

*Bioremediation Studies for Nitrobenzene, Aniline,  
and Diphenylamine at a Former Explosives  
Manufacturing Facility*

Presenter:

Raymond Lees

**Lingke Zeng**

Langan Engineering & Environmental Services, Inc.

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# Acknowledgement

## *Co-authors:*

- The Chemours Company, LLC

Sathya Yalvigi



- Viasant LL

Mark Lewis



- Langan Engineering & Environmental Services, Inc.

Kevin McKeever

Stewart Abrams

Ali Ciblak

Angelo falabell

**LANGAN**



# Outline

- Background
- Objectives
- Bench Procedures and Results
  - Sampling
  - Bulking
  - Chemical Oxidation
  - GAC
  - Landtreatment Simulation
- Pilot Study
- Conclusions

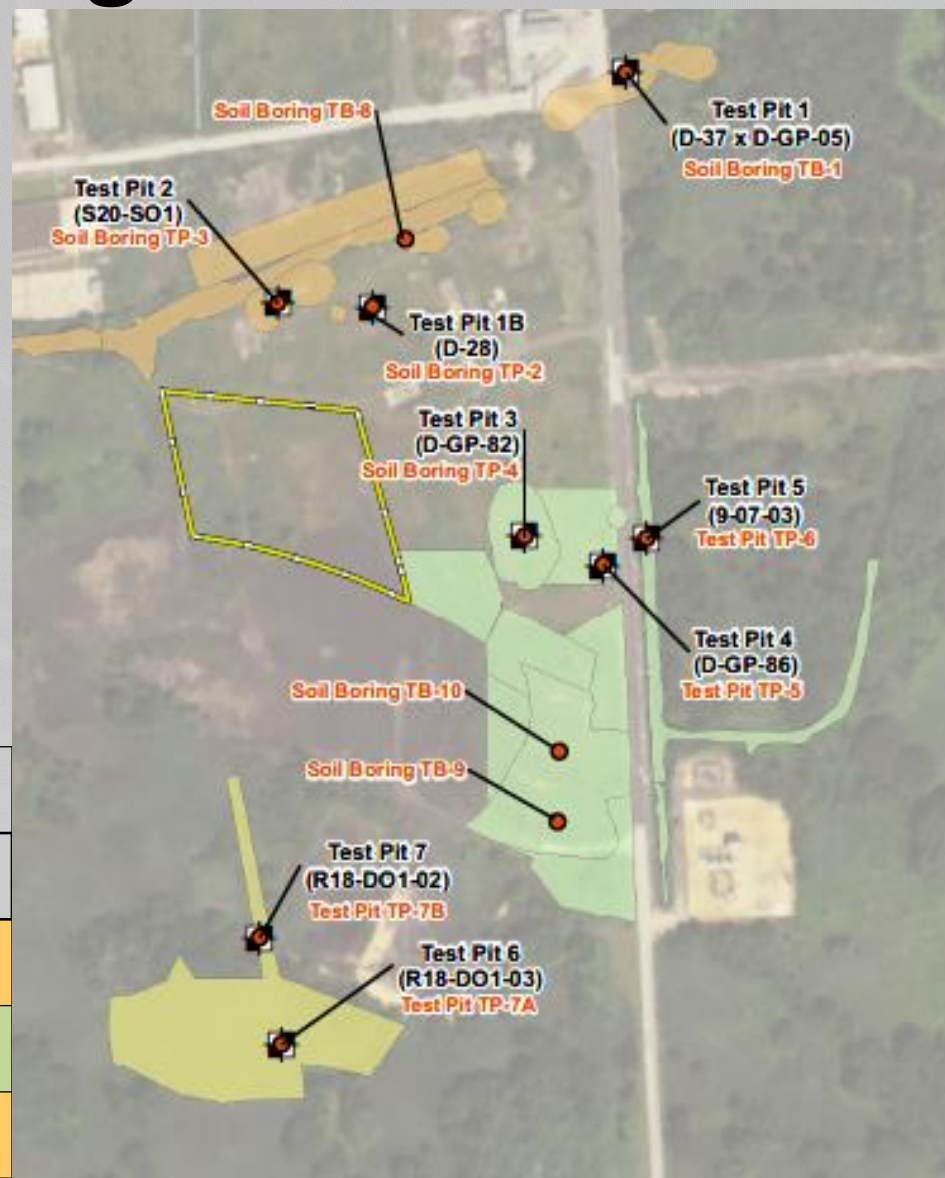




# Site Background

- Facility in southern New Jersey
- 37,000 cubic yards for treatment via landfarming
- Three years treatment cycle

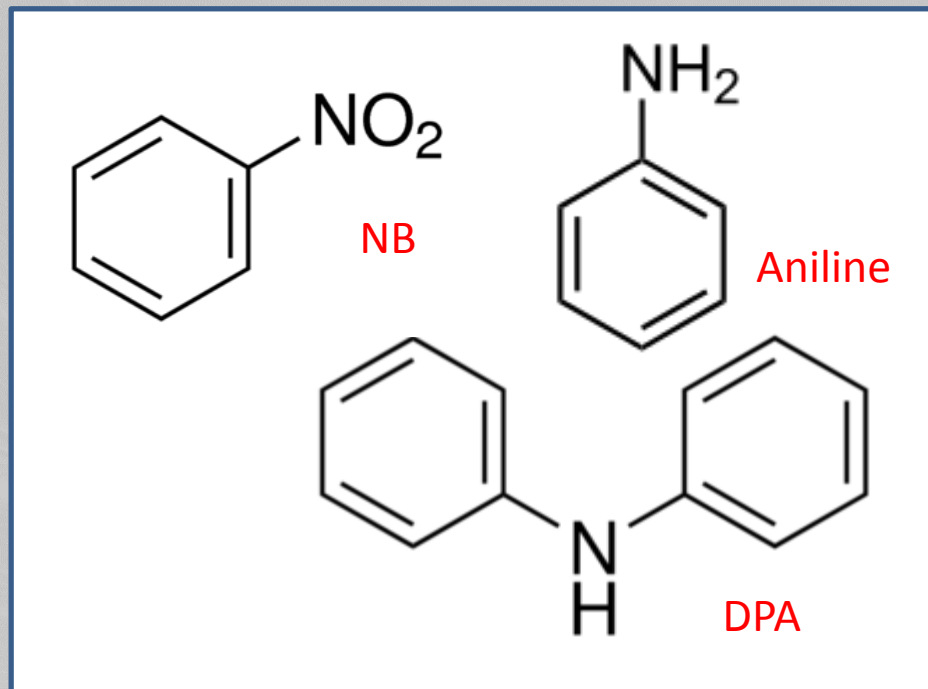
Standard	IGW
Unit	mg/kg
Aniline	35
Diphenylamine	630
Nitrobenzene	4





