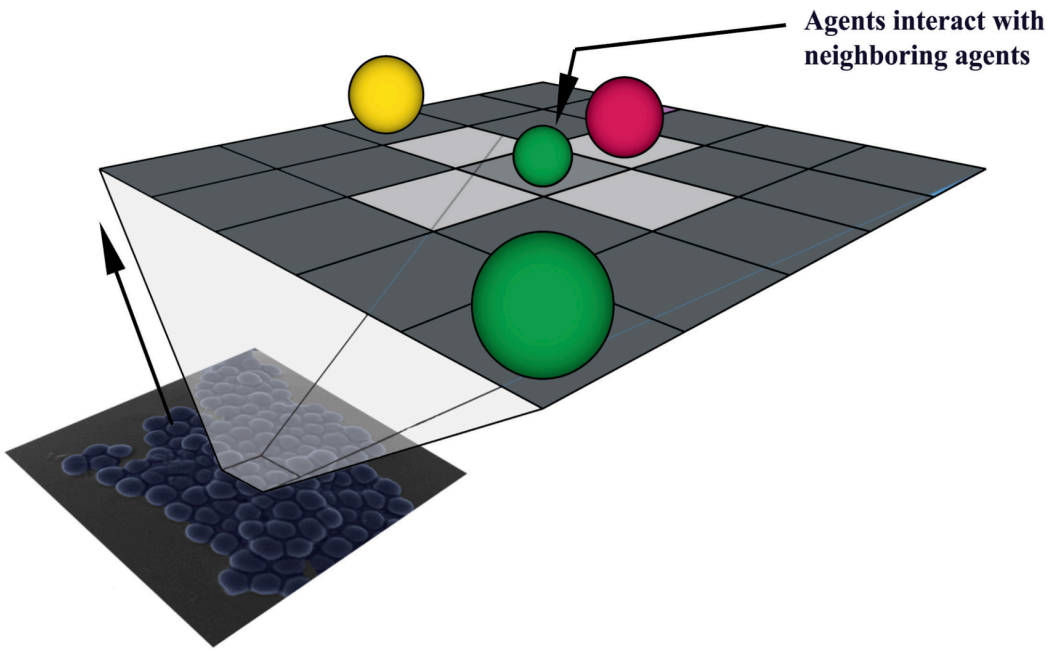
# The application of various computational methodologies help detect key interactions




- Ability to better capture individual heterogeneity within the microbiome
- Customizable platforms to apply to a wide range of bioremediation situations and data inputs
- Integration with other modeling tools for enhancing the reliability of predictions
- Leverage data generated from next-generation tools and techniques for translation into practical applications

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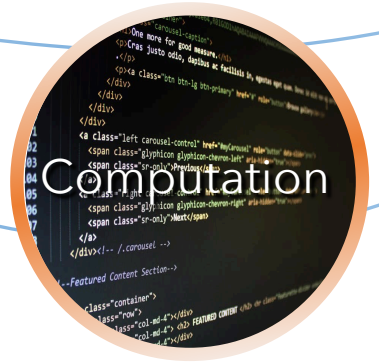
# Future directions

Improved microbiome tools and techniques for understanding complex behaviors and interactions


Use of multi-disciplinary platforms to translate fundamental data into functional systems


Integration of new sciences and platforms into existing theoretical, economic and physical infrastructure for remediation applications

# Thank you

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