

Biodegradation of Chlorobenzenes and Nitrotoluenes at an Industrial Site in South America

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**CDM
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Outline



Site/Project
Overview



Remediation
Concept



Results



Conclusions



Q&A

Site/ Project Overview



Site/ Project Overview

Among the **26** chemicals identified, **8** stand out based on their elevated concentrations and/or regulatory limits

- Chlorobenzene (CB)
- 1,2-Dichlorobenzene (1,2-DCB)
- 4-Nitrotoluene (4-NT)
- 2,6-Dinitrotoluene (2,6-DNT)
- 4-Isopropylaniline (4-IPA)
- 2,4-Dinitrotoluene (2,4-DNT)
- 1,2-Dichloroethane (1,2-DCA)
- 1,4-Dioxane

Main
Contaminants:
 $C_{\max} \geq 7$ mg/L

Co-contaminants:
 $C_{\max} \sim 0.2-6$ mg/L

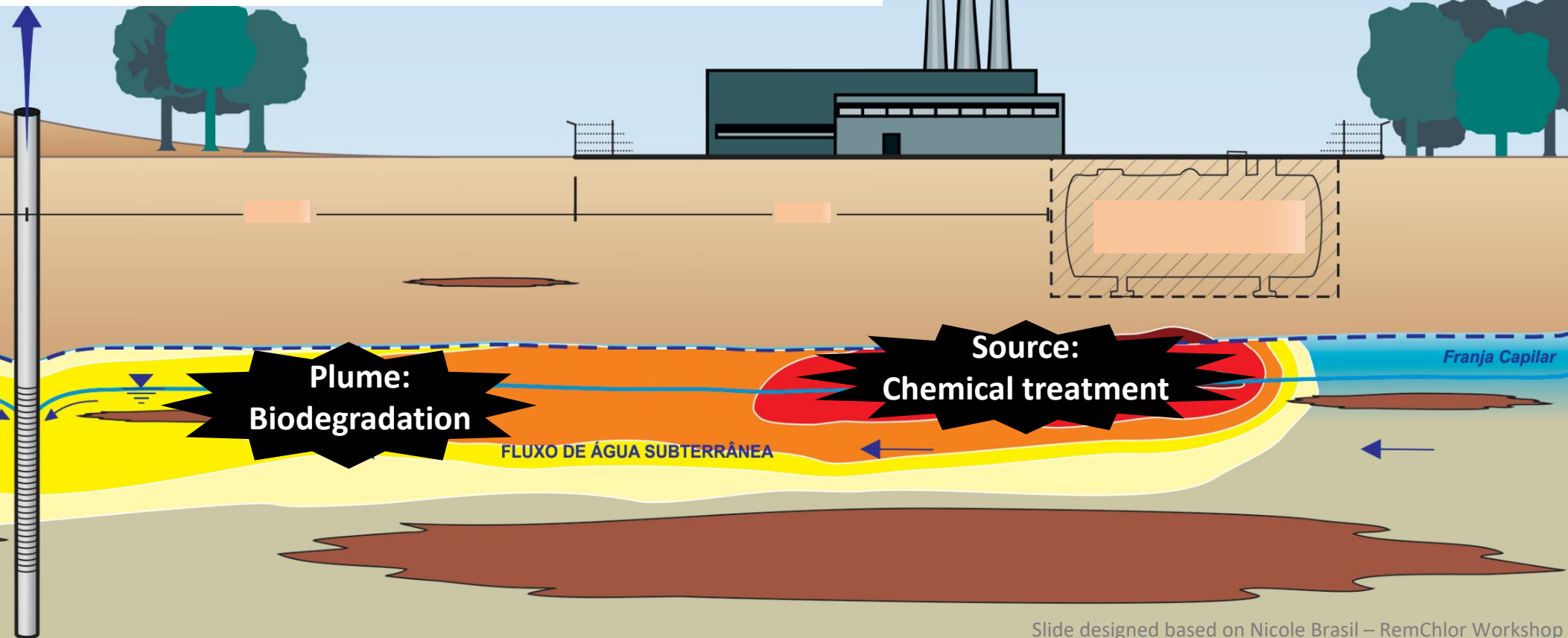


Remediation Concept

1- **Source:** ISCO alone or sequential ISCR/ISCO

2- **Plume:** - Microbes

- Electron donor/acceptor availability
- Geochemistry (pH, redox, alkalinity)



Slide designed based on Nicole Brasil – RemChlor Workshop

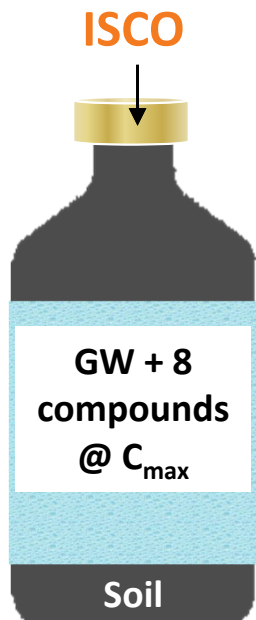
Concerns with the Remediation Concept

- Potential recalcitrance of CoC to chemical oxidation at concentrations found in the **source** zone
- Little known about how the products from chemical oxidation or chemical reduction/oxidation might impact downgradient (**plume**) biodegradability
 - Potential for toxicity
 - Potential for positive effects from an increase in readily degradable substrate
- Good evidence for the biodegradation of individual contaminants; little known about the biodegradability of this mixture of contaminants under aerobic and anaerobic conditions
 - Potential for inhibitory effects

Objectives

- For **source** zone treatment:
 - Compare chemical oxidation (persulfate) to sequential chemical reduction (ZVI) and oxidation (persulfate)
- For downgradient biodegradation/biotransformation (**plume**):
 - Evaluate the impact of co-contaminants (2,4-DNT, 4-IPA, 1,2-DCA, 1,4-dioxane) on
 - aerobic biodegradation of CB and 1,2-DCB
 - anaerobic biotransformation of 2,6-DNT and 4-NT
 - Evaluate the impact of products from chemical treatment of the source zone on
 - aerobic biodegradation of CB and 1,2-DCB
 - anaerobic biotransformation of 2,6-DNT and 4-NT

Source Zone Chemical Treatment: Batch Assay



Area N

- Klozur[®] persulfate + sodium hydroxide
- Raise pH to ~10.5



Area P

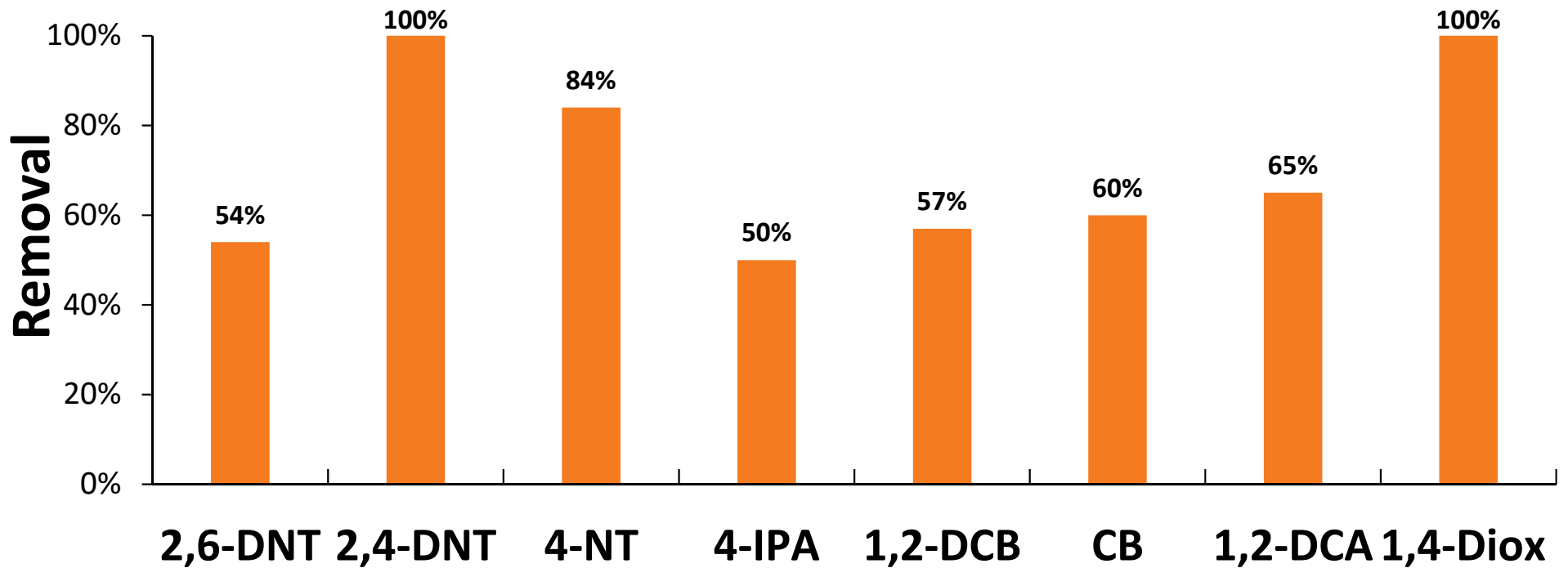
ISCR:

- ABC[®]+: mix of ZVI and short/longer term e^- donors, P buffer
- 2 day exposure: nitro groups reduced to amines

ISCO:

- OBC[™] sodium persulfate + calcium peroxide

ISCO Treatment: 1X Stoichiometric

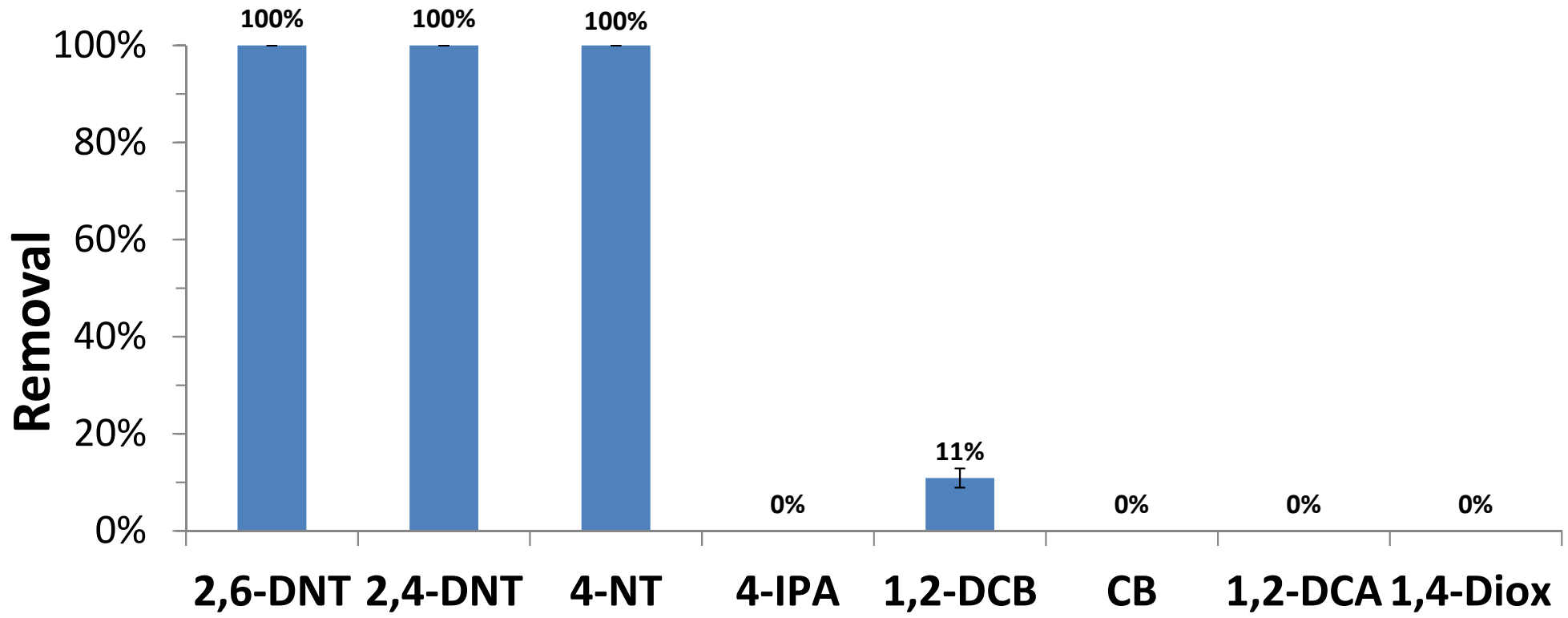


■ Oxidation with Klozur[®] persulfate with NaOH activation (26 days)