# Contaminants of Concern

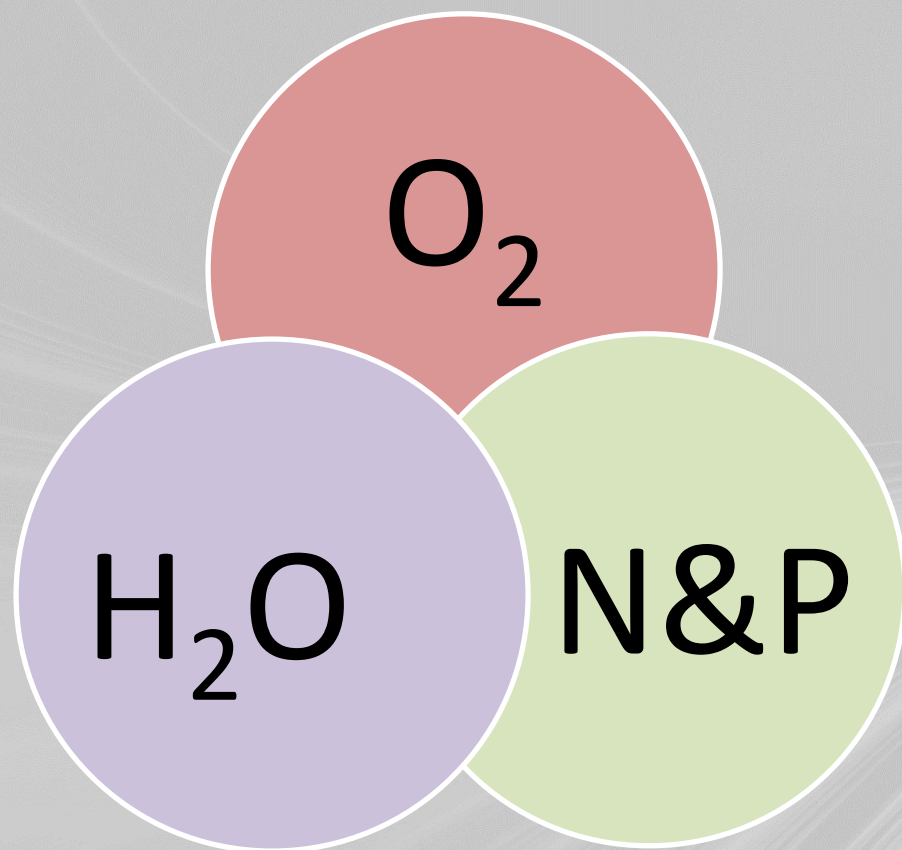
- Nitrobenzene (NB): aerobic and anaerobic degradation
- Aniline: aerobic
- Diphenylamine (DPA): aerobic



	Nitrobenzene	Aniline	DPA	Napthalene	TCE
Density, g/mL	1.2	1.02	1.2	1.145	1.46
Solubility in water, g/L	1.9	36	0.3	0.0316	1.28
Vapor pressure, mmHg	0.15 (@20 C)	0.6 (@20C)	1 (@108 C)	0.065 (@20C)	58 (@20 C)

# Remedial Obstacles

- NB showed strong toxicity at levels above  $140 \text{ mg/kg}^1 \ll \text{Average NB concentration}$
- Low permeability clay/silt
- Fixed time frame
  - One year for landfarming
  - 53 days per lift



1: Treatability study was completed by Professor Jim Spain of Georgia Tech



# Objectives

- Identify the reagent (bulking) to break cohesive soil
- Reduce contaminant toxicity
  - Chemical oxidation
  - GAC adsorption
  - Bioaugmentation
- Determine kinetics via simulating landfarming treatment



# Procedure and Results-Sampling

## Soil Sampling and Baseline Characterization:

- Soil collected from 7 test pits for 6 AOCs
- Concentrations – DPA up to 10,000 mg/kg, NB up to 3,000 mg/kg, and aniline up to 6,500 mg/kg
- Clay content – up to 80% highly plastic clay
- Moisture content – soil 20% to 30% by weight, but wetland soil up to 50% by weight





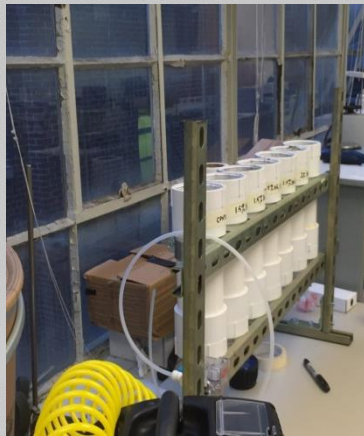
# Procedure and Results-Pretreatment

## Bulking

- Bulking – break up cohesive soil to increase permeability
- Seven Reagents: gypsum(s), lime, vermiculite, perlite(s), sawdust, mulch, corn cobb were tested in various combinations



Mixing



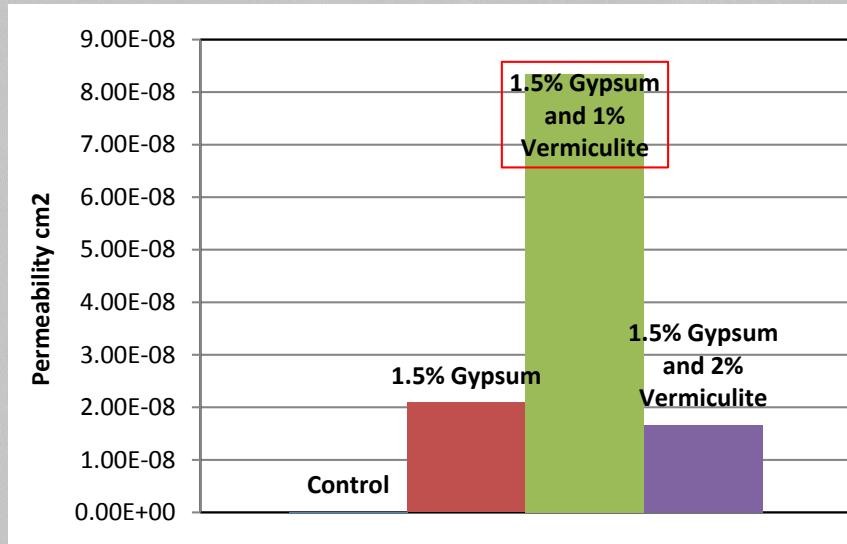
Air Permeability Test



NB soil mixed with various ratios of vermiculite



# Procedure and Results-Bulking



Soil Source Area	Clay Content	Bulking Agents	Instant Volume Change, %
NB Source	33%	2% DG and 1% V	12.5%
NB Ditch	50%	3% DG and 2.5% V	44.3%
DPA Source	83%	3% DG and 6% V	54.2%

