



# *Optimizing Bioremediation of Recalcitrant Soil Contaminants in Canada's Cold Climate*



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Presented by

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# Presentation Agenda



1. **About us**
2. **The Problem and The Opportunity**
3. **Sustainable Reagents for Aerobic and Anaerobic Bioremediation**
  - ✓ Composition of Aerobic Terramend® Carbon & Terramend® Inorganic reagents
  - ✓ Composition of Anaerobic Daramend® and Daramend® Plus Reagents
  - ✓ Compare and Contrast with traditional fertilizer-based approach
  - ✓ Microbiology & Biochemistry during soil treatment
4. **Bench-scale treatability approach and results**
5. **Project Snapshots**
6. **Questions & Answers**



## About us



**Canadian Company founded in 1988**

**Production and warehouses throughout Canada**

Quebec

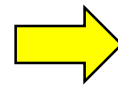
Ontario

Alberta

British Columbia

**Sectors of activity:**

Industrial and Municipal Potable & Waste Water



Contaminated Soil and Groundwater

Air, Odours and Atmospheric Emissions (Activated Carbon, filtering medias)

Process Water & Thermal Exchange Fluids (Glycols)

Drilling Fluids (Oil and Gas & Diamond exploration)

Aircraft De-icing Fluids



# Our Environmental Services



## Specialized Products Supply

- Chemical Oxidation
- Chemical Reduction
- Co solvent-Surfactant soil Washing
- Enhanced Bioremediation
- Permeable Reactive Barrier Amendments
- Metals Stabilization
- Activated Carbon Technologies







# Excellence & Science through proud Suppliers & Partners



ADVANCED OXIDATION TECHNOLOGY (AOT) *Since 2005*



# First - Establishing the fact about Canada cold climate





## The Problem

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- Traditional approach relies on supplying nitrogen and phosphorus at an “optimized” C:N:P ratio to support biodegradation of targeted hydrocarbons (PAHs, TPH, CP)
- Typical amendments used include commercial and agricultural fertilizers
- This approach sometime fails as inorganic nutrients are used rapidly when bioavailable, and are lost through wasteful processes including luxury consumption, denitrification, and precipitation
- The fertilizer approach doesn't address the issues of acute microbial toxicity and inadequate bioavailable water
- Soil volume could increase post-treatment due to the addition of bulking agents (e.g. wood chips)



## The Opportunity



- Overcome inefficiencies in the traditional approach by using specialized soil amendments that provide nutrients, increase bioavailable water, and protect soil microorganisms from high acute toxicity.
  - Sustainable amendments capable of creating the optimal conditions for degradation
  - Capable of treating high concentrations of contaminants while overcoming acute toxicity to indigenous microbes
  - Allows balance between soil water content (bioavailable water) and the ability to maintain aerobic conditions
  - Lower overall remediation costs







# Terramend<sup>®</sup> Reagents for Aerobic Treatment



Attribute	Terramend <sup>®</sup> Carbon	Terramend <sup>®</sup> Inorganic
High Surface Area Hydrophilic Plant Fiber	✓	✓
<u>Slow-release</u> Organic Carbon & Nutrients (N, P, S)	✓	✓
Inorganic Nitrogen & Phosphorus	-	✓
Emulsifying Agent	✓	✓
pH Balanced	✓	✓

- Designed to stimulate the growth of native aerobic microorganisms by providing an effective blend of organic carbon, amino acids, and organic nitrogen and phosphorus.
- Terramend Carbon treats PAHs, phthalates, and chlorophenols (including PCP).
- Terramend Inorganic treats BTEX, GRO, DRO, and TPH.

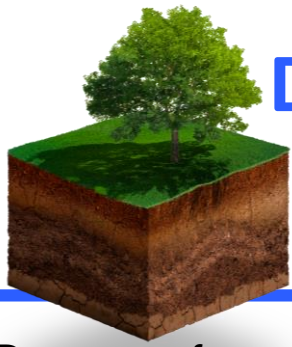


# Daramend® Reagents for Anaerobic Treatment



Attribute	Daramend®	Daramend® Plus
High Surface Area Hydrophilic Plant Fiber	✓	✓
<u>Rapid-release</u> Organic Carbon & Nutrients (N, P, S)	✓	✓
Emulsifying Agent	✓	✓
pH Balanced	✓	✓
Microscale ZVI	✓	✓
Activated Carbon	-	✓

- For the treatment of chlorinated pesticides, herbicides, organic explosives, chlorinated solvents and heavy metals.
- Creates anaerobic and reducing conditions