Soil and GW from Area N

Used in the inhibition tests at 10% dilution

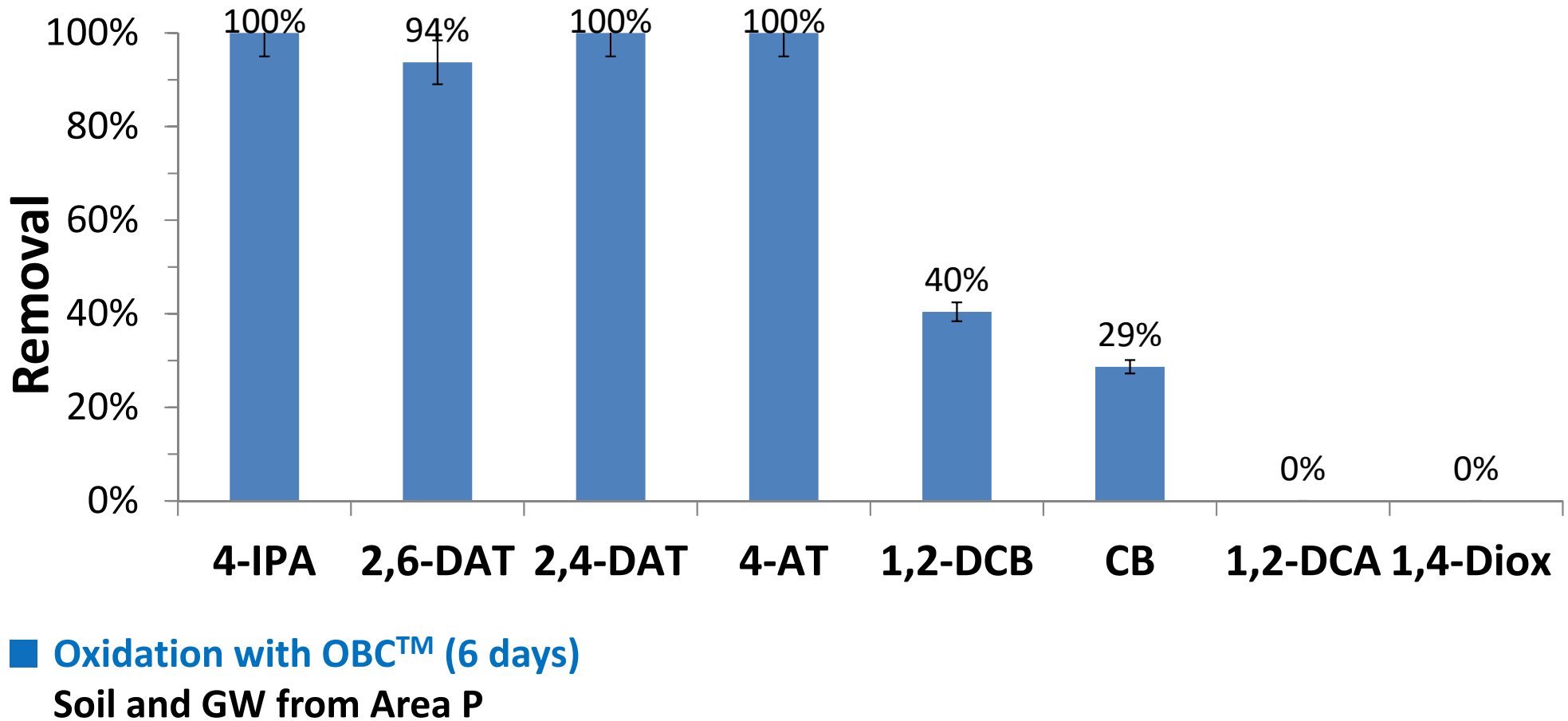
ISCR/ISCO treatment: 1X stoichiometric



■ Reduction with ABC+® (2 days)

Soil and GW from Area P

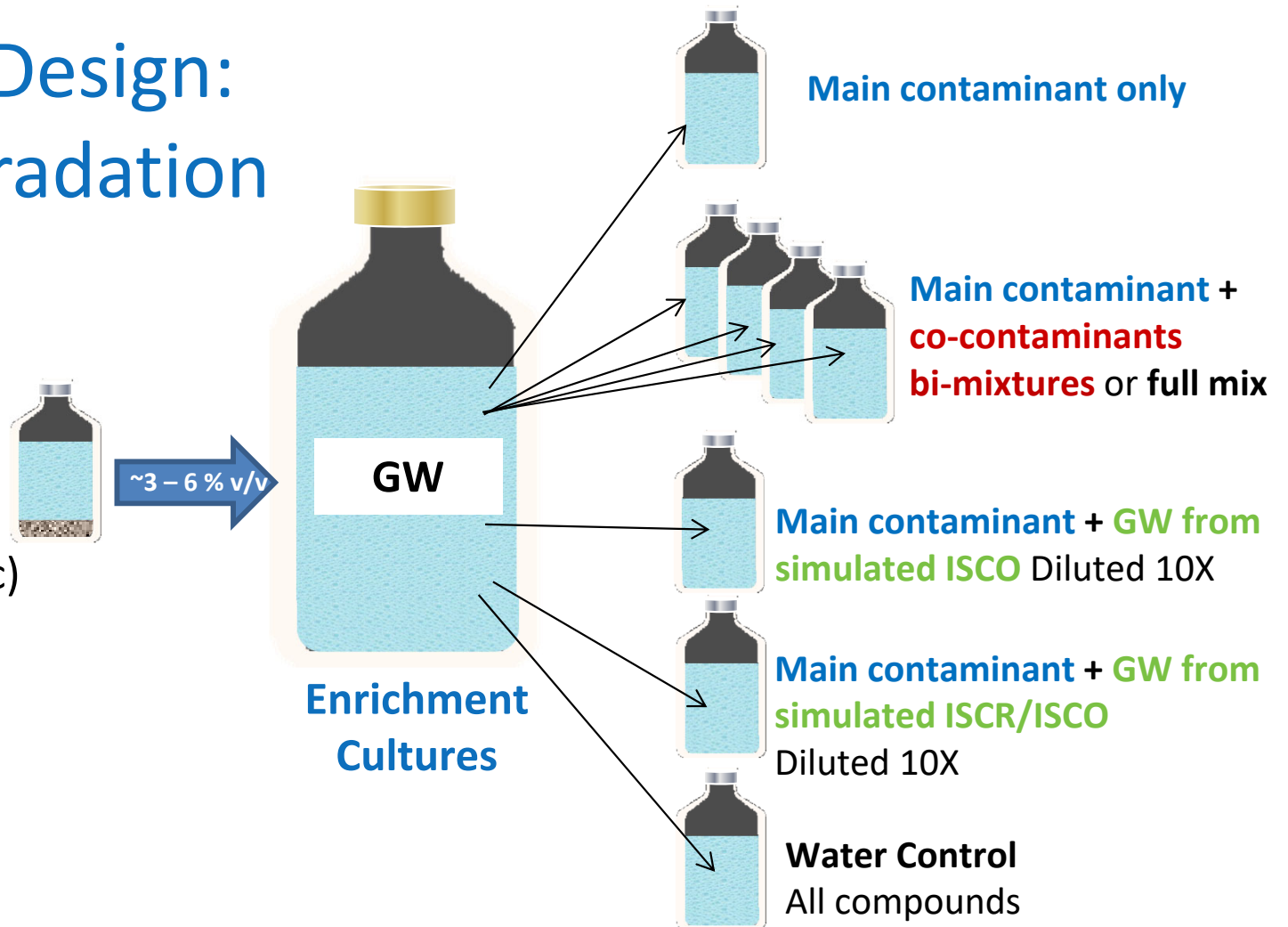
ISCR/ISCO Treatment: 1X Stoichiometric



Experimental Design: Plume Biodegradation

Initial Microcosms:

- CB (aerobic)
- 1,2-DCB (aerobic)
- 2,6-DNT (anaerobic)
- 4-NT (anaerobic)

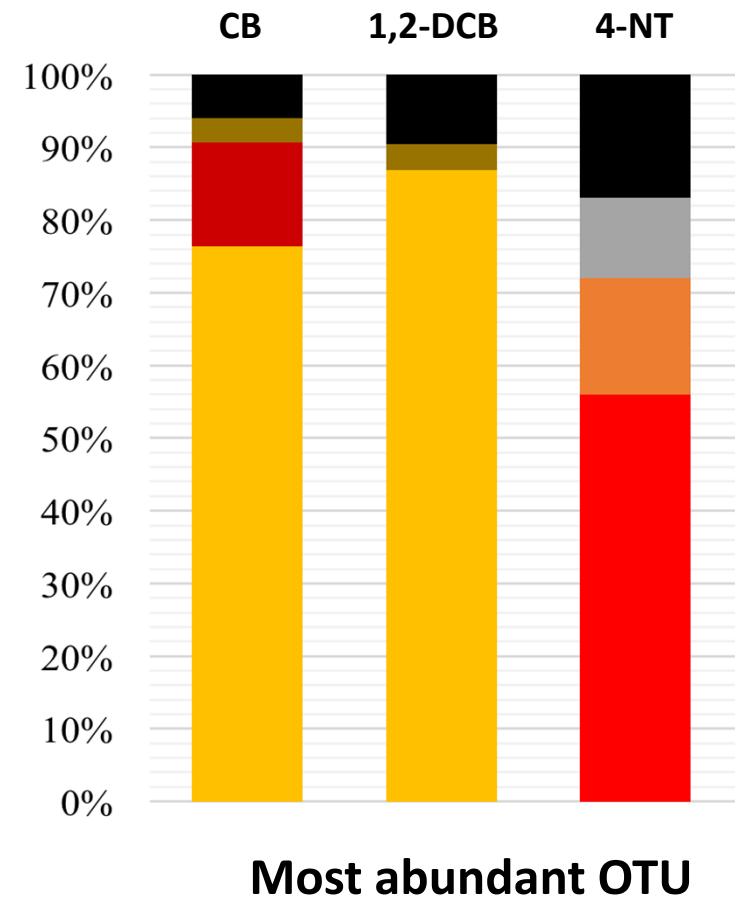
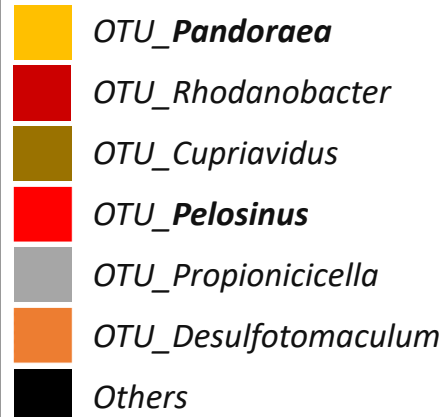


Enrichment Culture: Microbial Community

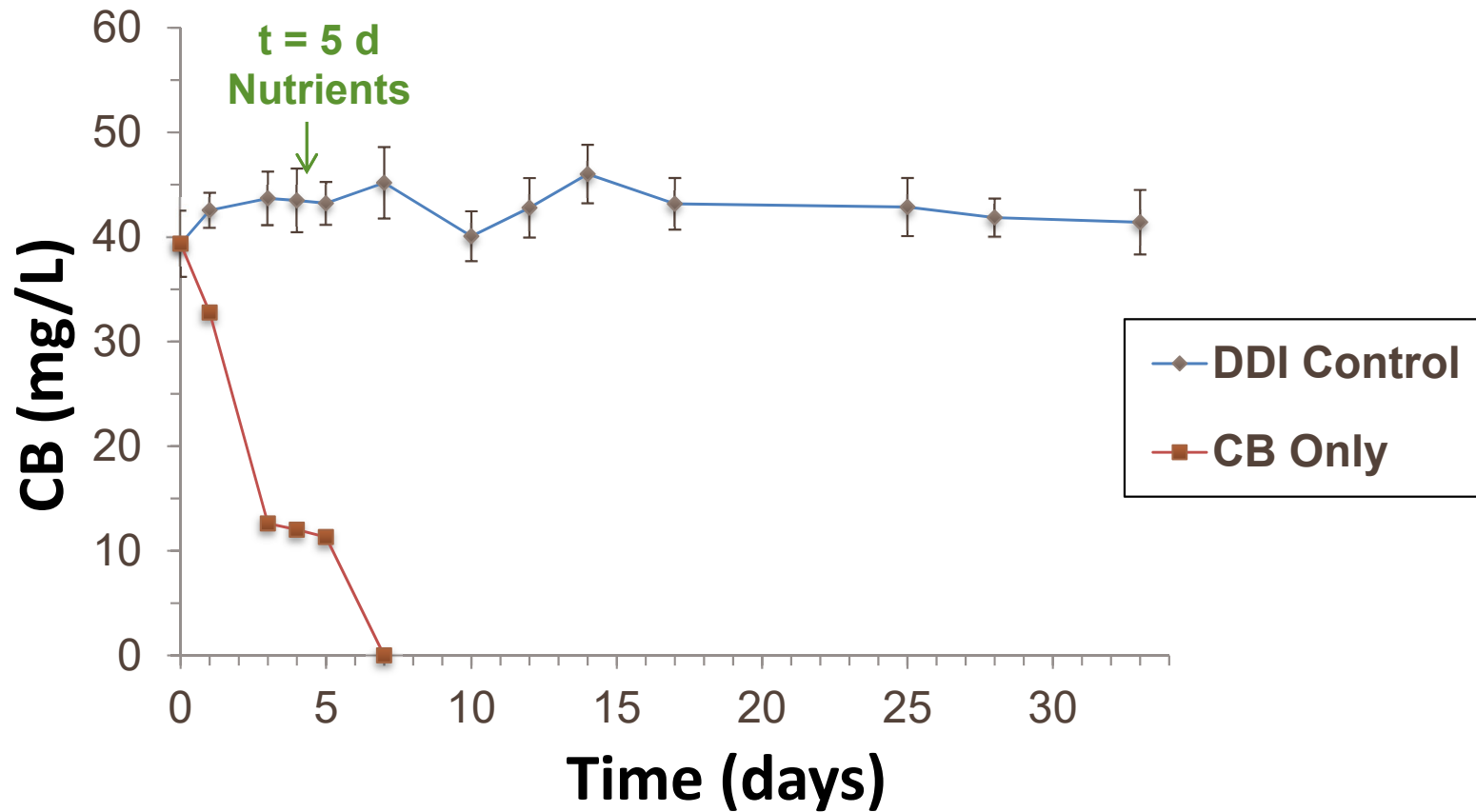
Analysis courtesy
of E. A. Edwards:



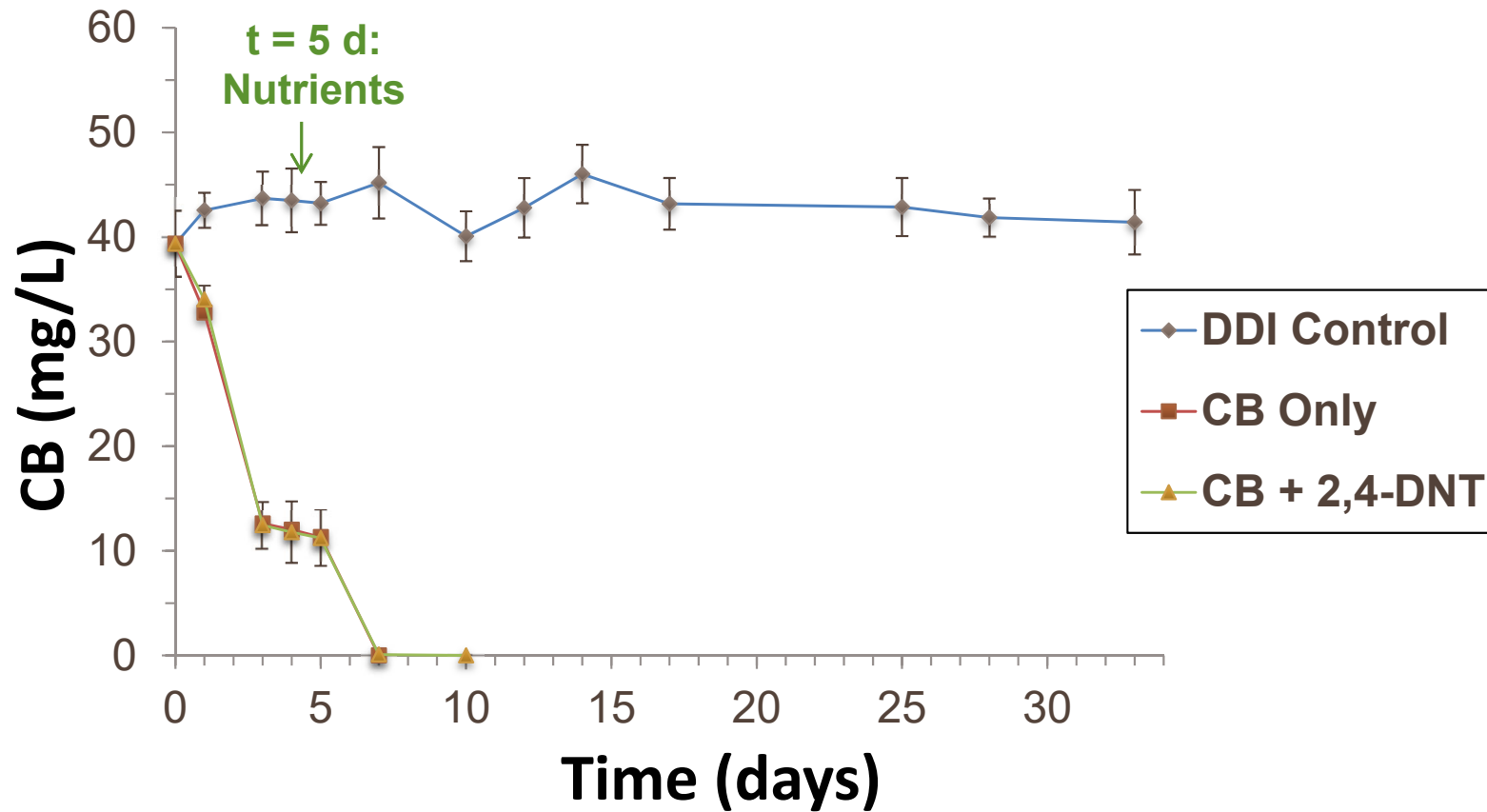
Legend:



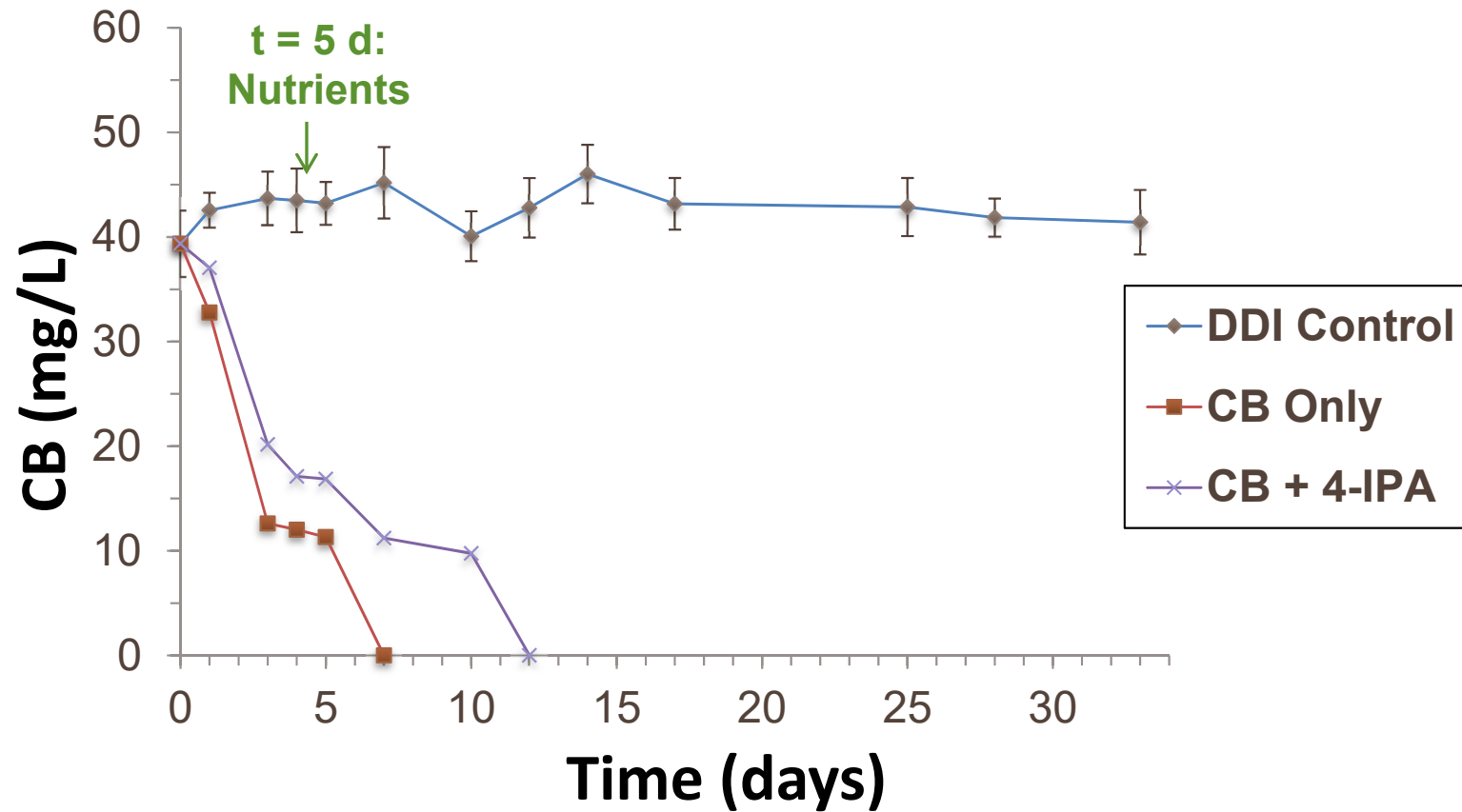
CB: Aerobic Biodegradation



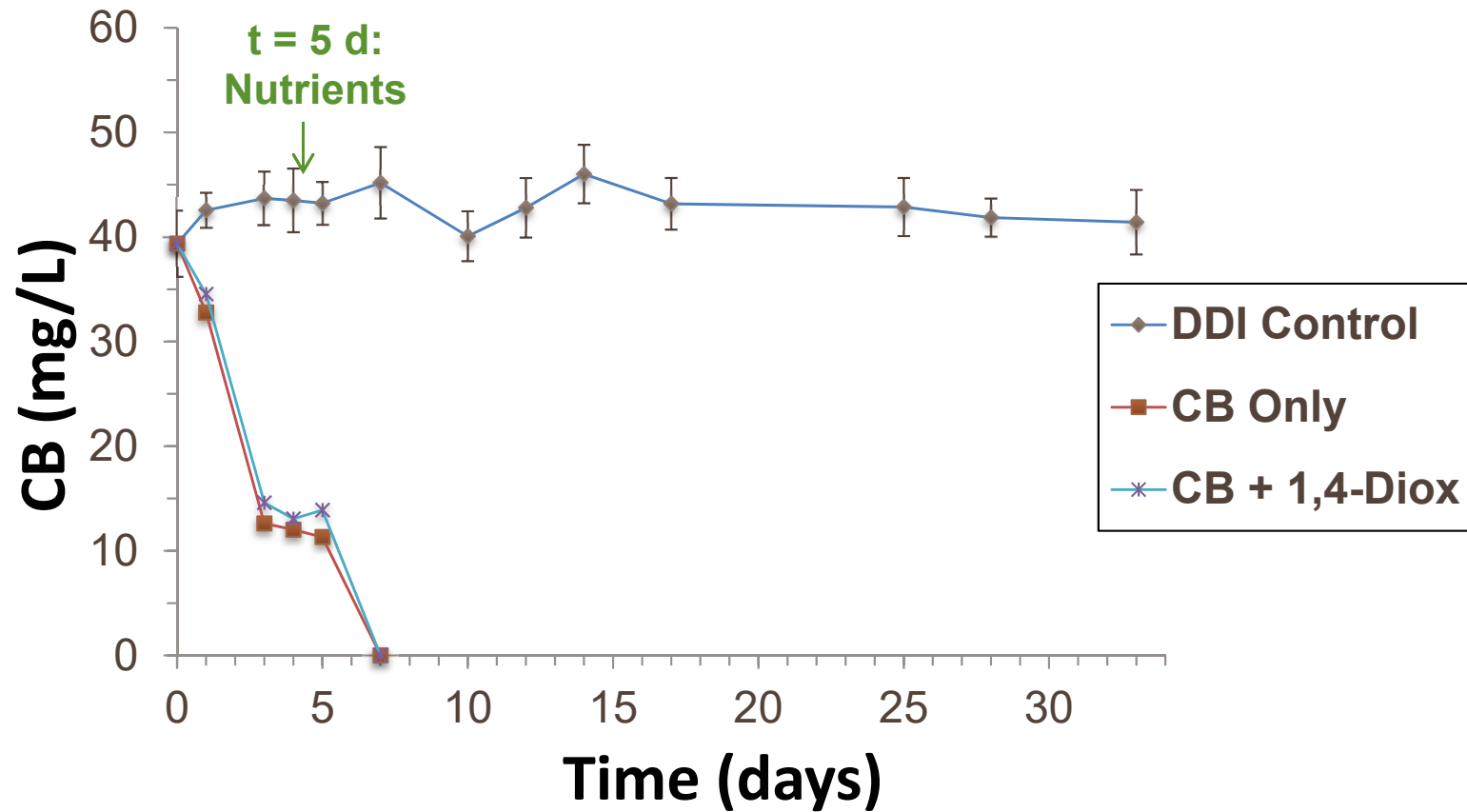
CB: Aerobic Biodegradation



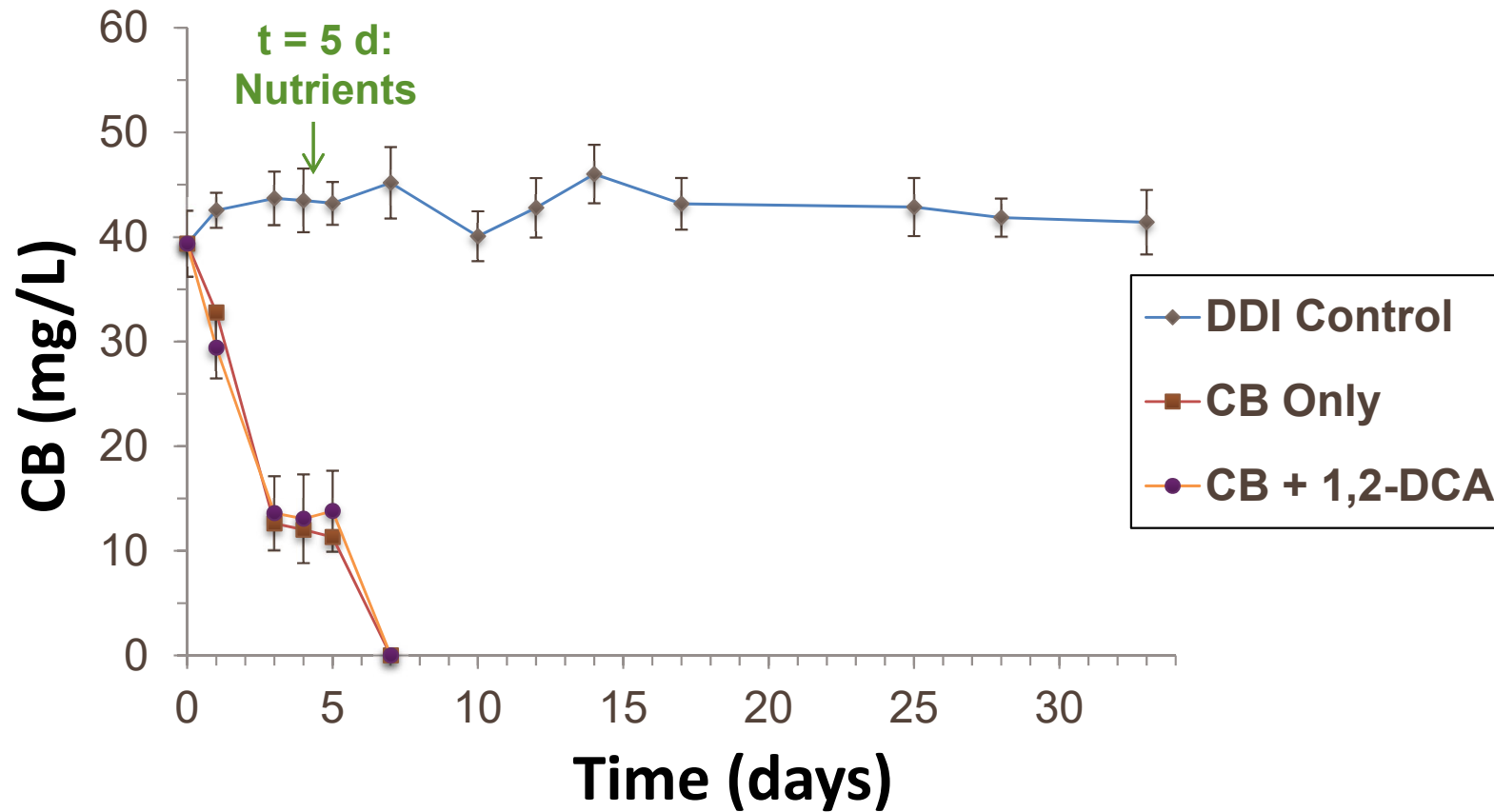
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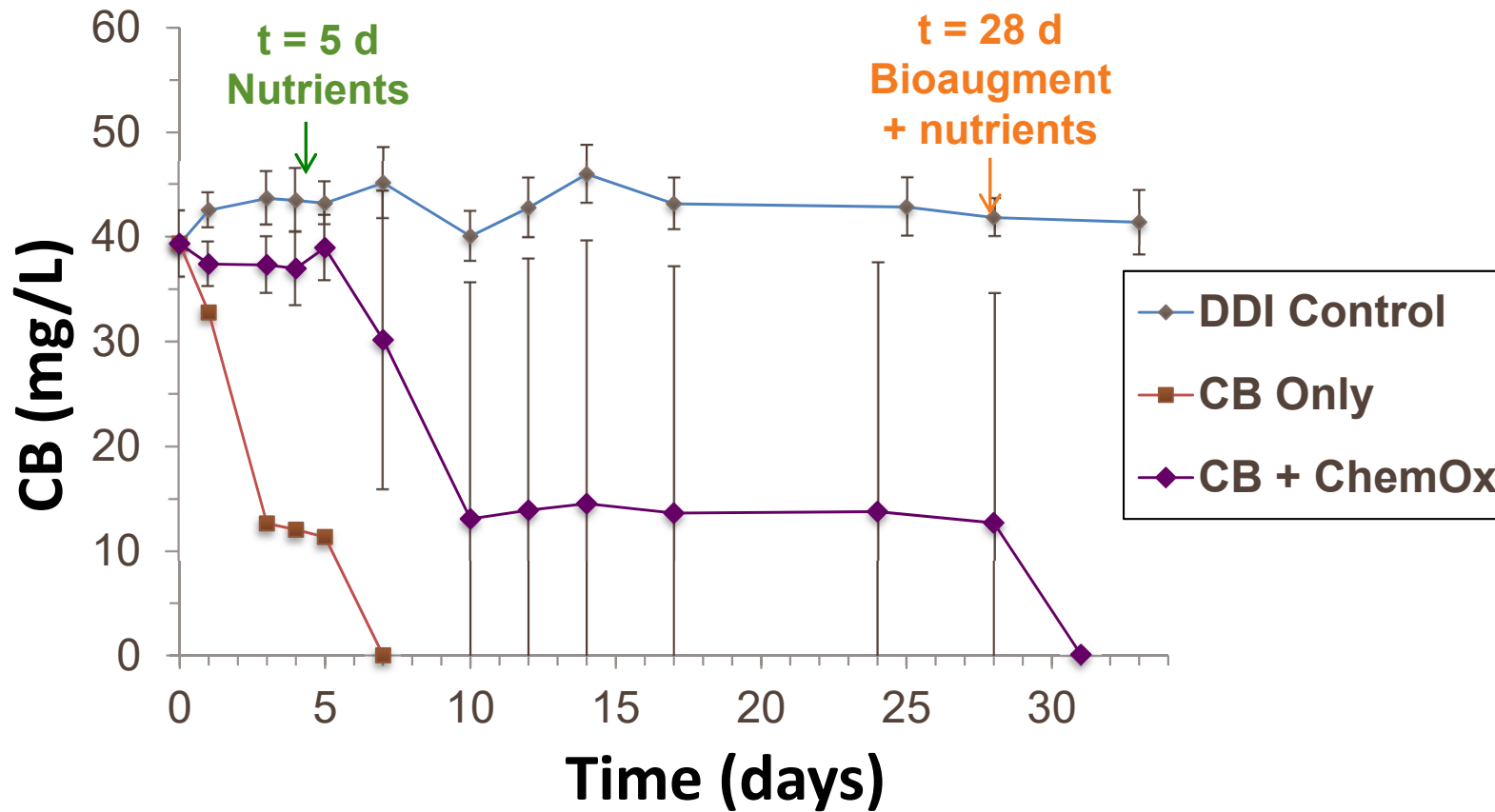
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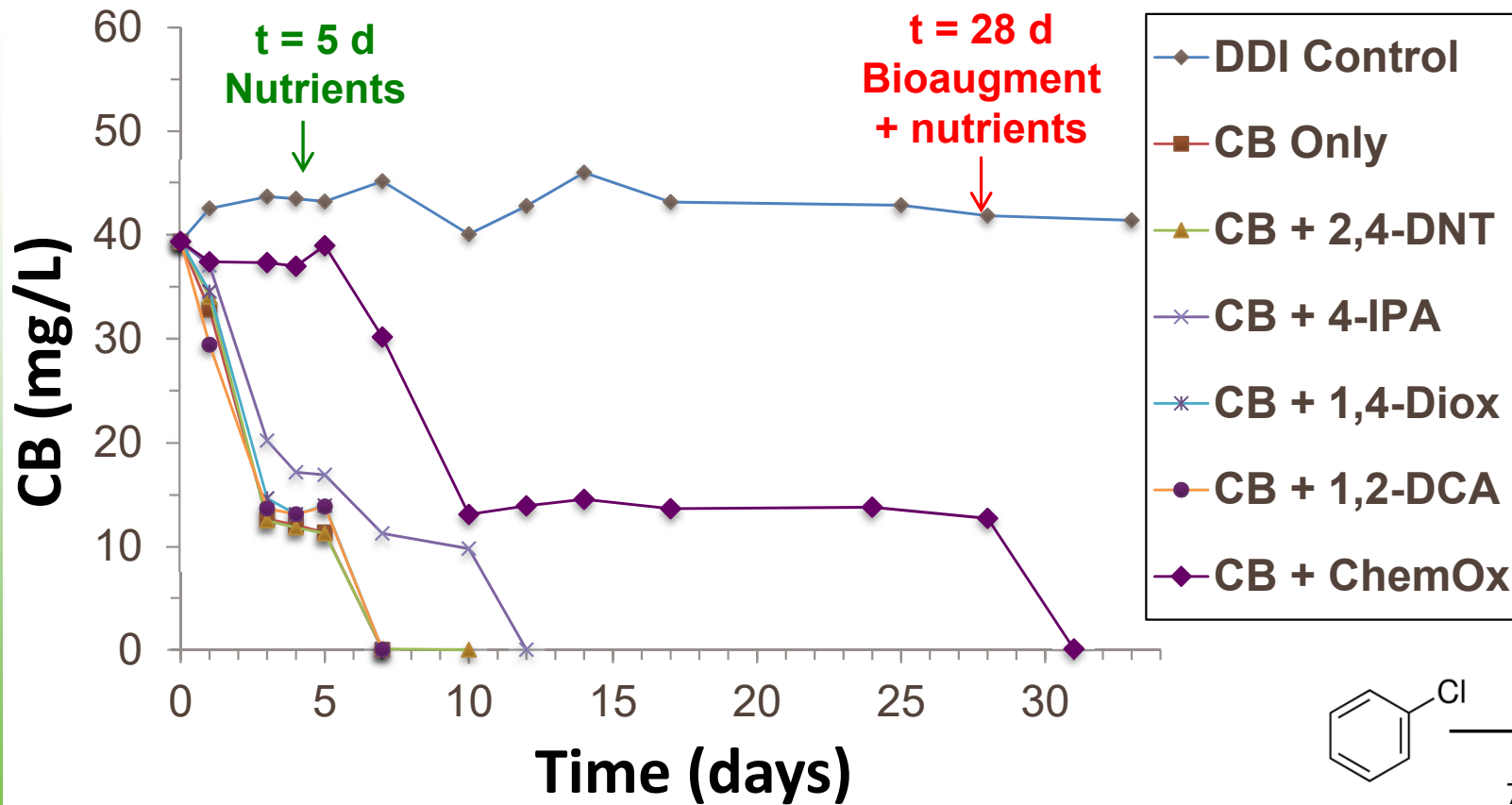
CB: Aerobic Biodegradation