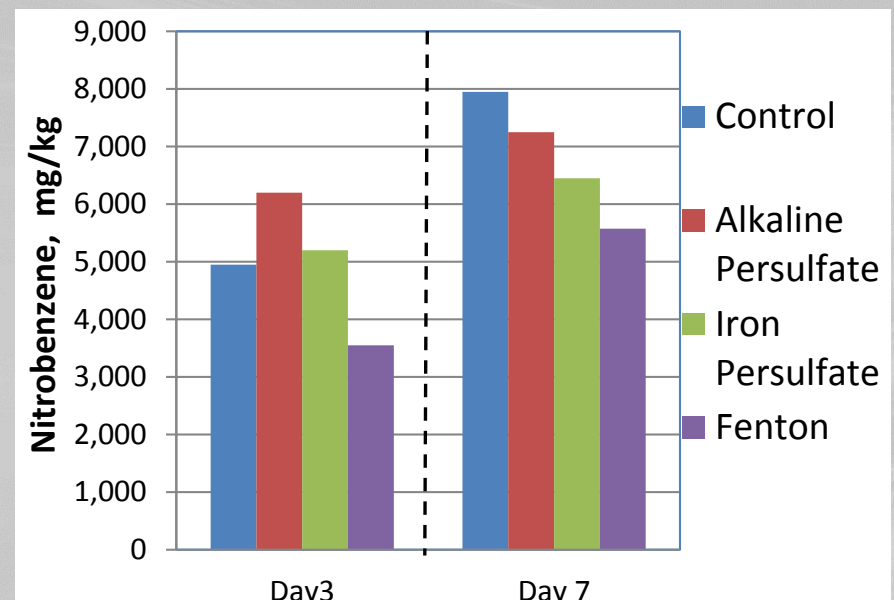
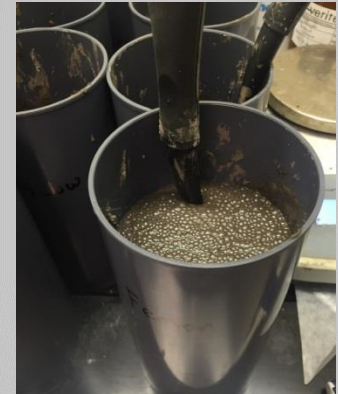
- Combination of Damp gypsum (DG) and vermiculite (V)

- 10% clay needs 1% (w/w) vermiculite
- 1% vermiculite increases soil volume by 10% to 15%



# Chemical Oxidation

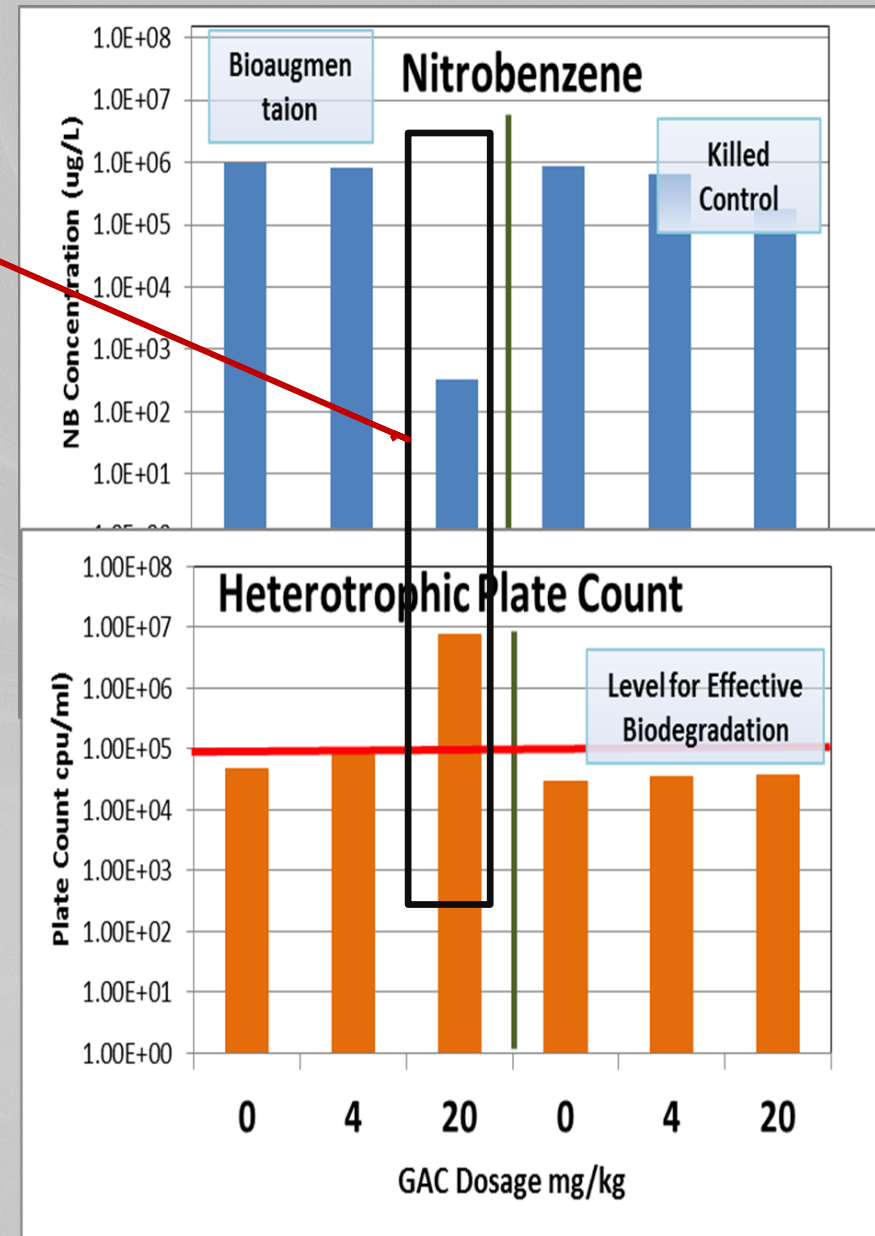
- Spiked soil to 8,000 mg/kg of NB
- Alkaline and iron activated persulfate, and Fenton
  - No reduction with persulfate
  - 35% reduction with Fenton
  - High SOD of 35 g/kg