# Distinguishing Features of the Terramend<sup>®</sup> Reagents



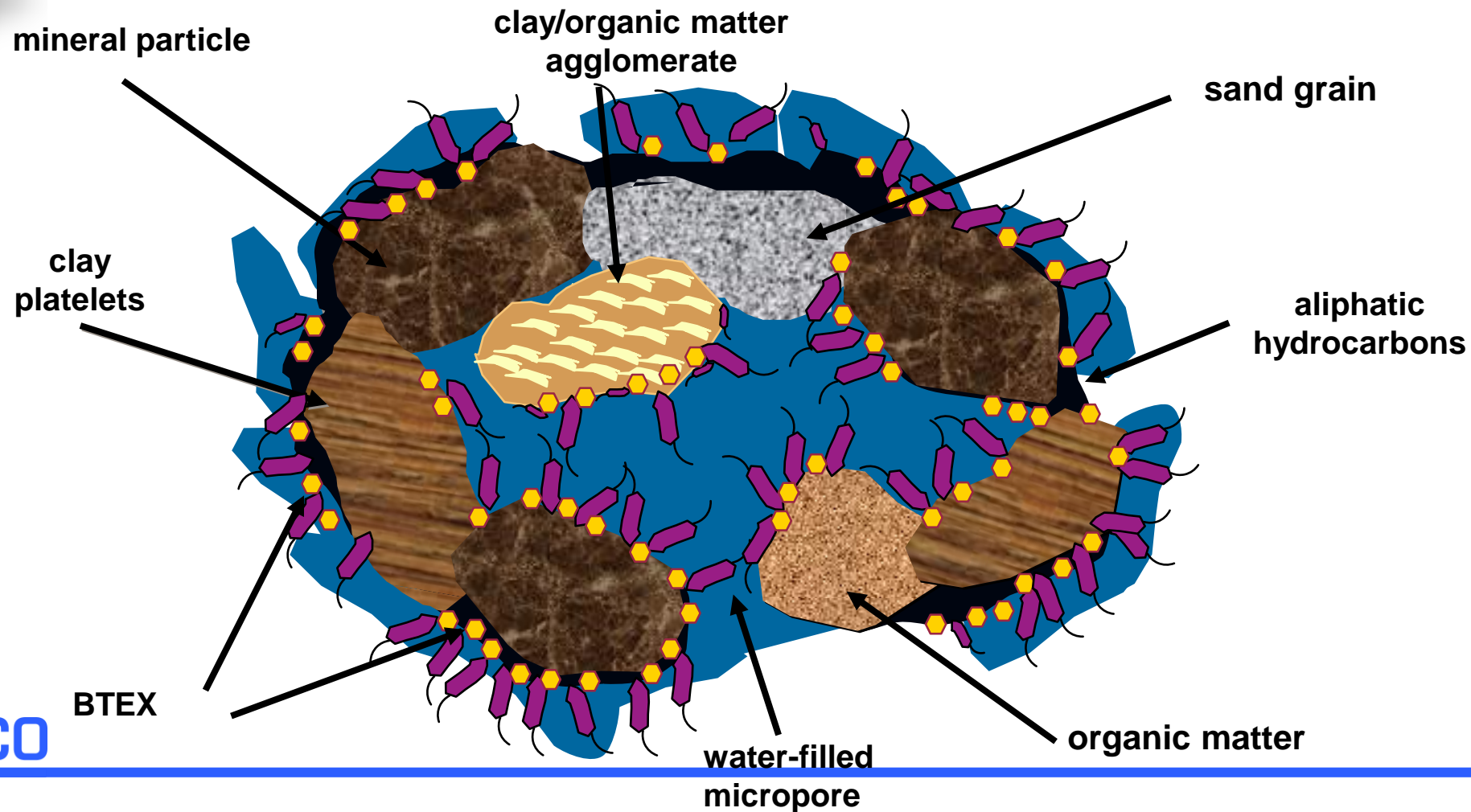
- Prevents formation of large, dense aggregates, with anoxic centers, as often seen with other soil bioremediation technologies
- Small particle size and hydrophilic nature
  - Requires a relatively small dosage to achieve a large increase in soil water holding capacity (WHC) and bioavailable water
  - Makes the soil easier to handle
  - Reduces the need to collect and treat free water
- Processed from plant materials rich in cellulose and hemicellulose, with very little lignin (unlike wood chips/saw dust that are high in lignin content)
  - Readily biodegradable
  - Does not bind contaminants in a manner that shields them from biodegradation
- Works effectively at lower dosages
  - 1% to 5% by wt. of soil as opposed to 10% to 20% by wt. of saw dust, wood chips, or other common bulking agents





# Terramend<sup>®</sup> Treatment Mechanism

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# How do I use Terramend® Reagents?



In-situ treatment of surface soil (0 – 24" bgs)