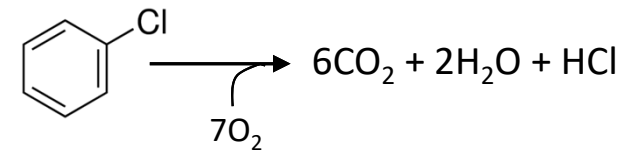
CB: Aerobic Biodegradation



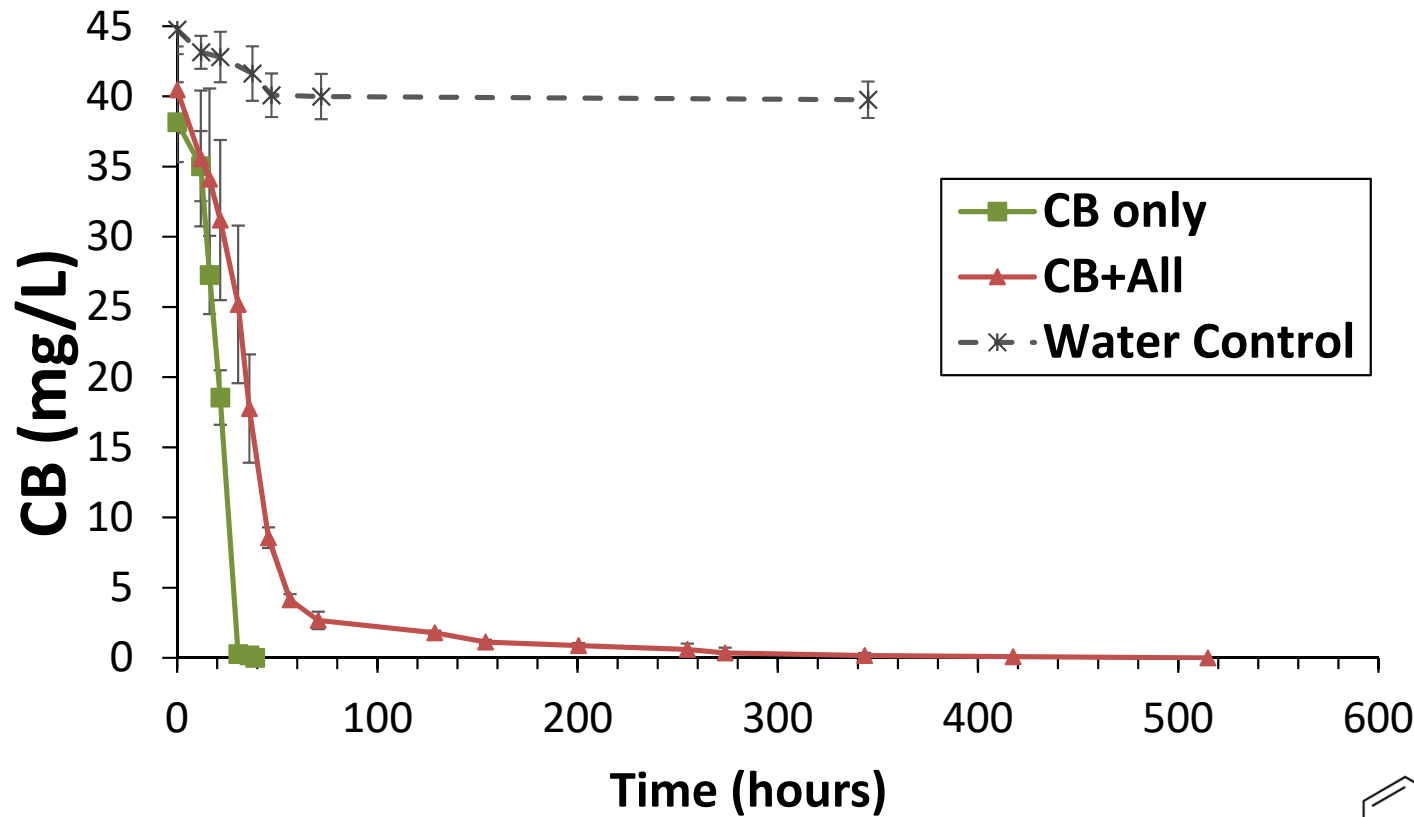
CB: Aerobic Biodegradation



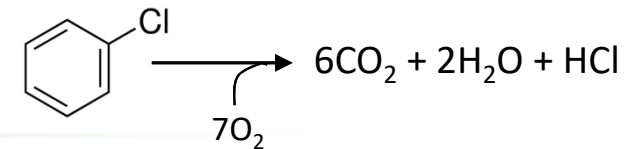
- CB in bi-mixtures: modest impact of 4-IPA
- ChemOx water slowed but did not stop biodegradation



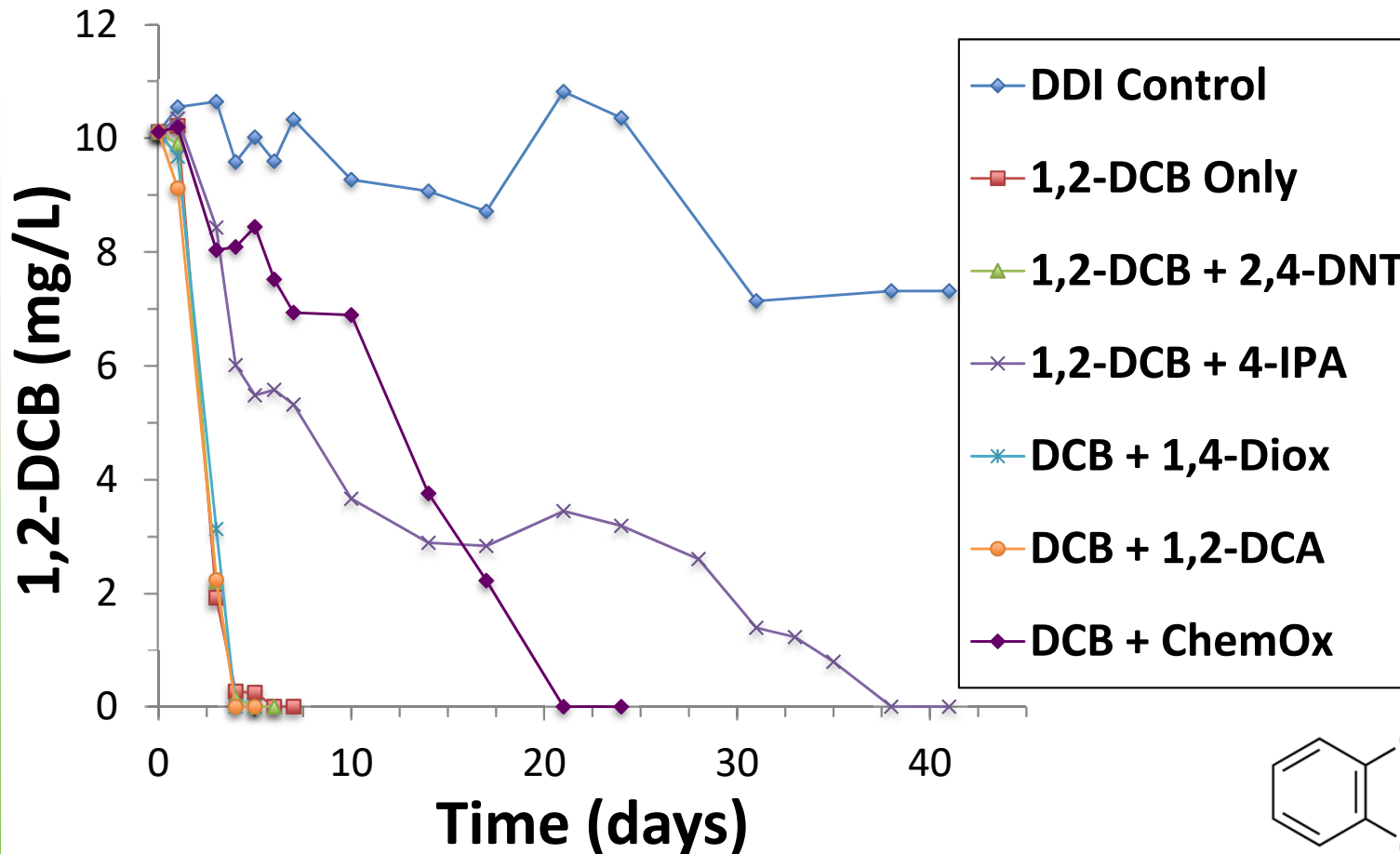
CB: Aerobic Biodegradation



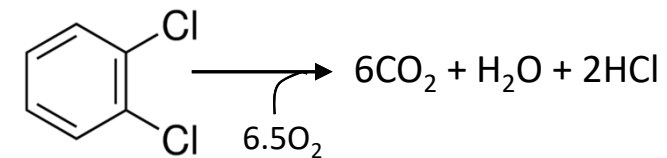
- Presence of all compounds reduced rate of CB biodegradation, not extent



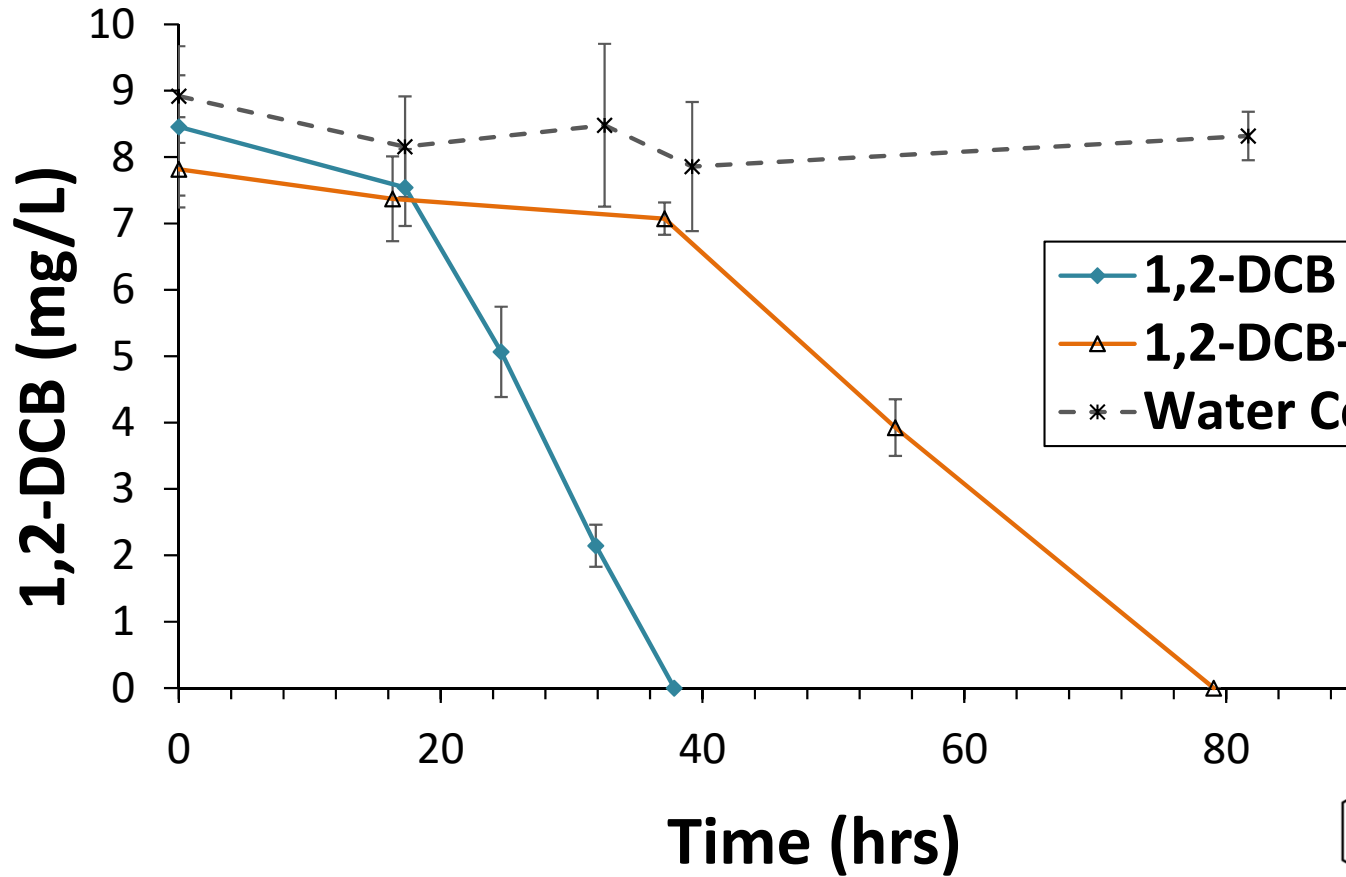
1,2-DCB: Aerobic Biodegradation



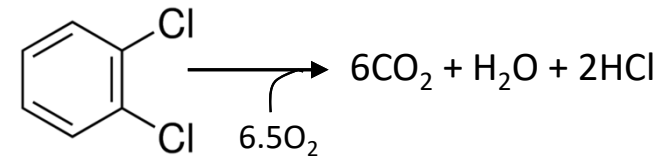
- No inhibition of 1,2-DCB in bi-mixtures, except for 4-IPA
- Transient inhibition by the ChemOx water