# GAC Adsorption

- Purposely reduced aqueous concentrations to stimulate microbial growth
- Elevated TOC resulted in effective dosage of 14 g/kg



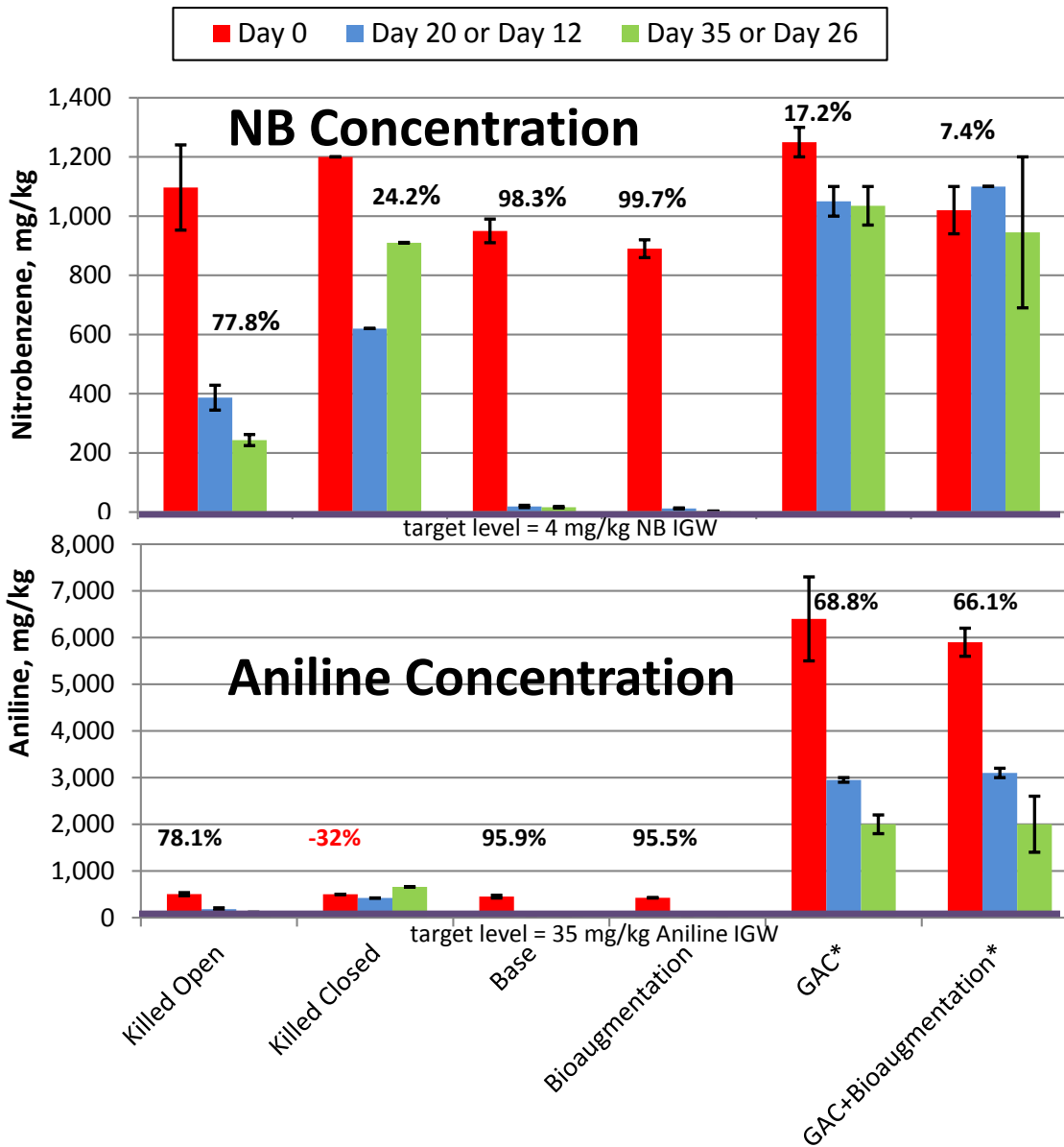


# Landfarming Simulation

- 72 reactors
  - Bulking – combination of DG and vermiculite
  - Toxicity Control - GAC 4 and 14 g/kg and bioaugmentation culture ENV 625, produced by CB&I's biotechnology group
- 10 inch soil columns
- 3 to 4 times/week of mixing and moisture addition
- Up to 35 days of treatment