On-site treatment of excavated soil in HDPE-lined biocell



Off-site treatment of excavated soil in mixed biopiles



On-site treatment of excavated soil in aerated biopiles



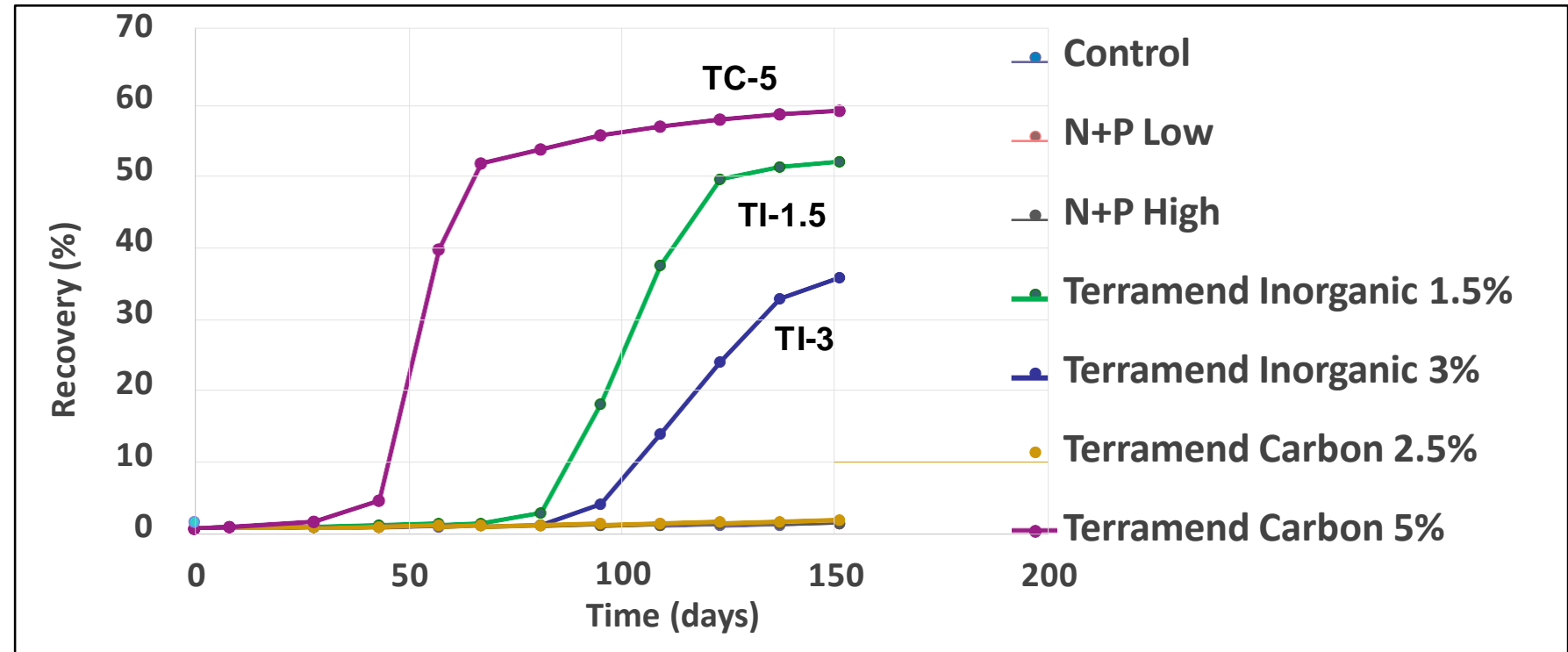
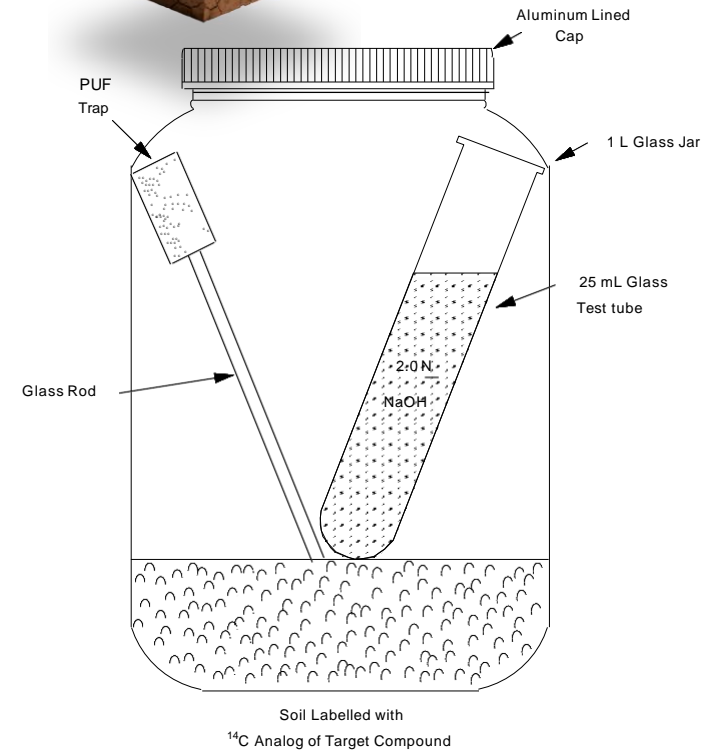
# Bench-scale Treatability Testing

- ✓ Objectives
- ✓ Methodology
- ✓ Results for PCP, and Petroleum Hydrocarbons

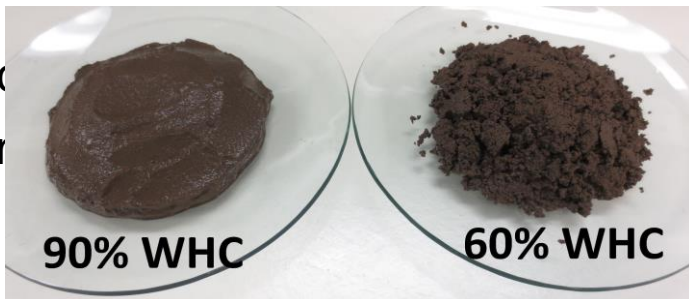
# Bench-scale Treatability Testing for PCP in Soil