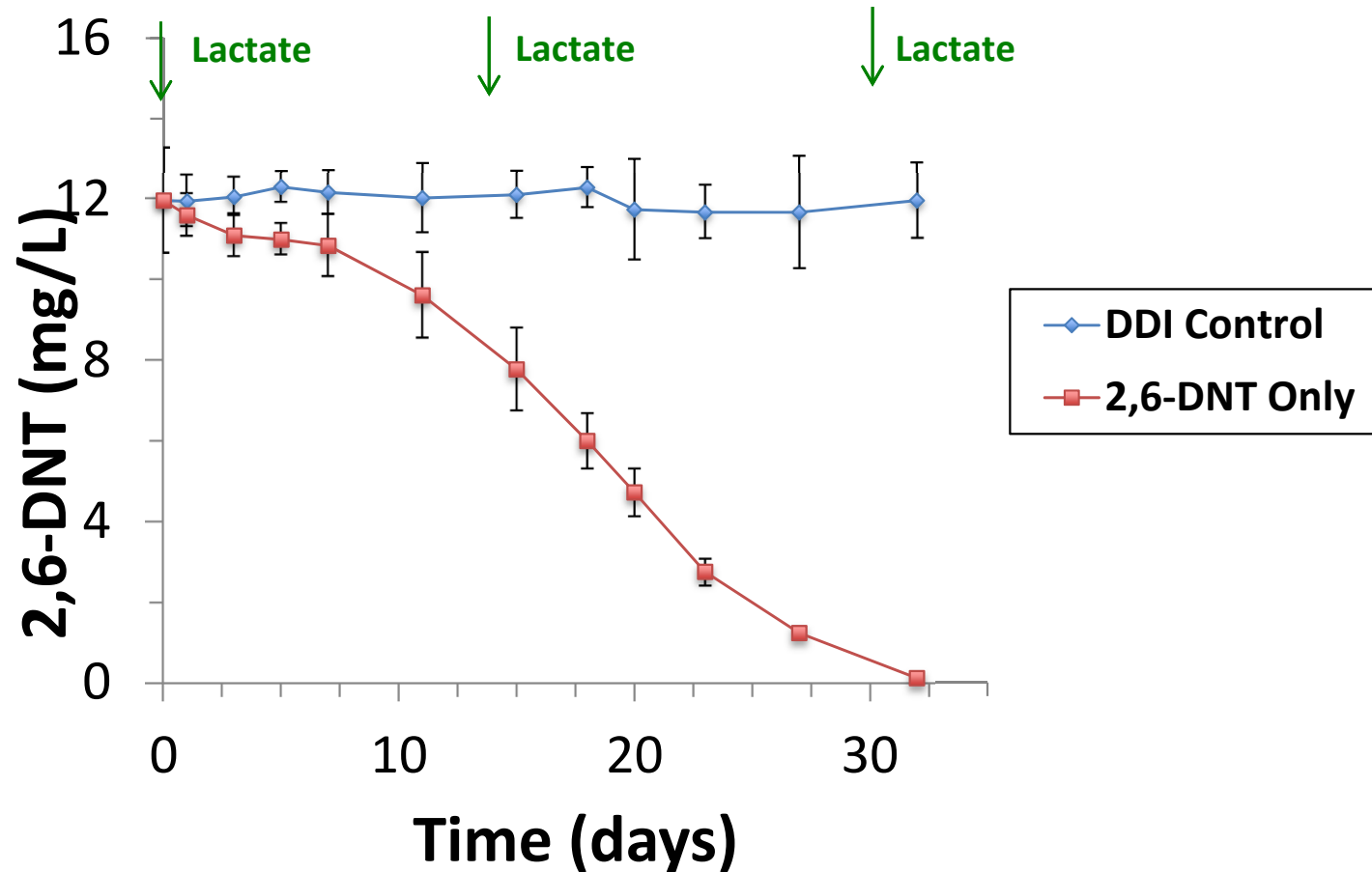
1,2-DCB: Aerobic Biodegradation



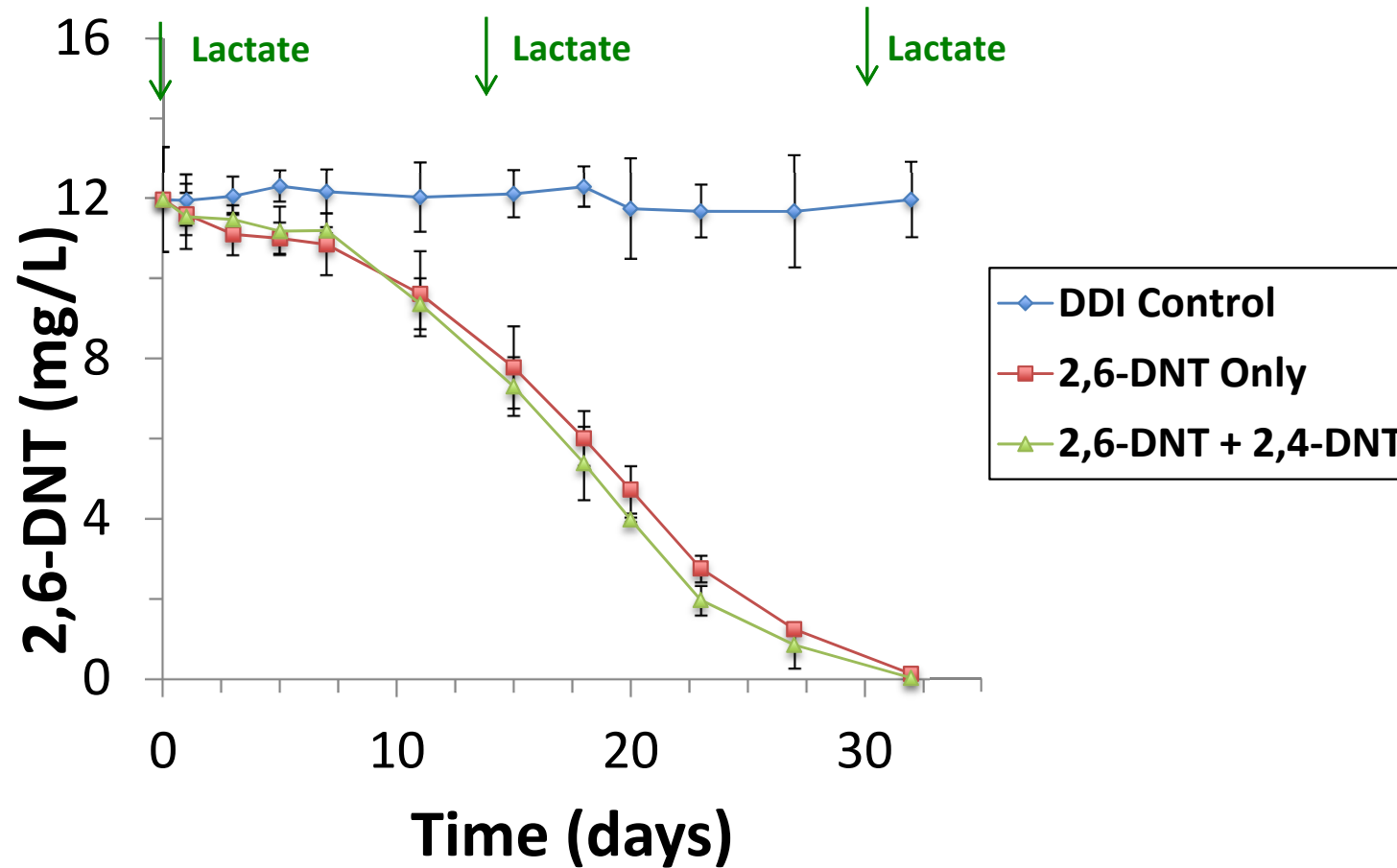
- Presence of all compounds reduced rate of 1,2-DCB biodegradation, not extent