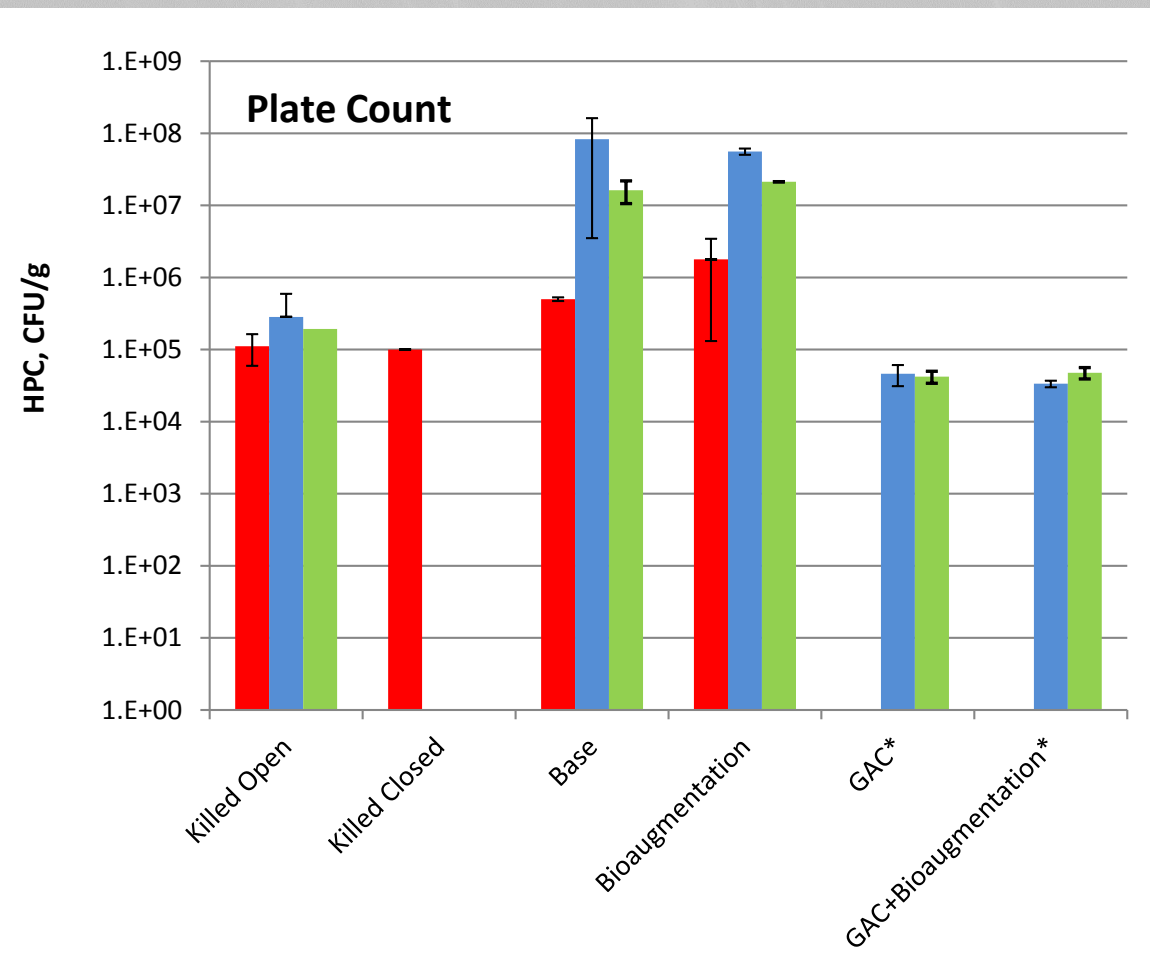


## NB and Aniline Soil Results

- Abiotic reduction contributed to the NB and aniline reduction.
- Elevated aniline also showed toxicity.
- Bioaugmentation did not significantly enhance NB reduction.



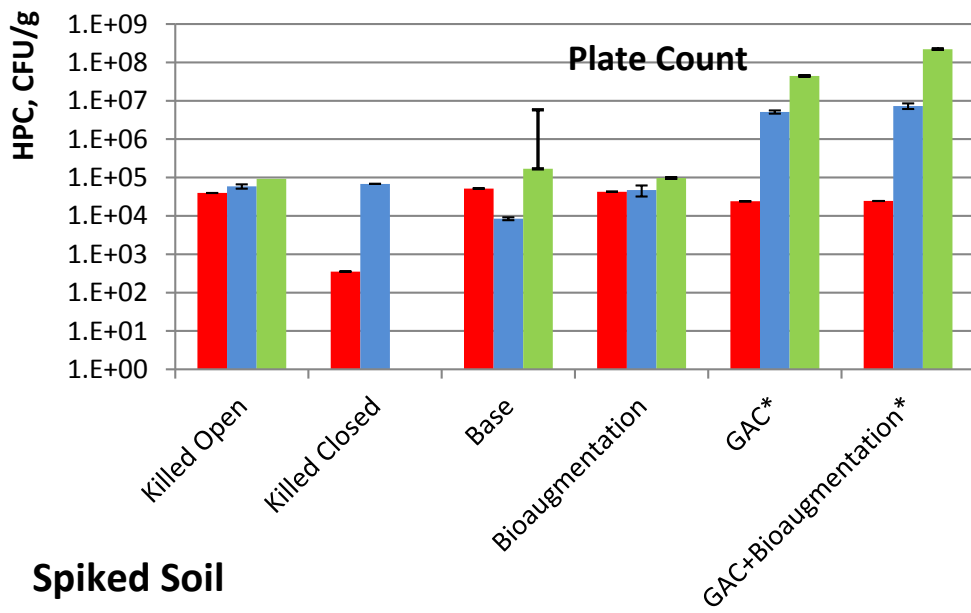
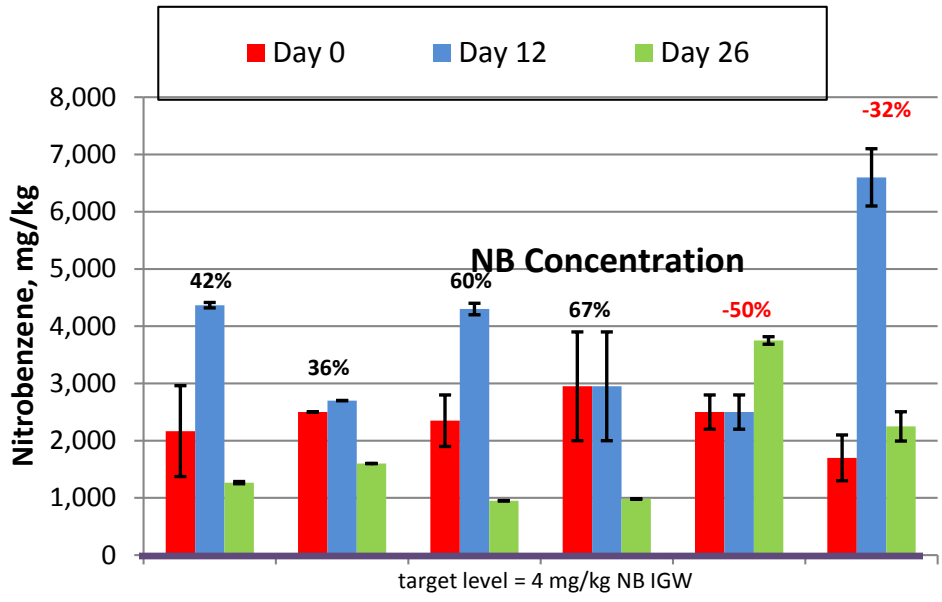
# NB and Aniline Soil Results