## Mineralization of $^{14}\text{C}$ -PCP to $^{14}\text{C}$ - $\text{CO}_2$



- Doc
  - Cor
- n of PCP  
and dosages

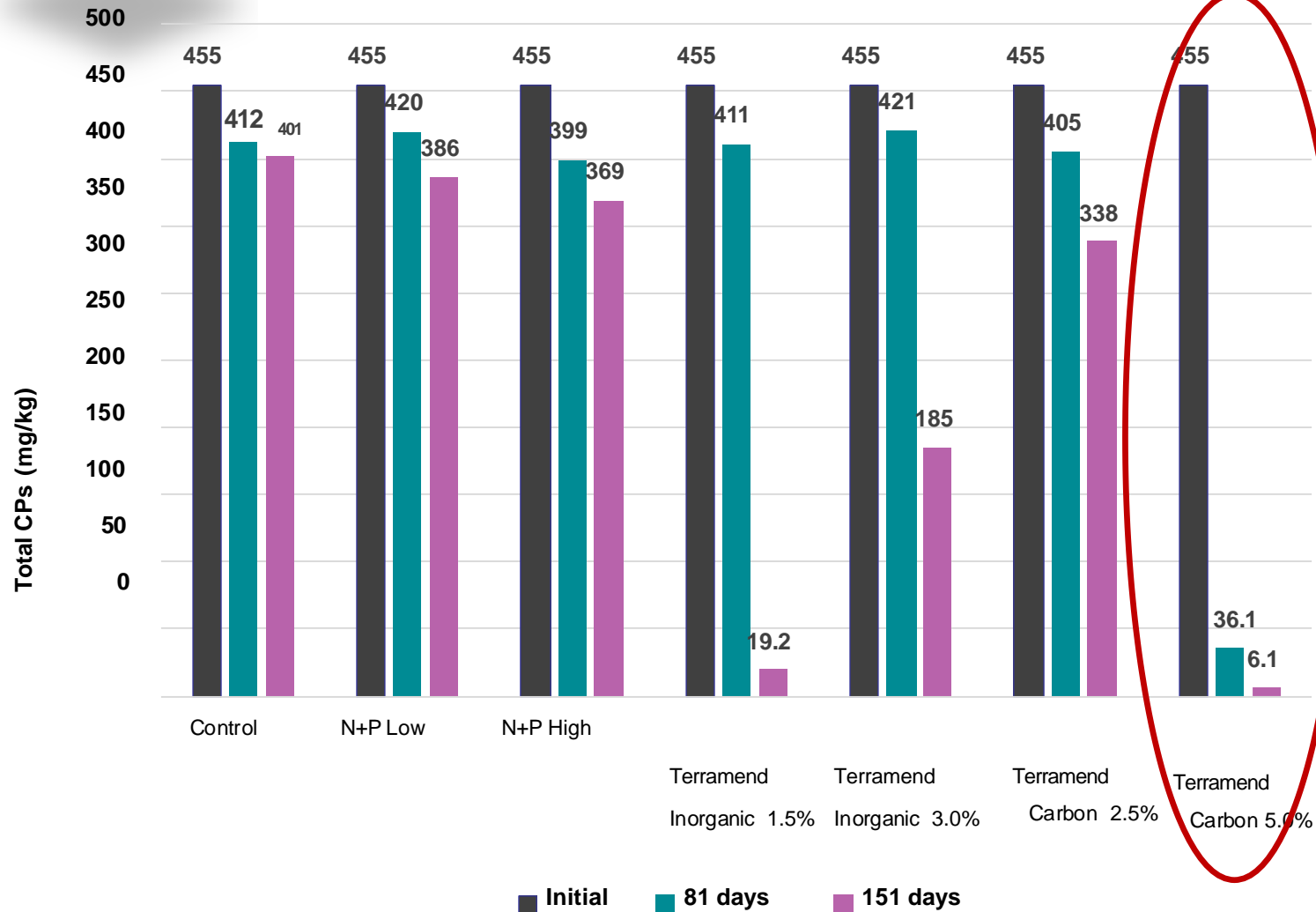


- Hydrophobic soil with acutely toxic COI
- Terramend® Carbon at 5% w/w performed best
- Poor response to both N+P nutrient treatments



