ENHANCED BIOREMEDIATION OF SOIL CONTAMINATED WITH LINDANE AND OTHER CHLORINATED PESTICIDES USING ORGANIC CARBON / ZVI REAGENTS

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Agenda

1. Modes of Application
2. Daramend® Reagents (composition)
3. Background on Research and Development
4. Important Aspects of Chemistry & Biochemistry for Good Pesticide Treatment
5. Short Project Snapshots

Applicability

In-Situ Treatment of Pesticides in Surface Soil, 0-60 cm (Industrial Site)

Applicability

In-Situ Treatment of DDT and Dieldrin in Soil (Agricultural Site)

Applicability

Ex-Situ Treatment of Chlorinated Phenols (Chemical Production Site)

Applicability

Ex-Situ Treatment of Organic Explosive Compounds (US Army Ammunition Plant)

Applicability

In-Situ Pretreatment of Sediment (US Navy Site)

Applicability

Ex-Situ Soil Treatment in Windrows (US Army Site)

Daramend® Reagent Composition & Application

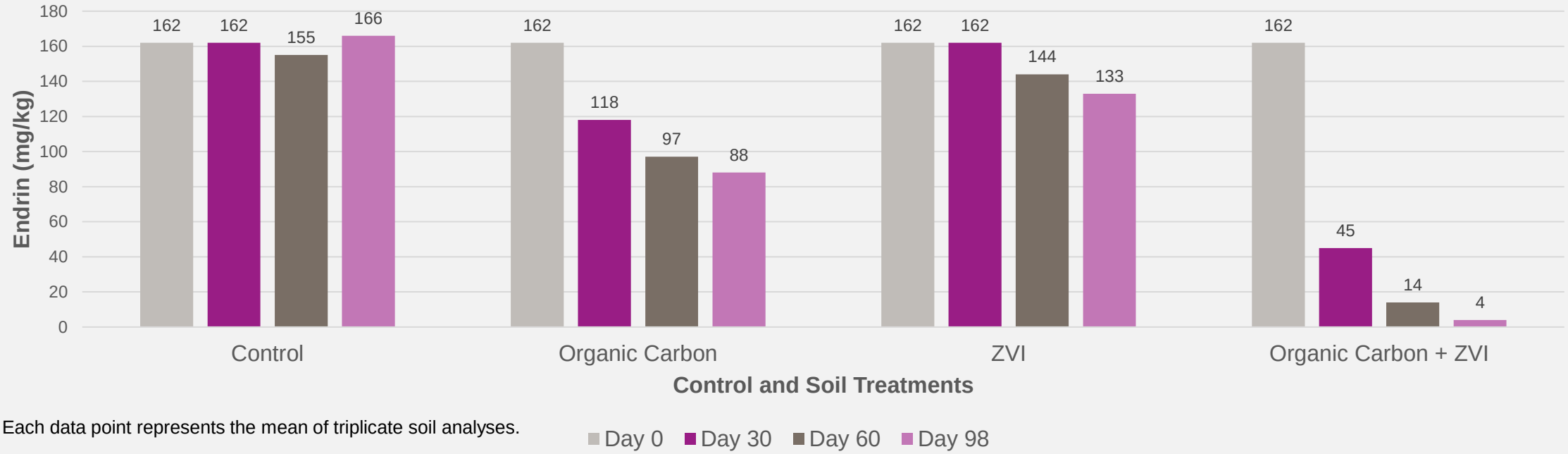
- Daramend® = nutrient-rich organic carbon + reduced iron powder + and a food-grade emulsifier
- Flowable, low-dust fine-grained powder delivered in 25 kg bags or 1-ton totes
- Typical application rates are between 0.5% and 4% (w/w)
- Results in reagent cost of between €15/ton and €90/ton of treated soil (subject to soil conditions)
- Thorough soil mixing to achieve good distribution of reagent
- Irrigation required to achieve and maintain adequate soil moisture content
- Usually applied to surface soil but can be applied at depth with specialized soil mixing equipment




Initial Observations on the Performance of Various Soil Amendments

Degradation of Endrin in Soil from South Carolina, USA Pesticide Site

Figure 1. Influence of soil amendments on Endrin concentration[1] during 98 days of treatment.



1. Each data point represents the mean of triplicate soil analyses.

- ✓ Stable concentration in control
- ✓ Slow, steady degradation with organic carbon
- ✓ Slower degradation with microscale ZVI

- ✓ MUCH more rapid degradation with both organic carbon *plus* ZVI
- ✓ Why is the combination so much better?