- Bioaugmentation did not appear to significantly enhance NB reduction.
- More  $10^8$  CFU/g - rapid degradation



# Spiked Soil-NB 5,000 mg/kg

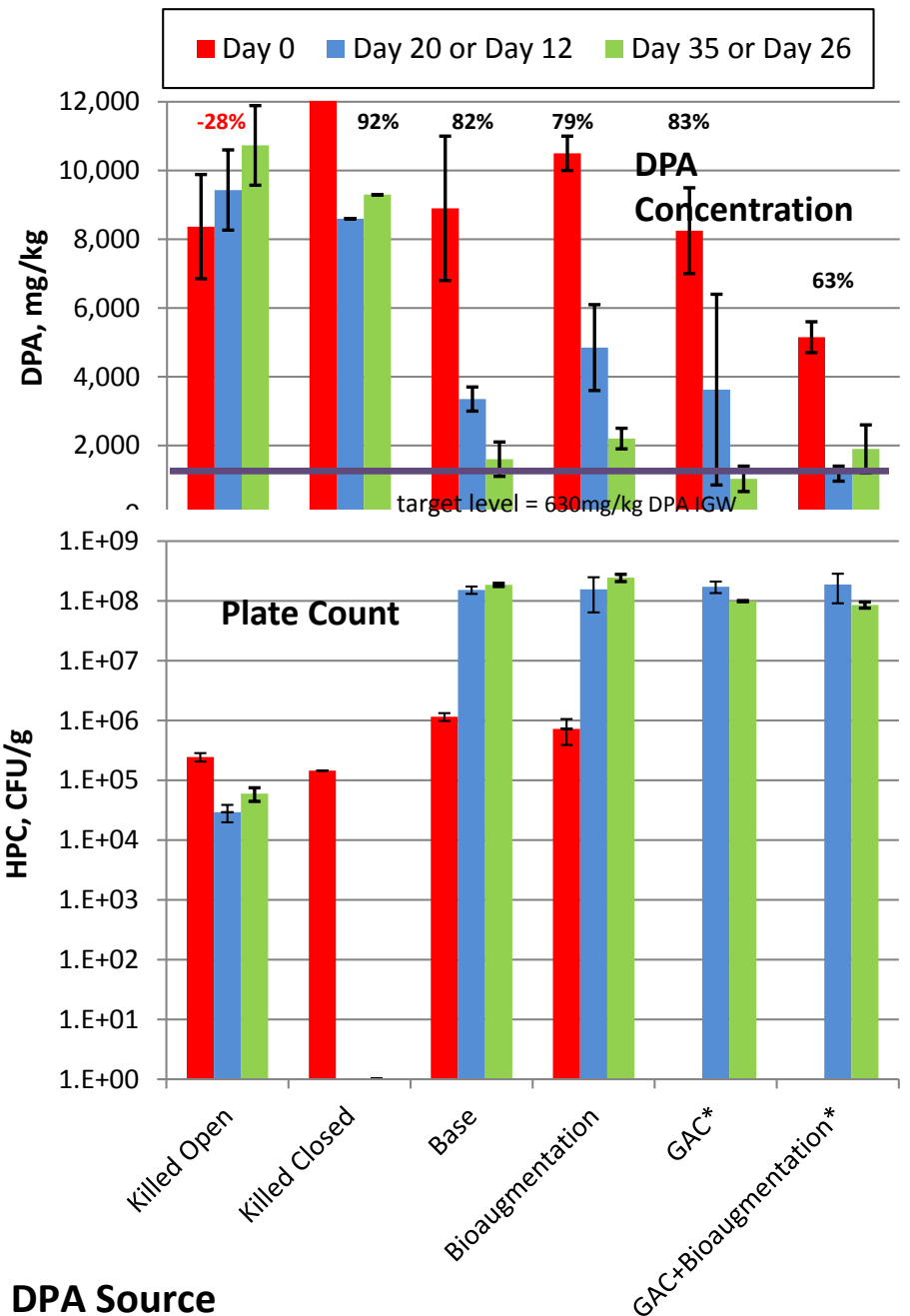


- Elevated NB showed toxicity.
- GAC reduced toxicity and increased microbe population but also prevented contaminant loss via abiotic path.



# DPA Soil

- Only biotic reduction contributed to DPA reduction.
- Elevated DPA was not toxic.
- GAC & Bioaugmentation enhanced DPA reduction.