# Bench-scale Treatability Testing for PCP in Soil

## Total Extractable Chlorinated Phenols

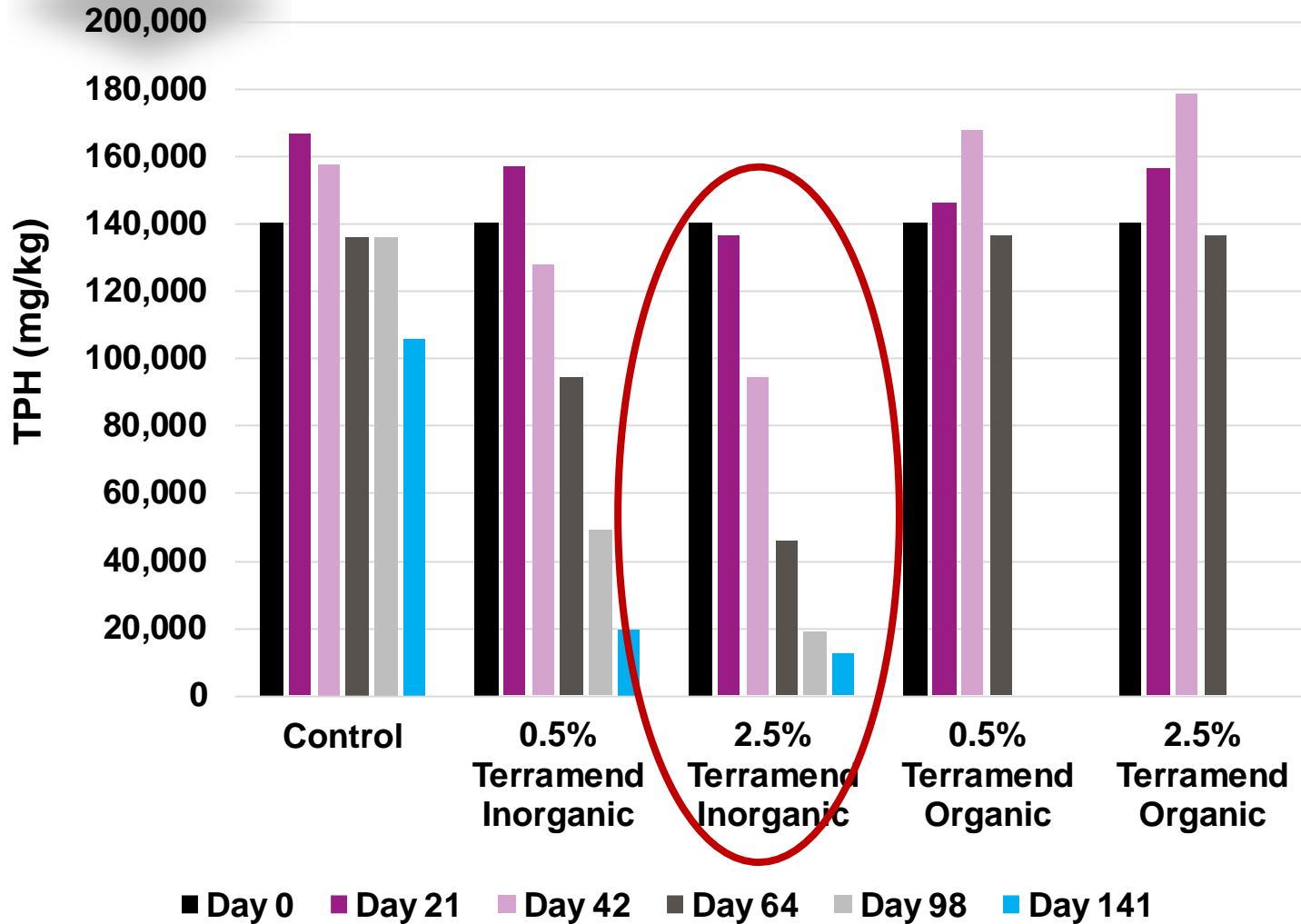


- Strong correlation between mineralization of  $^{14}\text{C}$ -PCP and reduction in total soil PCP
- Treatment that supported greatest conversion of PCP to  $\text{CO}_2$  also achieved lowest residual PCP concentrations
- Higher dose of slowly-released Terramend Carbon provided optimal moisture without turning soil anaerobic
- Inorganic N+P was ineffective regardless of dosage



# Bench-scale Treatability Testing

## Terramend<sup>®</sup> Treatment of stabilized Drill Cutting



- Very high TPH drill cuttings from oil extraction
- Initial treatment with wood mulch (10% w/w) did not achieve the desired TPH reduction
- The as-received soil (pre-treated with mulch) were subjected to 141 days of Terramend<sup>®</sup> treatment with weekly aeration by mixing
- There was a sharp difference in response to Terramend Inorganic vs Terramend<sup>®</sup> Carbon.
- Most effective treatment was the higher dosage of Terramend<sup>®</sup> Inorganic
- TPH was reduced by 91% in response to this treatment

# Project Snapshots

1. Terramend<sup>®</sup> Inorganic Treatment of Aged Hydraulic Oil and Diesel Fuel
2. Terramend Carbon Treatment of PAHs, PCP, and Mineral Oil TPH
3. Darramend<sup>®</sup> Treatment of Organic Explosives (TNT and RDX)



## Project Snapshot #1

Terramend<sup>®</sup> Inorganic

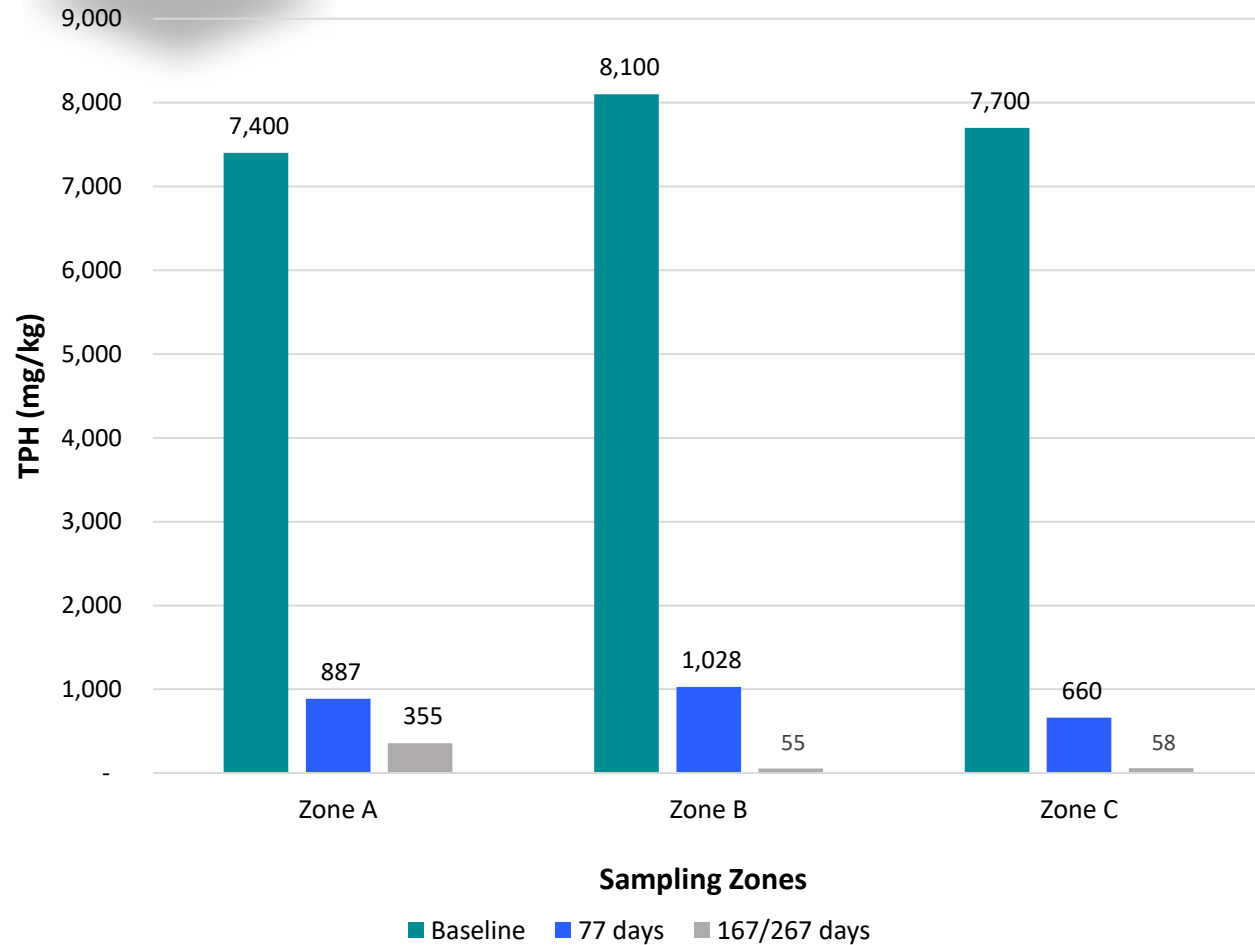
Ex-Situ Treatment of Hydraulic Oil  
& Diesel Fuel

- Midwest Industrial site
- Former agricultural equipment repair facility
- Approximately 4,400 tons of soil treated on-site
- Terramend<sup>®</sup> reagent cost was about \$39 /ton of treated soil.