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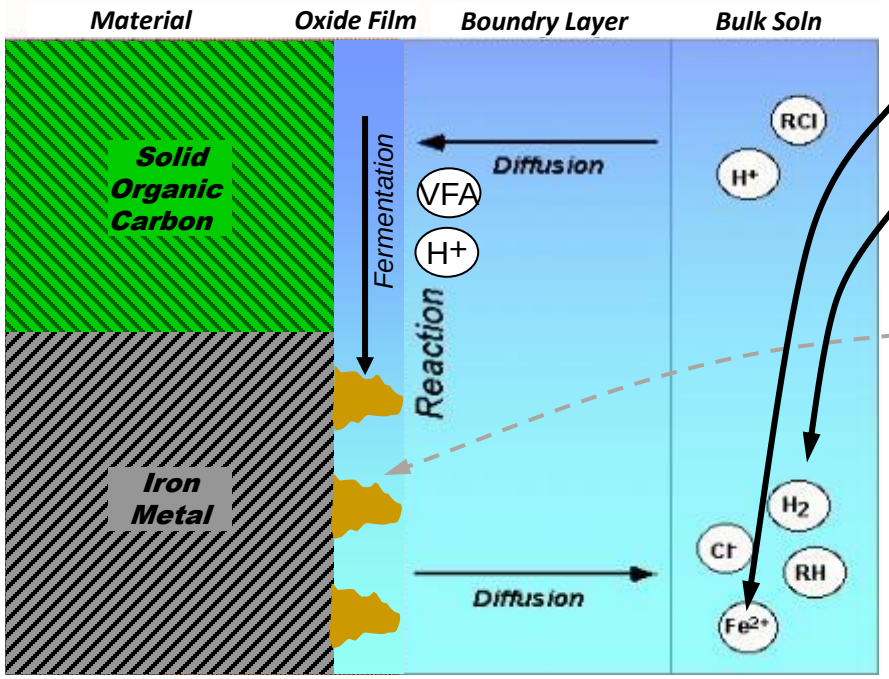
Carbon Fermentation Increases ZVI Reactivity and Promotes Multiple Dechlorination Mechanisms

- High pH at ZVI surface promotes precipitate formation and this *causes passivation*.
- Organic carbon fermentation generates organic acids (acetic, butyric, propionic, lactic).
- These organic acids have pK_a values ±5.0 and buffer the high alkalinity of ZVI oxidation and this *prevents ZVI passivation*.



Fe^{+2} generation

H_2 generation

ZVI Reactions:

$Fe^0 \rightarrow Fe^{2+} + 2e^-$

$2H_2O \rightarrow 2H^+ + 2OH^-$

$2H^+ + 2e^- \rightarrow H_{2\,(g)}$

$R\text{-}Cl + H^+ + 2e^- \rightarrow R\text{-}H + Cl^-$

Favorable thermodynamic conditions for dechlorination:

- Combined oxygen consumption from carbon fermentation and iron oxidation → Strongly reduced environment (-250 to -500 mV)
- High electron/H^+ pressure

Production of organic acids (VFAs):

- Serves as electron donor for microbial reduction of CVOCs and other oxidized species such as O_2, NO_3, and SO_4
- The release of acids keeps the pH down and thereby serve to reduce precipitate formation on ZVI surfaces to increase reactivity
- Increase rate of iron corrosion/H_2 generation

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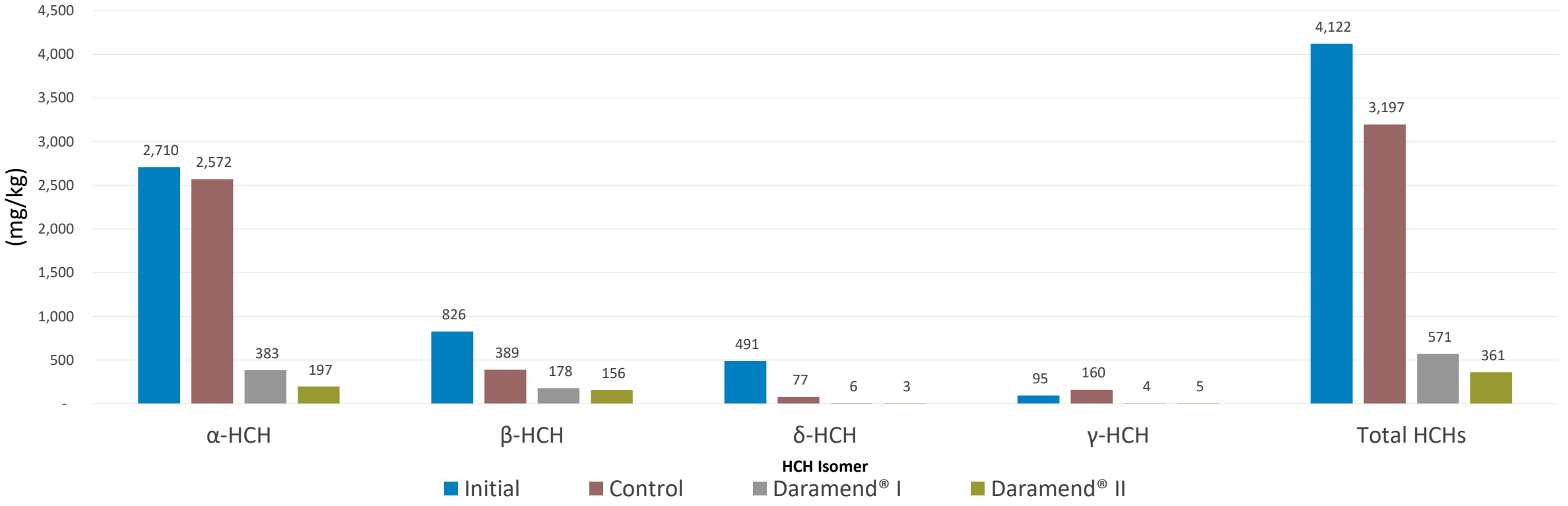
Daramend® Bench Scale Results:

Influence of treatments on HCH concentrations in soil after 250 days of treatment.



- ✓ Daramend® formulations differed in nutrient profile
- ✓ Nearly complete removal of δ-HCH and γ-HCH
- ✓ α-HCH and β-HCH isomers have higher acute toxicity
- ✓ Control was addition of water and mixing

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Daramend® Bench Scale Results

Influence on concentrations of HCH compounds in soil (Alabama, USA Industrial Site, higher [HCH])

Table 1. Influence of bench-scale Daramend® treatment on Lindane and other HCH compounds in soil.

Condition	α-HCH		β-HCH		γ-HCH (Lindane)		δ-HCH		Total HCH	
	(mg/kg)									
	Initial	Final[1]	Initial	Final	Initial	Final	Initial	Final	Initial	Final
Control (no treatment)	2,710	2,572	826	389	491	77	95	160	4,122	3,197
Daramend®	2,710	197	826	156	491	3	95	5	4,122	361

1. Final soil HCH concentrations were determined after 250 days of treatment.

99% removal of Lindane; 93% removal of α-HCH; 91% removal of total HCH

Three Project Snapshots

1. Very brief
2. Meant to provide representative soil remediation data
3. Full case studies are available upon request

Project Snapshot 1:

Daramend® Treatment of Toxaphene and DDT

Industrial site in Imperial Valley, California USA


Pesticide & Sulfur Impacts


Toxaphene Cattle Dip


Soil Tillage & Irrigation

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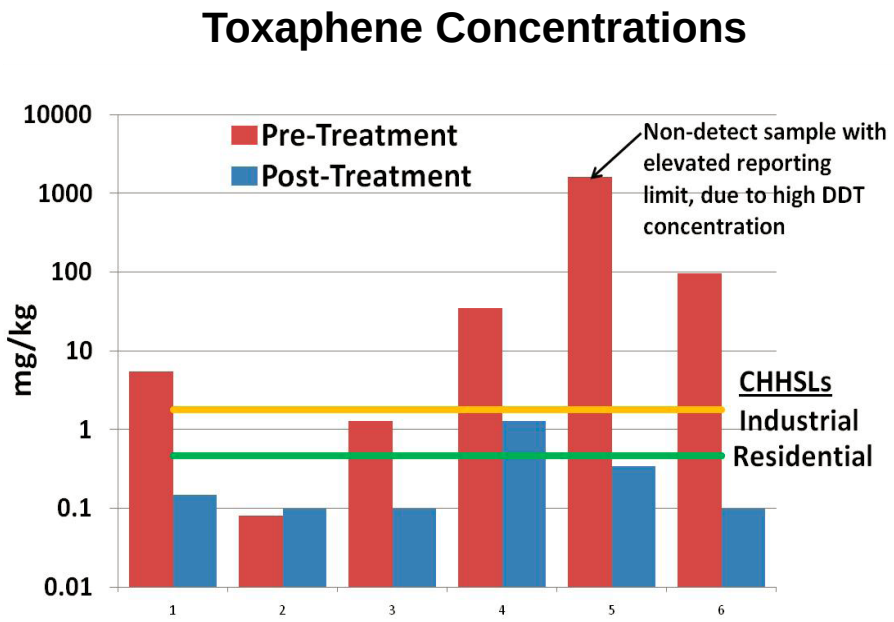
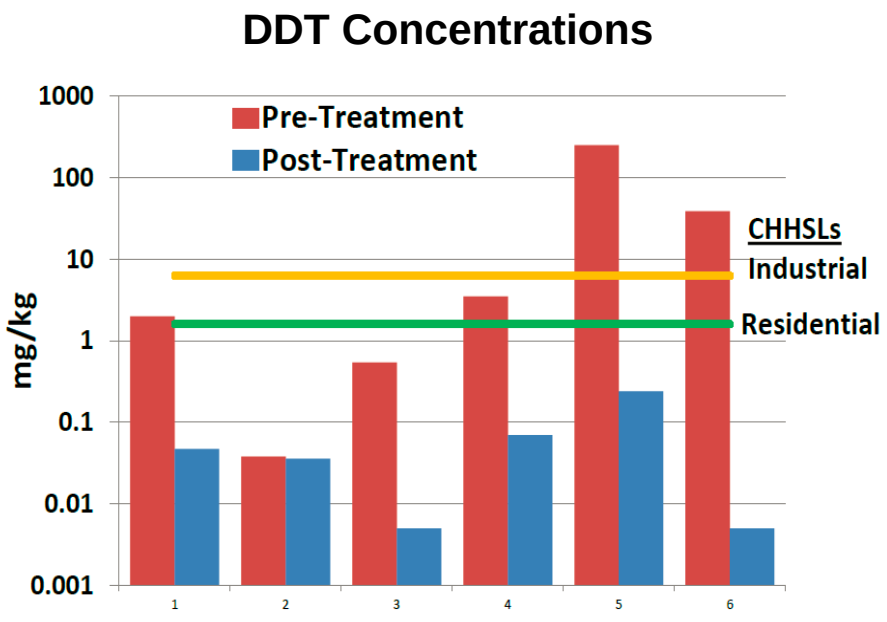
Project Snapshot 1: Industrial site in Imperial Valley, CA
Performance Data for Toxaphene and DDT