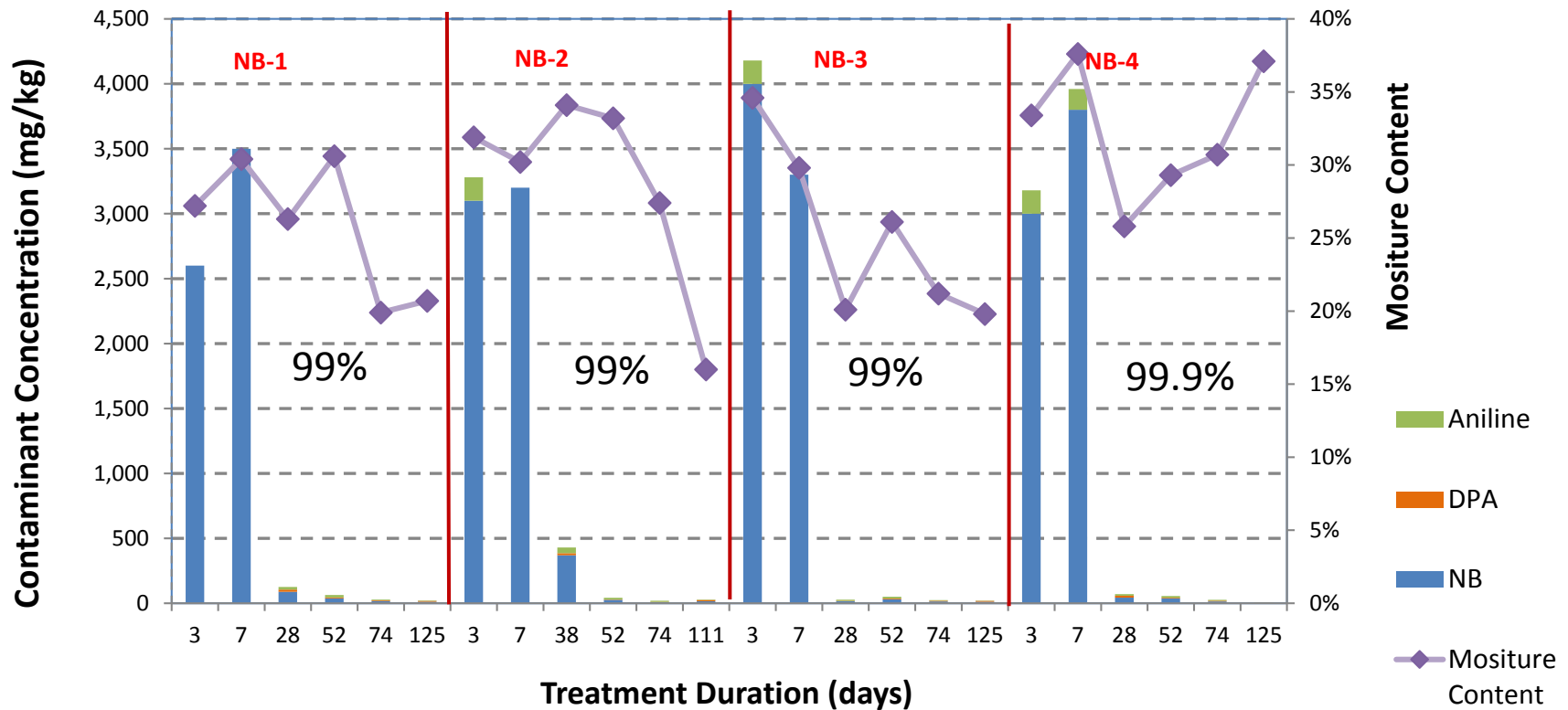
# Pilot Study

- Eight soil piles of 1.5 feet high
  - 4 NB soil piles
  - 4 DPA soil piles
- 50 cubic yards per soil pile
- 125 days of treatment