# Bioremediation of Hydraulic Oil + Diesel Fuel Contaminated Soil with Terramend® Inorganic Reagent



## • On-Site Treatment of Industrial Soil

- 4,400 tons treated in HDPE lined biocell with soil in a layer of 24" (60 cm) thickness
- Hydraulic oil and diesel fuel ( $C_{16} - C_{35}$ )
- Calcareous sandy loam, neutral pH, low organic matter
- Terramend® Inorganic dosage of 3.0% w/w in split application (2.0% at start and 1.0% on day 90)
- Soil water content maintained near 60% WHC
- Aeration by tillage twice weekly for the first month, with tillage reduced to weekly thereafter
- Each data point represents the mean of 5 composite samples with each composite created by blending 10 grab samples from full depth of treatment





## Project Snapshot #2

Terramend® Carbon

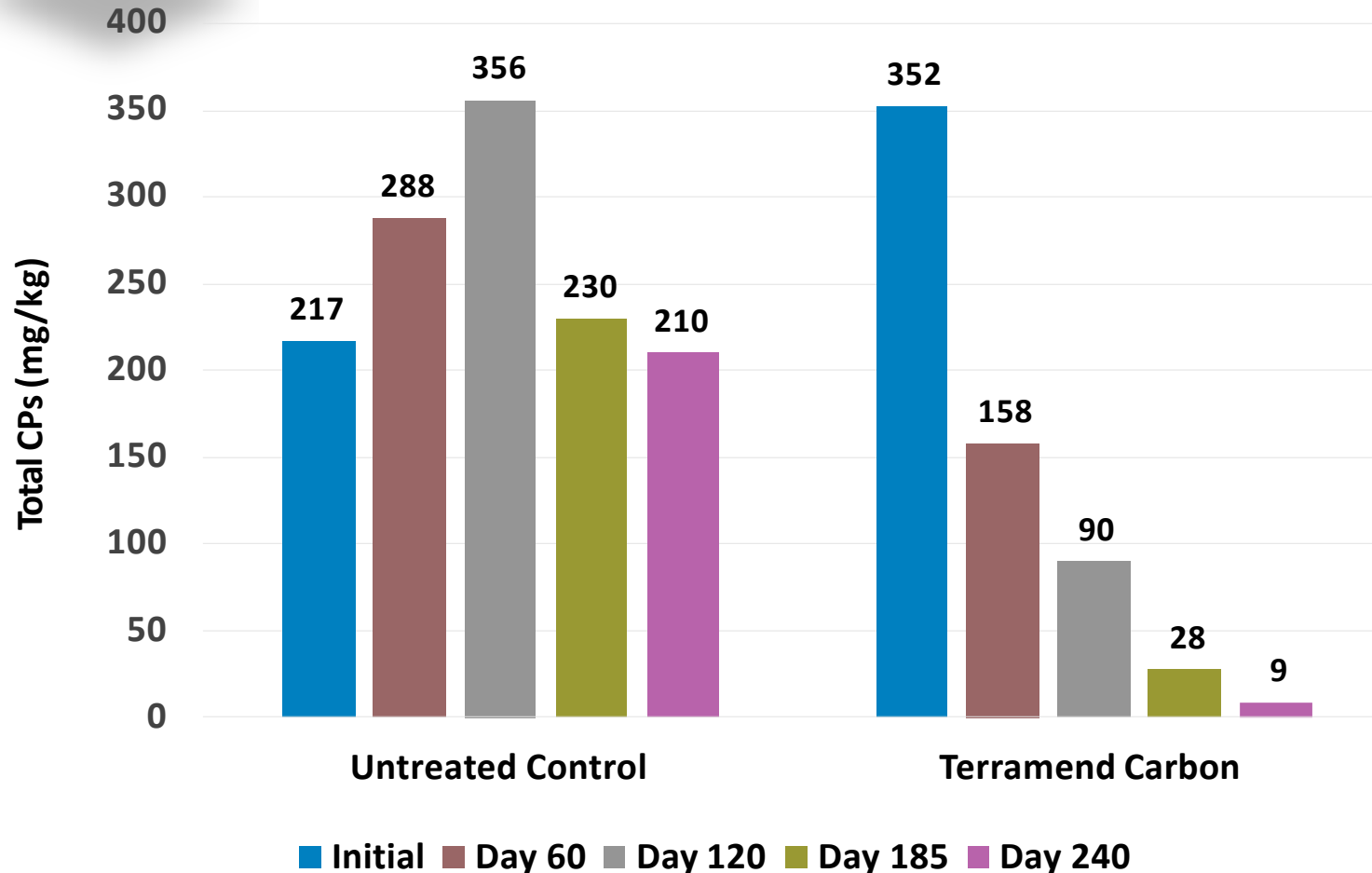
Ex-Situ Treatment of PAHs, PCP, and Petroleum Hydrocarbons

- Industrial Wood Preserving Site in Ontario
- Pressure treatment using creosote, PCP and mineral oil
- On-site treatment of excavated soil in HDPE-lined cell
- 1,200 tons/year in batch system over three years
- Terramend® reagent cost was about \$24 /ton of treated soil for the lightly impacted soil and about \$48/ton of treated soil for the heavily impacted soil.