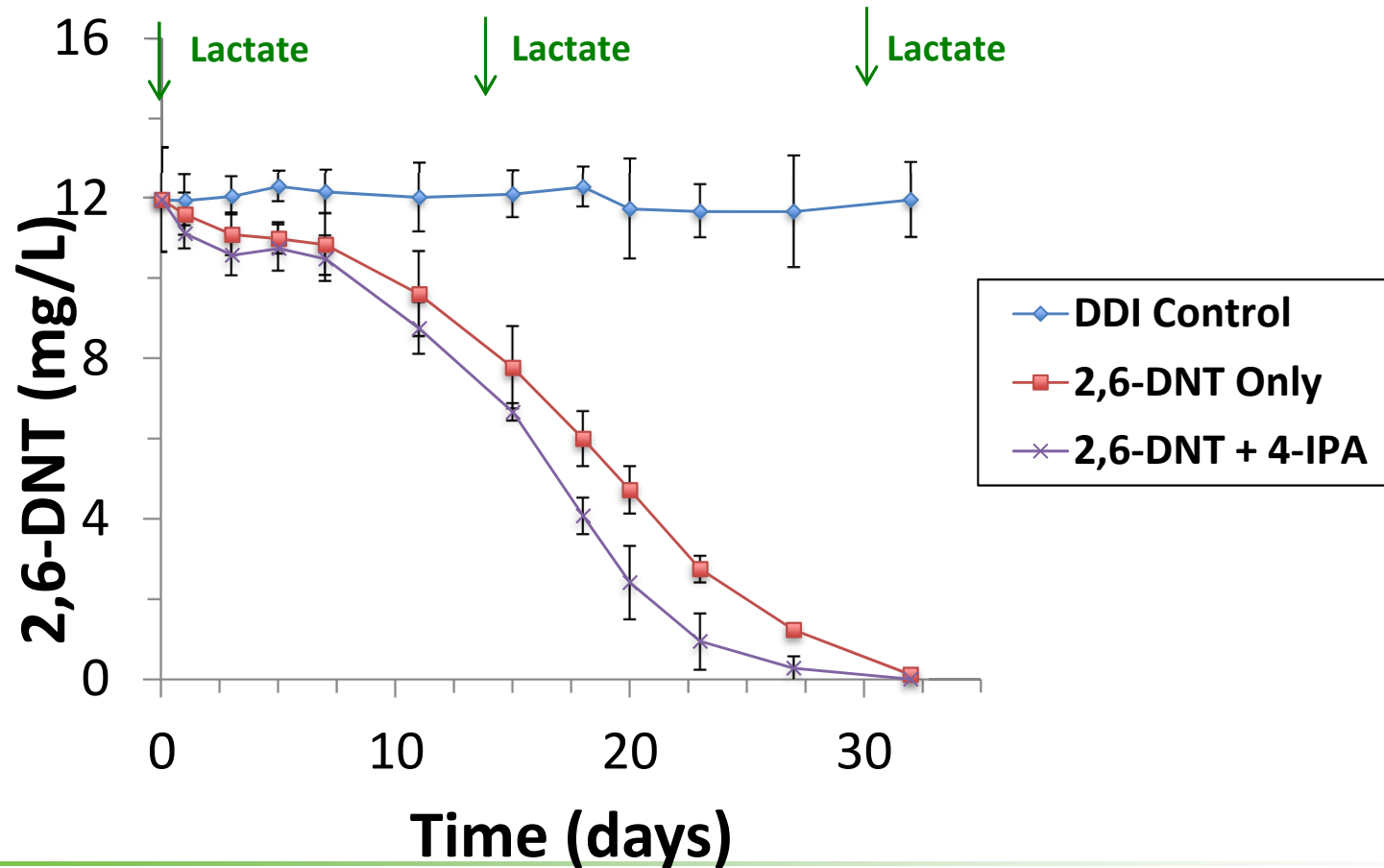
2,6-DNT: Anaerobic Biotransformation



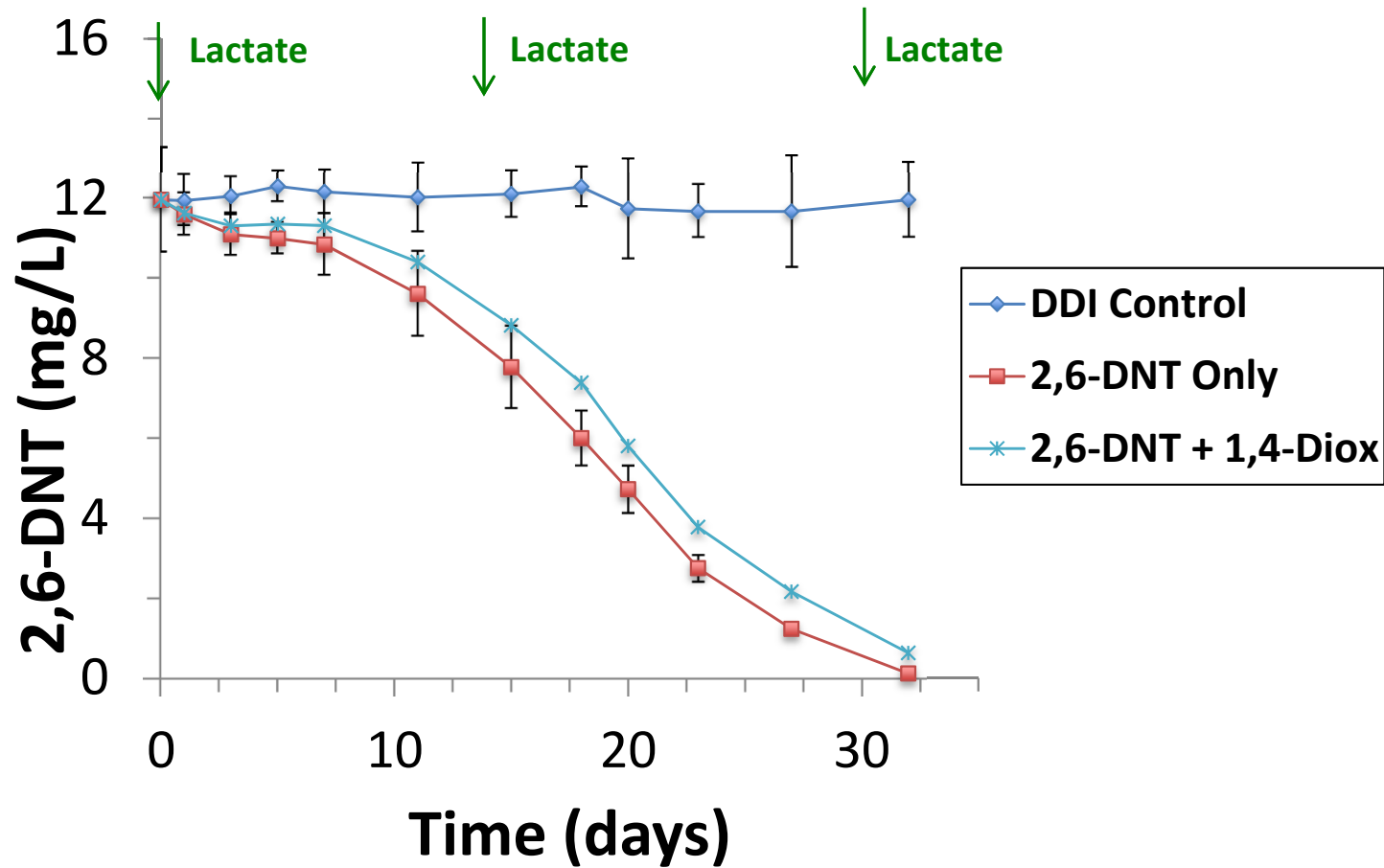
2,6-DNT: Anaerobic Biotransformation



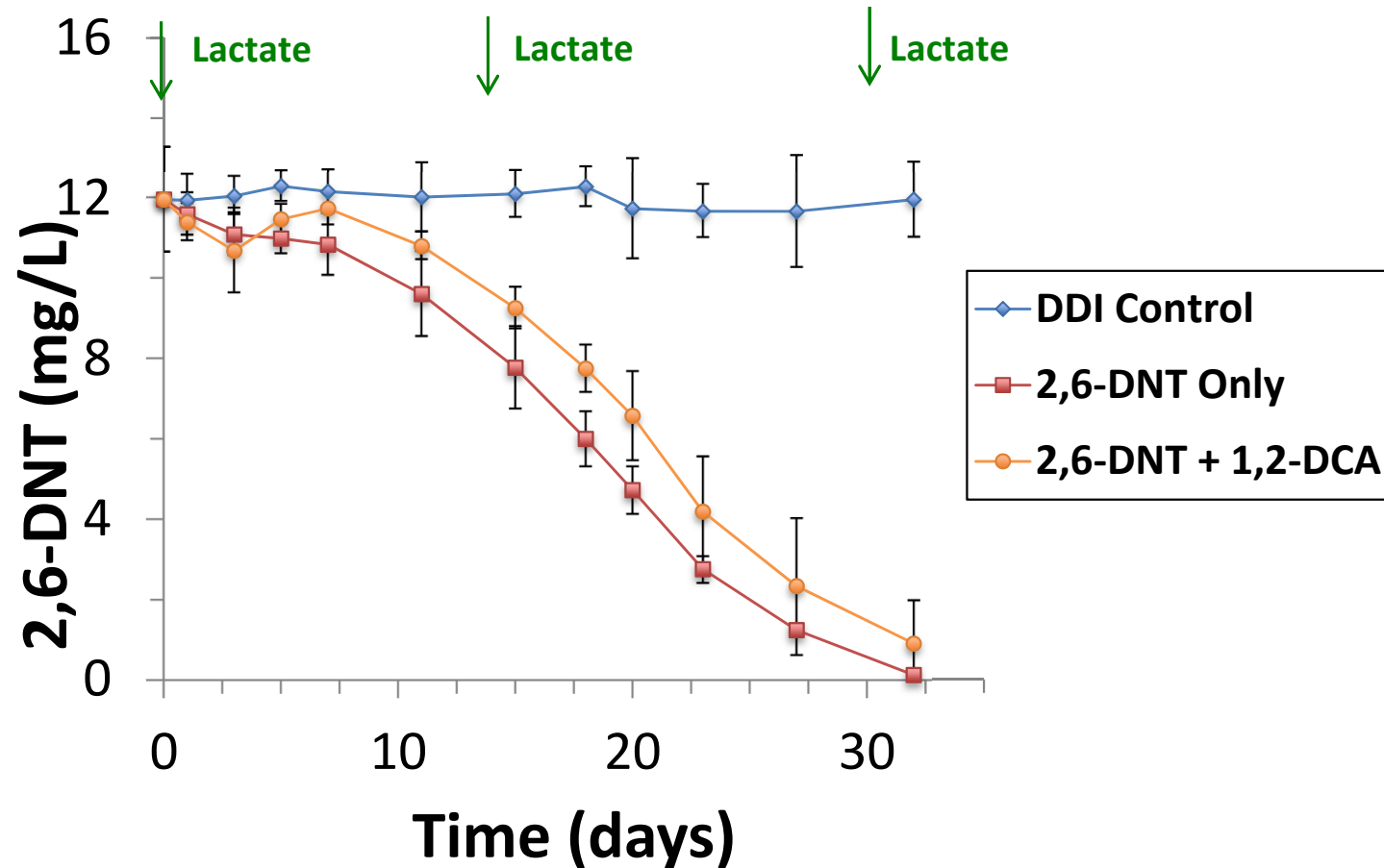
2,6-DNT: Anaerobic Biotransformation



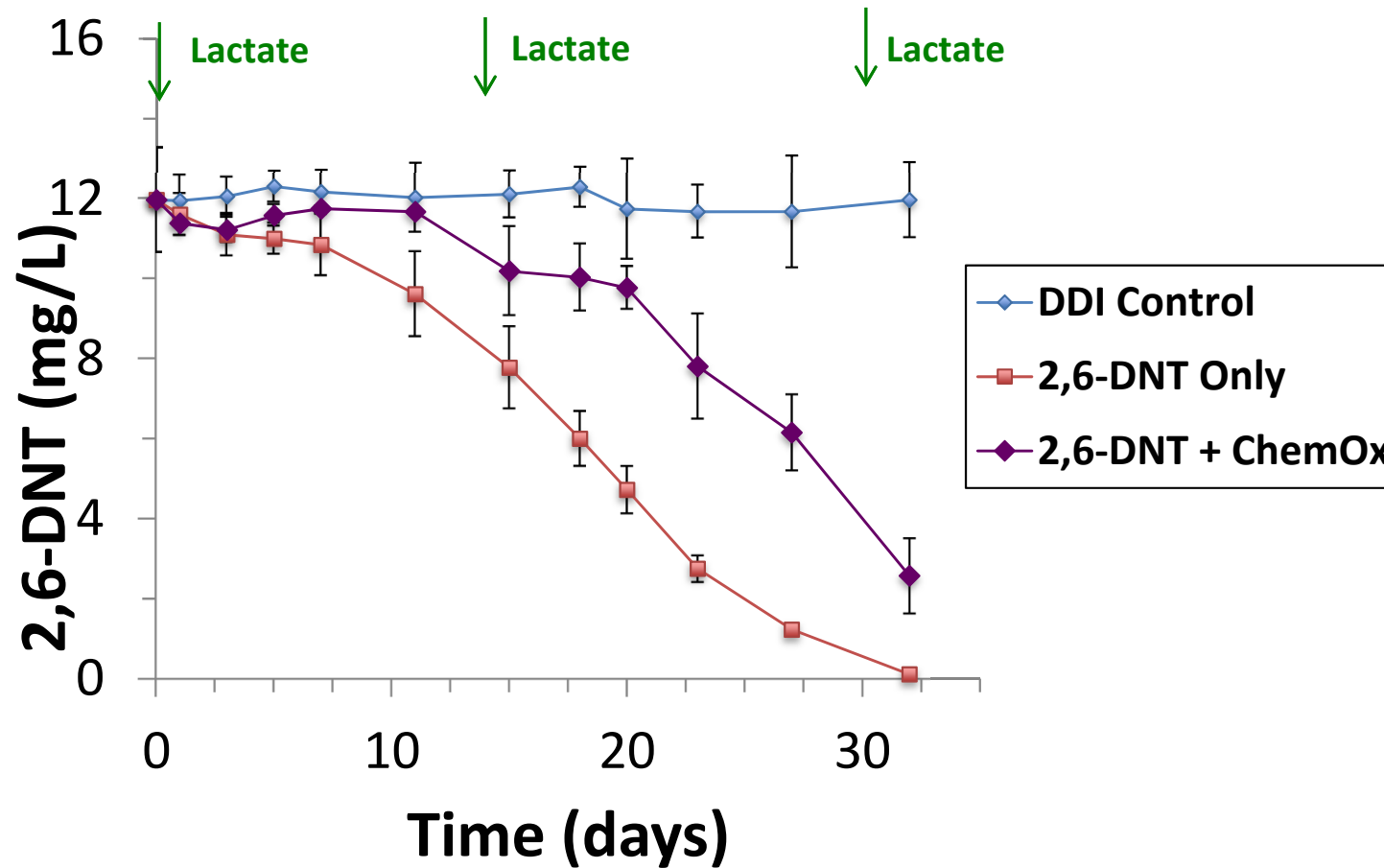
2,6-DNT: Anaerobic Biotransformation



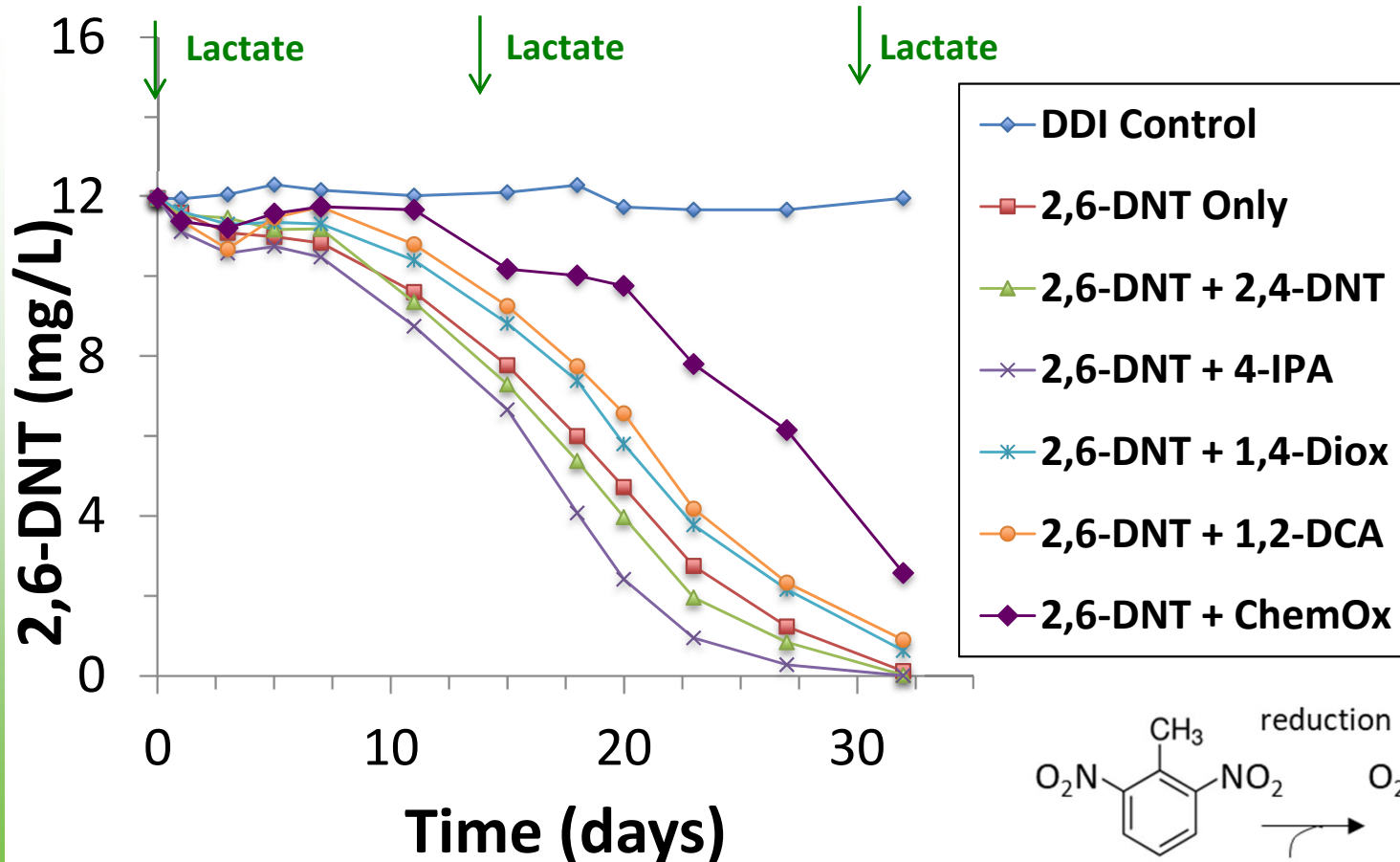
2,6-DNT: Anaerobic Biotransformation



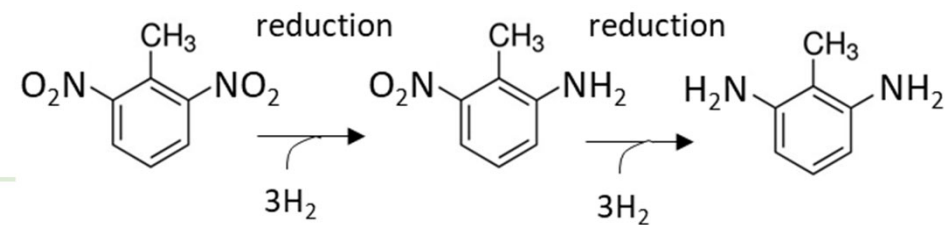
2,6-DNT: Anaerobic Biotransformation



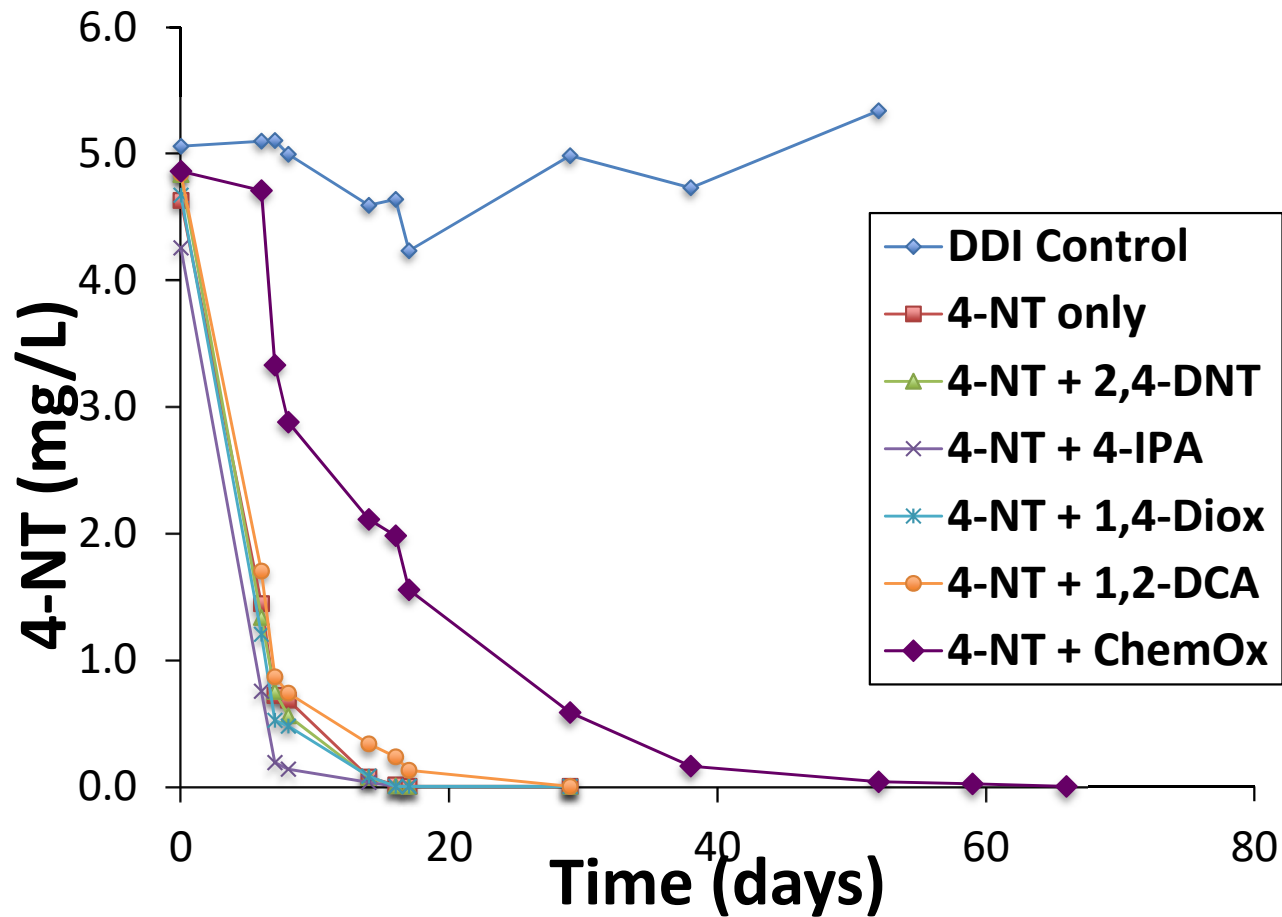
2,6-DNT: Anaerobic Biotransformation



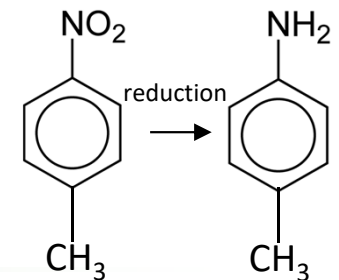
- Products from 2,6-DNT = 2-A-6-Nitrotoluene + 2,6-Diaminotoluene
- Bi-mixture effects: slightly stimulatory, slightly inhibitory
- Partial inhibition by the ChemOx water
- Effect of all compounds: in progress



4-NT: Anaerobic Biotransformation

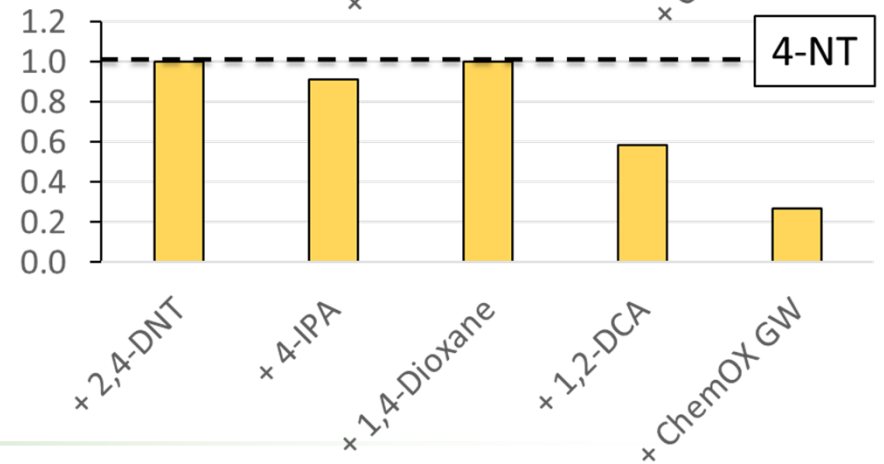
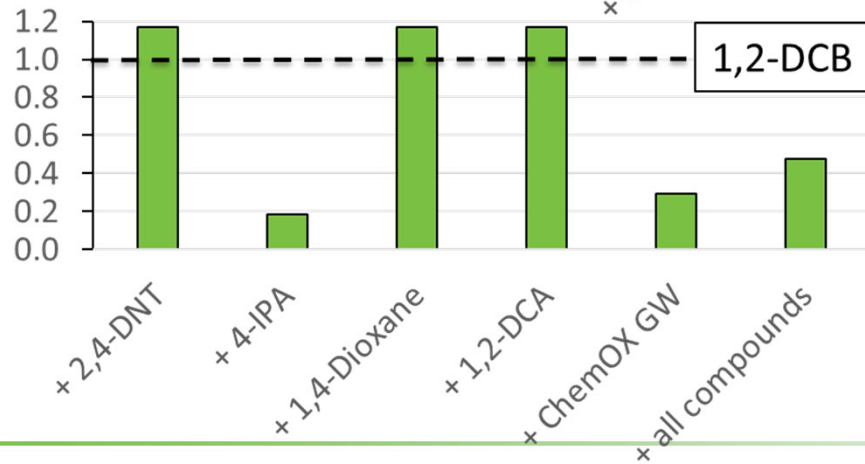
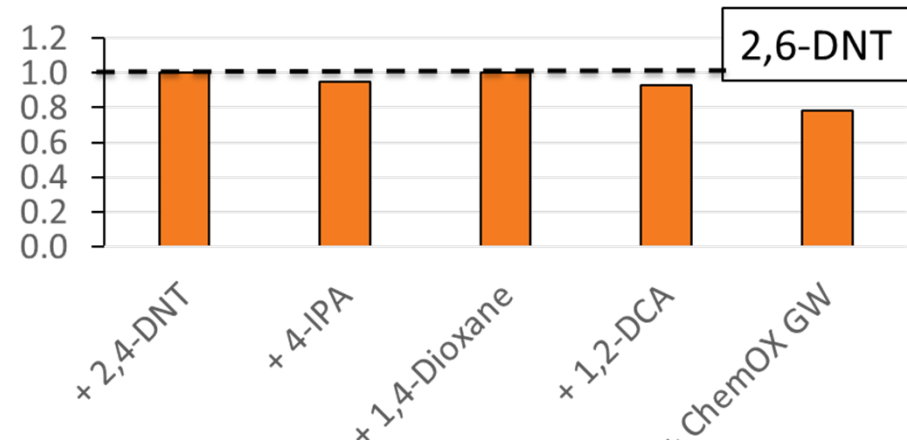
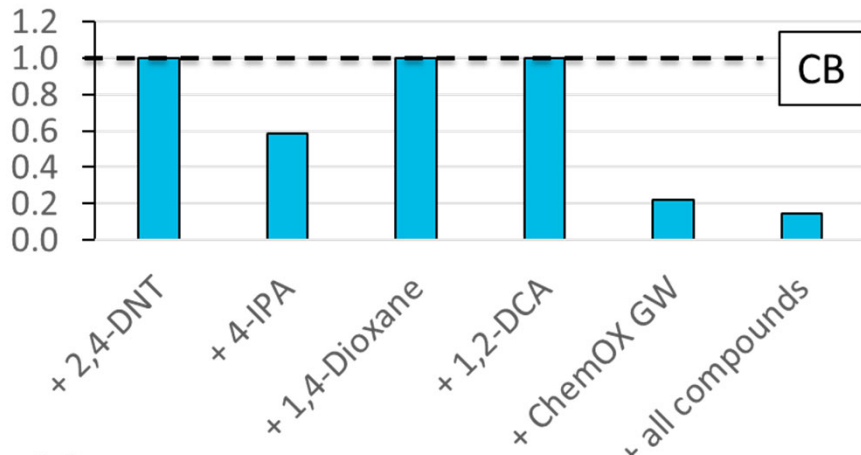


- Product from 4-NT = 4-Aminotoluene
- Bi-mixture effects: slightly stimulatory, slightly inhibitory
- Partial inhibition by the ChemOx water
- Effect of all compounds: in progress



Summary of Effects:

(Average Rate with Contaminant)/(Average Rate of Parent Enrichment Culture)



Conclusions

- **For source zone treatment:**
 - ISCR/ISCO shows greater promise than ISCO alone for nitrotoluenes
 - Aminotoluenes easier to chemically oxidize than nitrotoluenes
- **For downgradient biodegradation:**
 - Good potential for anaerobic reduction of nitrotoluenes to aminotoluenes
 - Good potential of aerobic biodegradation of CB and 1,2-DCB
 - Modest level of transient inhibition caused by bi-mixture (4-IPA) and + all contaminants present at the same time
 - Higher level of transient inhibition caused by the presence of ChemOx groundwater at 10X dilution; may be a concern if less dilution occurs
- **Overall:**
 - Chemical treatment of source zone combined with downgradient biodegradation looks promising



Any questions?