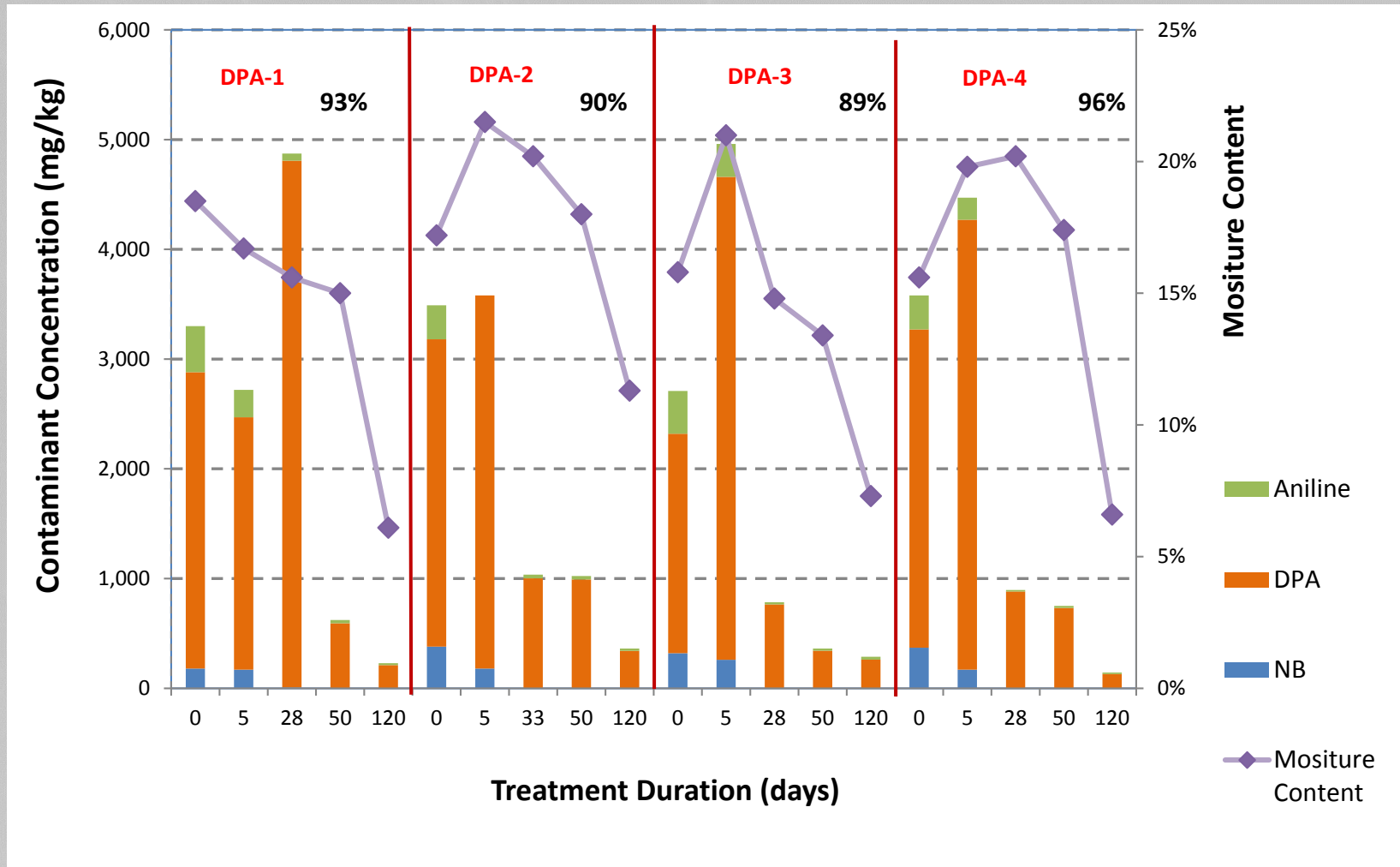
# Pilot Test Results



- Similar reduction rates
- Detrimental affect from moisture saturation

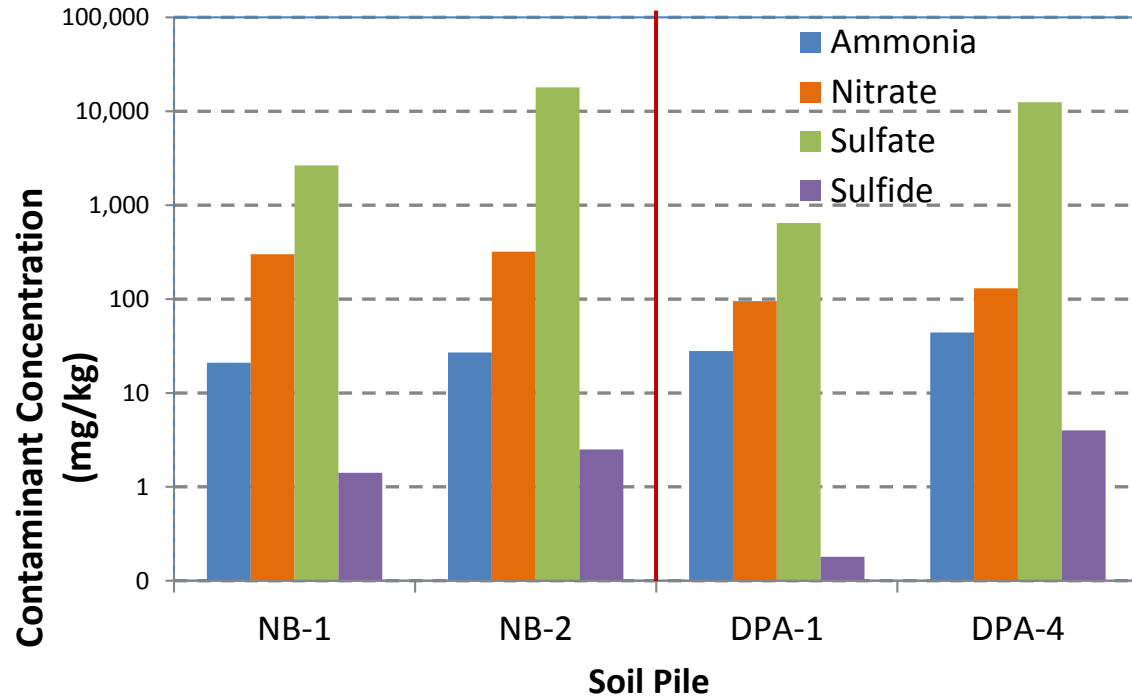


# Results



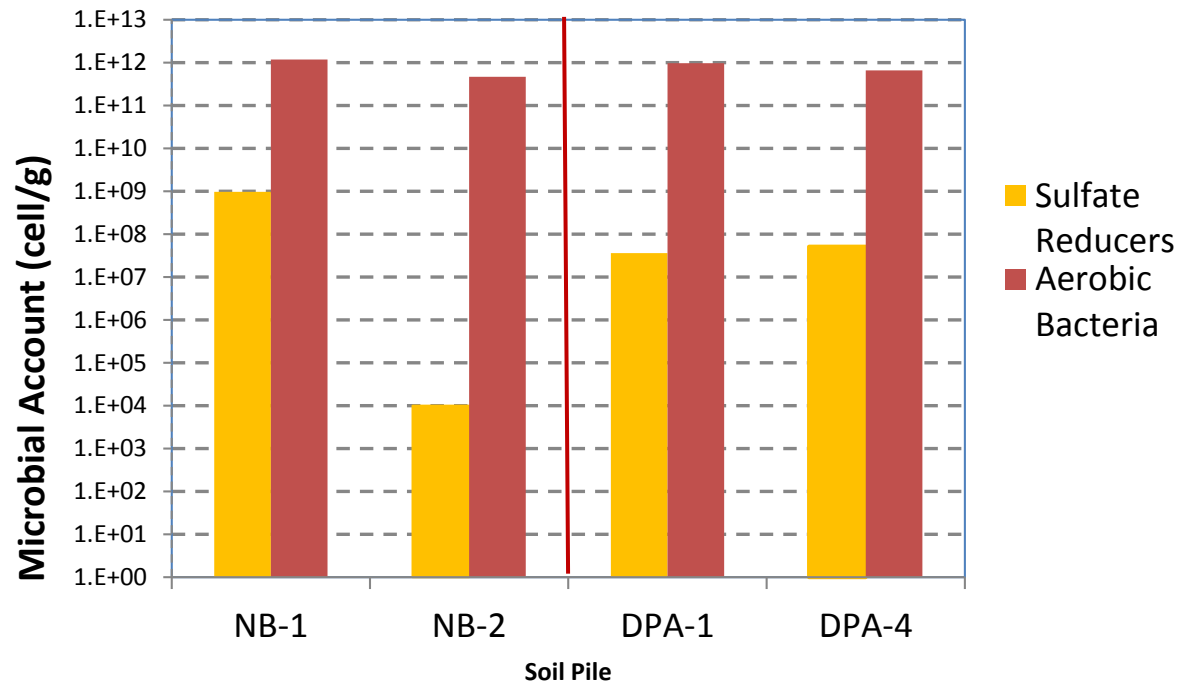
- Similar reduction





# Results

- Nitrate accumulated while ammonia did not accumulate.
- Aerobic microbe  $\gg$  sulfate reducers





# Conclusions

- Kinetics: Bench and pilot study obtained **highly consistent results.**

Height of Soil Pile	Half life	
	NB	DPA
10 inch	5 to 6 days	15 to 21 days
18 inch	7 to 8 days	18 to 22 days

- Toxicity
  - DPA no toxicity
  - NB and aniline > 3,000 mg/kg

# Conclusions

- Reagent Recommendation
  - Vermiculite (1%:10%), straw, and phosphate
  - No GAC and oxidants
- Operation Parameters
  - Optimal moisture content range between 10% and 15%
  - Water addition may not be required
  - Soil Pile Height < 18 inch.



# Conclusion

- Kinetics
  - Degradation of NB stalled at concentrations starting 20 mg/kg
  - Degradation of DPA stalled at concentrations starting at 300 mg/kg
  - Unable to reach the most stringent goal of 4 mg/kg for NB within 53 days (per treatment lift)



# Questions?



Raymond Lees

[RLEES@LANGAN.COM](mailto:RLEES@LANGAN.COM)

Lingke Zeng

[LZENG@LANGAN.COM](mailto:LZENG@LANGAN.COM)