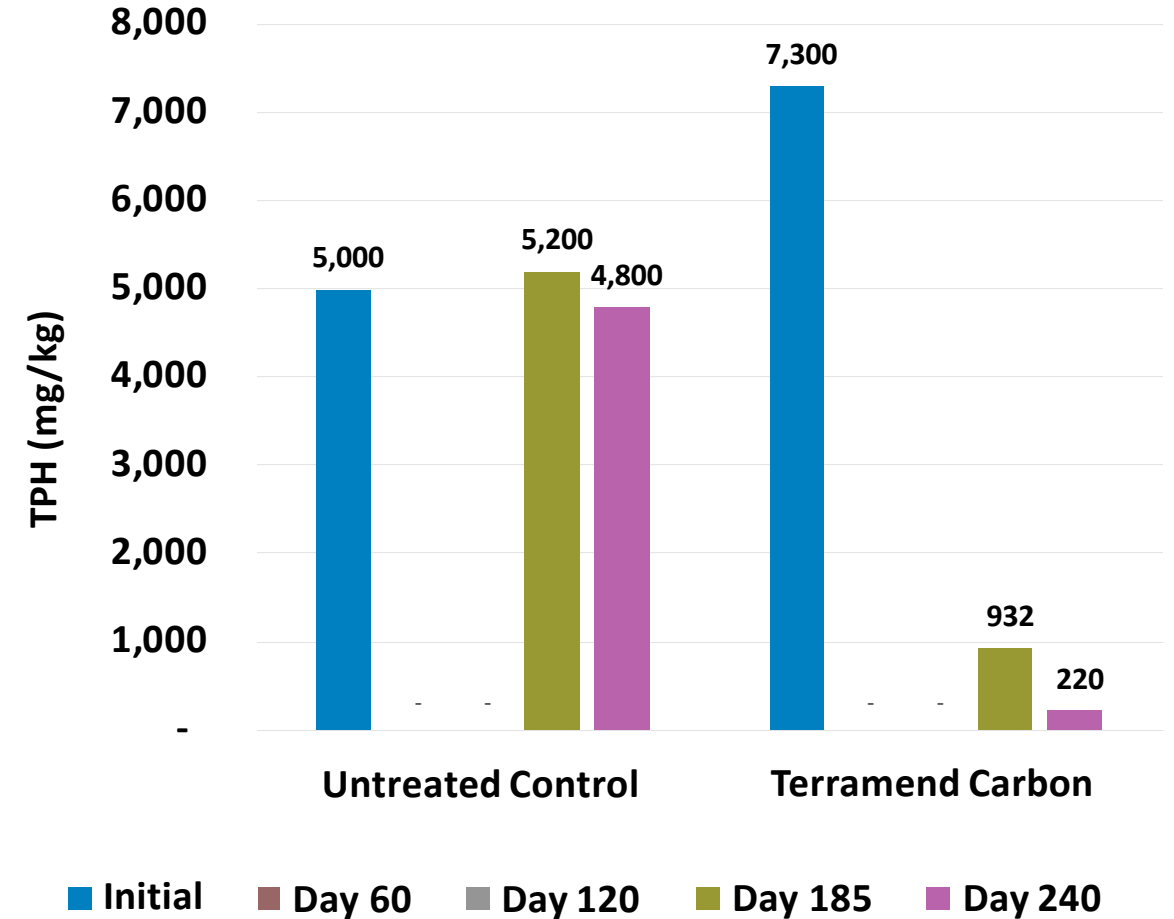
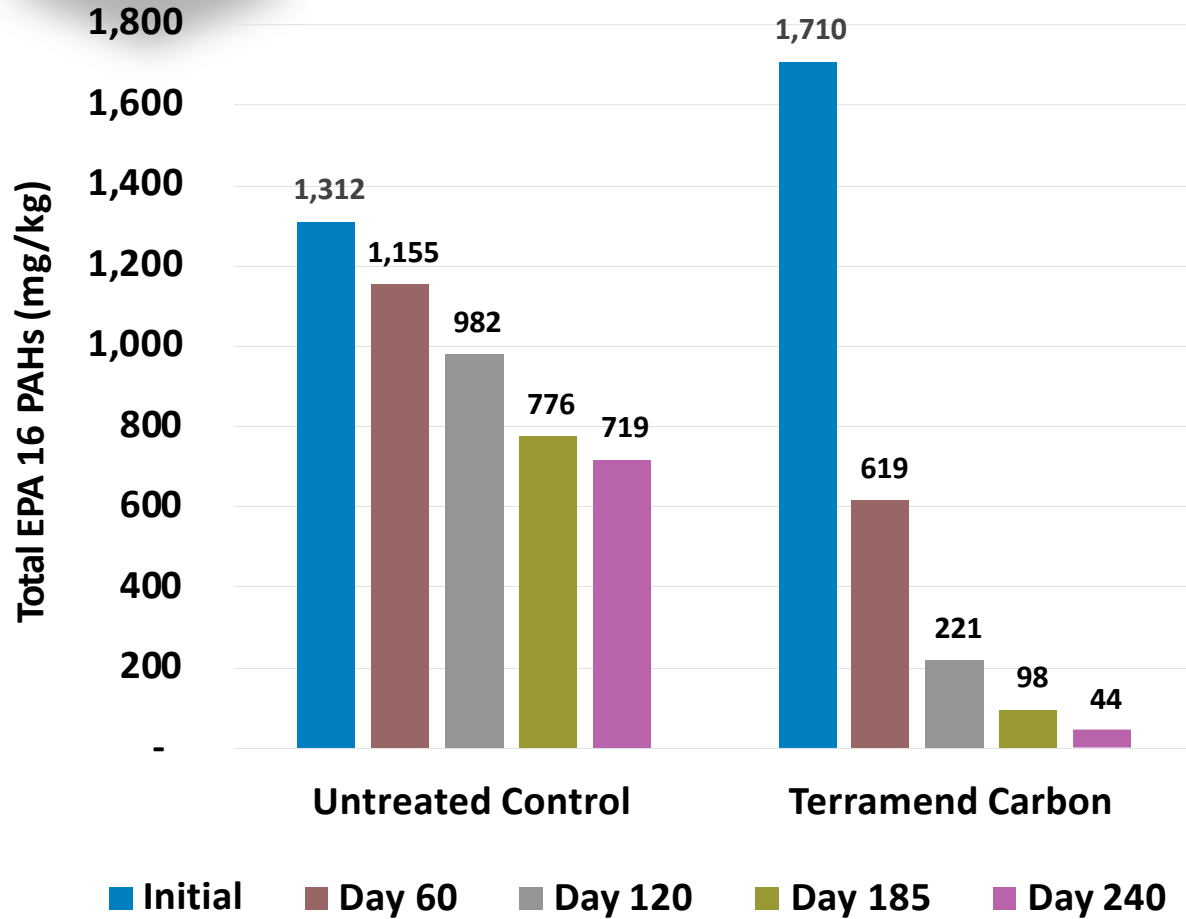
# Ex-Situ Bioremediation of PCP-impacted Wood Treatment Soil with Terramend<sup>®</sup> Carbon