- Industrial treatment standards achieved with only one treatment cycle for all the sampling zones (California Human Health Screening Levels)
- Residential treatment standards achieved with only one treatment cycle for all but one sampling zone
- Very high removal efficiencies and low residuals achieved for both DDT and Toxaphene
- Presence of elemental sulfur may have enhanced removal.

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Project Snapshot 2:

Lindane and HCH Compounds Industrial Site (USA)

- Confidential Agricultural Chemical Industry Site
- United States (South Carolina)

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Project Snapshot 2:
In Situ Treatment of Lindane and HCH Compounds (South Carolina)

Influence of field scale in-situ Daramend® treatment on concentrations of Lindane and other HCH compounds in soil (agricultural site, United States).

Condition	α-HCH		β-HCH		γ-HCH (Lindane)		δ-HCH		Total HCH	
	(mg/kg)									
	Initial	Final[1,2]	Initial	Final	Initial	Final	Initial	Final	Initial	Final
Daramend® Treatment	17	1.1	13	1.0	14	1.1	3.5	1.0	47.5	4.2

- Treatment time was 192 days with periodic soil mixing and irrigation
- Total Daramend dosage was between 2.0% and 6.0% w/w of soil subject to initial HCH concentration
- Surface soil (0 – 60 cm bgs) without excavation

Project Snapshot 3:

Chemical Industry Site

Midwest USA

In-situ Surface Soil (0 – 60 cm bgs)

Lindane in Soil

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Project Snapshot 3:

In Situ Daramend® Treatment of Lindane (US Midwest Chemical Industry Site)

Influence of field scale in-situ Daramend® treatment on concentrations of Lindane in soil

Condition	Initial	154 days	371 days	Lindane Removal (%)
	Lindane (mg/kg)			
Control (Tillage Alone)	266	289	481	-
Daramend® Treatment	1,610	471	133	91.7

- Chemical industry site
- Soil treated in-place from 0 – 60 cm bgs
- Daramend® reagent was applied four times with soil mixing and irrigation
- Total Daramend® reagent dosage was 5.0% w/w of soil
- Treatment time includes winter months (soil was frozen)

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Daramend® Reagents Summary

- ✓ Proven, biochemical, multi-mechanism reductive treatment of HCH and most other pesticides
- ✓ Also effective for treatment of halogenated and nitroaromatic organics
- ✓ Proven performance on Lindane, DDT, Aldrin, Dieldrin, Chlordane, Toxaphene, 2,4-D
- ✓ Also proven performance on organic explosive compounds (TNT, DNT, RDX, HMX, Tetryl)
- ✓ Rapid treatment of chlorinated solvents (TCE, PCE, DCA)
- ✓ Economical alternative to off site disposal for many soils, sediments, and industrial wastes
- ✓ Excellent 25-year worldwide track record in hundreds of field-scale applications

Questions are Welcome!

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