- Treatment cell was covered to extend treatment season in a cool climate area
- First batch included monitoring of untreated control soil simultaneous with Terramend<sup>®</sup> Carbon treated soil
- Also treated 4,800 tons of lightly impacted soil in-situ (0 – 60 cm bgs)



# Treatment of PAHs and Petroleum Hydrocarbons





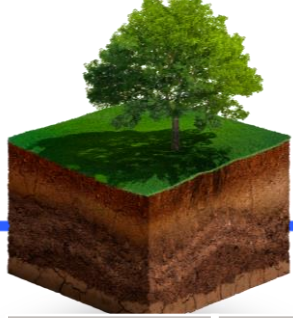
## Project Snapshot #3

Daramend® Treatment of TNT and RDX in Soil  
Naval Weapons Station Yorktown, Yorktown VA



- 8,400 y<sup>3</sup> soil (ca. 12,000 tons)
- Soil TNT concentrations as high as 43,000 mg/kg (average about 10,000 mg/kg)
- Treatment goals were 14 mg/kg for TNT and 5 mg/kg for RDX
- Ex Situ Treatment of soil and sediment (impacted by effluent from washout of TNT manufacturing plant)
- Engineered HDPE biocell, covered to prevent flooding and allow extended treatment season
- Completed seven batches (1,200 y<sup>3</sup>/batch)





# Naval Weapons Station Yorktown TNT and RDX Concentrations before and after Daramend<sup>®</sup> Treatment

Sampling Zone	Batch #1		Batch #2		Batch #3		Batch #4	
	Initial	Final	Initial	Final	Initial	Final	Initial	Final
	TNT (mg/kg)				RDX (mg/kg)			
1	14,000	4.1	1,520	0.6	185	0.2	10	0.6
2	7,900	6.5	2,400	10.4	230	0.4	92	1.0
3	12,000	3.1	1,560	0.5	120	0.3	40	0.5
4	17,000	7.0	8,000	1.0	500	0.3	930	0.7
5	19.0	2.6	2,210	2.7	250	12.0	150	0.5
6	5,100	5.7	15,500	11.5	185	0.5	160	0.3
7	33,000	8.8	30,200	5.7	2,500	0.4	290	0.5
8	1,300	2.9	10,900	2.0	1,000	0.1	850	0.7
9	8,400	14.0	40,400	9.5	2,500	2.9	24	0.7
10	2,800	6.8	40,900	8.8	3,430	2.4	0.8	0.5
<b>Mean</b>	<b>10,151</b>	<b>6.2</b>	<b>15,359</b>	<b>5.3</b>	<b>1,090</b>	<b>2.0</b>	<b>255</b>	<b>0.6</b>

- Daramend dosage of 1.0% w/w for first cycle and 0.5% w/w for subsequent cycles
- Between 7 to 10 treatment cycles
- Each treatment cycle includes addition of Daramend, tillage, irrigation, and a post irrigation reaction period of 7 – 10 days
- Soil moisture content set to 70% to 80% of WHC
- Repeated performance of +99% destruction of both TNT and RDX



# should I use Terramend® Reagents?



- **Allows In-situ or On-site Treatment of Soils Contaminated with TPH, PAH, PCP, phthalates, and certain pesticides:** Ideal for both in-situ treatment of surface soil and on-site treatment of excavated soils by tilling or in mechanically-aerated biopiles.
- **Substantial Cost Savings:** Eliminates excavation, transportation, and off-site disposal resulting in remediation costs that are less than half of the next best alternative treatment.
- **Preserve, Protect & Reuse Soil:** In-situ and on-site treatment allows soil to remain on-site for site rehabilitation or used in construction.
- **Sustainable Remediation:** Terramend® reagents provide a sustainable form of remediation *from the perspectives of carbon footprint* and recycling of agricultural and industrial process byproducts.
- **Excellent 25-year track record in many field-scale applications**

## Alternative to Landfill Disposal



## Beneficial On-Site Reuse of Soil





*Thank you for your attention !!  
Questions ?!?*



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