Benzene Removal by a Novel Modification of Enhanced Anaerobic Bioremediation

Wenhui Xiong, Ph.D., P.Eng.; Chris Mathies, P.Eng.; Kris Bradshaw, P.Eng.; Trevor Carlson; Kimberley Tang, M.Sc., P.Eng.

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Introduction

- Petroleum hydrocarbon (PHC) release into soil and groundwater occur at every stage of oil extraction, refinement, storage, transportation, and disposal
- Anaerobic subsurface environmental development
  - Fast oxygen consumption rate
  - Slow oxygen supply rate
- Enhanced anaerobic bioremediation (EAB) - a practical and cost effective PHC remediation method
  - Electron donor: PHC
  - Electron acceptor: nitrate or sulfate

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Introduction

- EAB is effective for the removal of toluene, ethylbenzene, and xylenes; however, benzene is particularly persistent
- Phosphorus usually controls the PHC biodegradation process
- Precipitation of inorganic phosphorus (phosphorus source for organism growth) , making phosphorus unavailable to the microbes
- Organic phosphorus is much more mobile in soil than inorganic phosphorus; however, length of time for organic phosphorus to release orthophosphate may be significant

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Introduction

- A novel EAB approach was developed, which consisted of injecting nitrate and organic phosphorus into the subsurface followed by the addition of non-activated persulfate
- Injected persulfate would be capable of breaking down organic phosphorus into orthophosphate
- Released orthophosphate might stimulate benzene removal through promoting nitrate reduction and/or sulfate reducing bacterial (SRB) activities

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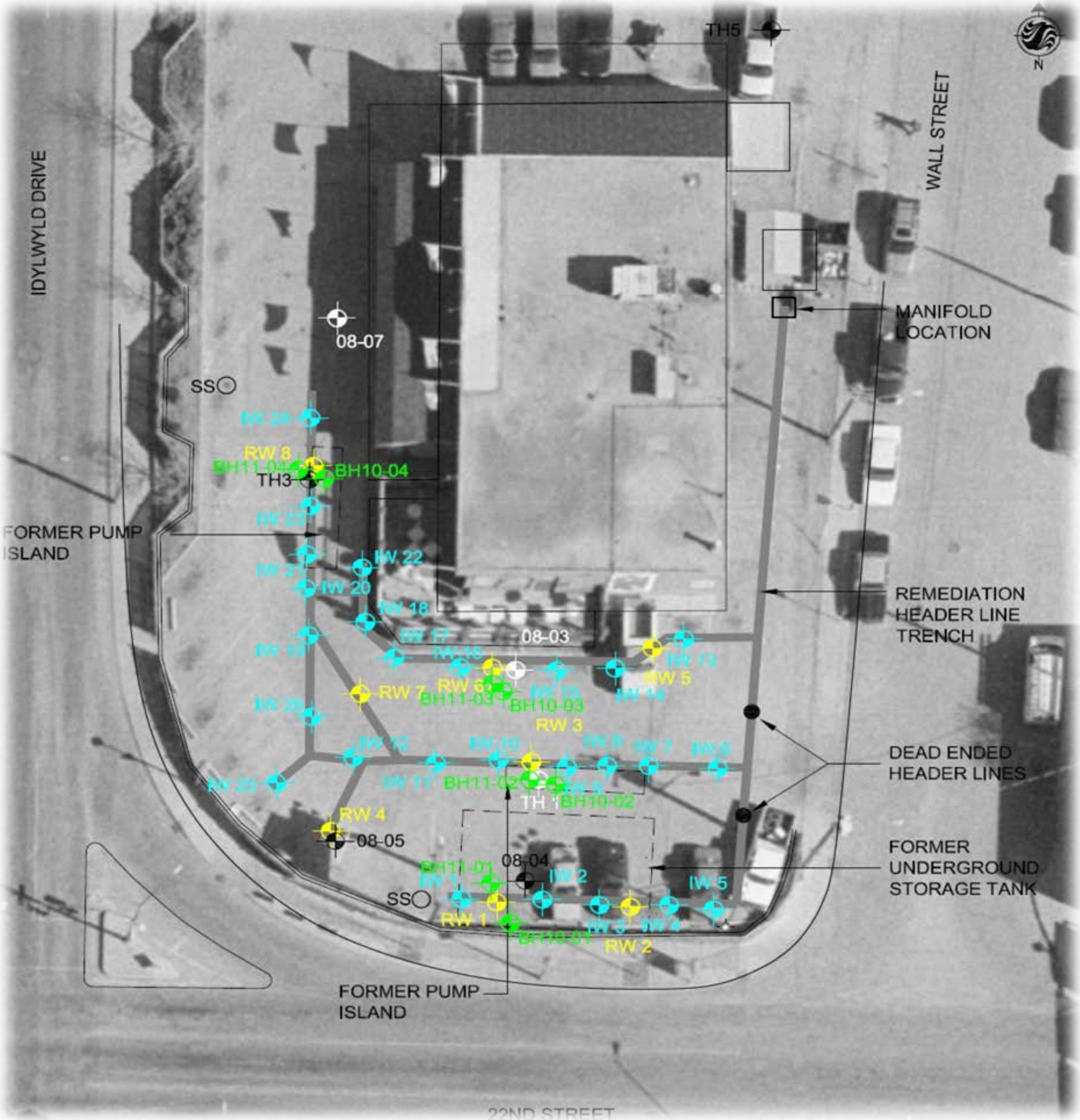
Study Site



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Methods

- Stage 1 was completed in November 2009 and consisted of the injection of approximately 42,000 L of water, 1,400 kg of potassium nitrate (KNO_3), and 219 kg of triethly phosphate (TEP, $(C_2H_5)_3PO_4$).
- Stage 2 was completed in September and October 2010 and consisted of injecting approximately 13,100 kg of non-activated sodium persulfate ($Na_2S_2O_8$) mixed with approximately 49,000 L of water.

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Methods

- Soil – Direct push drilling methods were used to evaluate attenuation rates of absorbed-phase hydrocarbons.
- Groundwater – Low flow sampling techniques were used to evaluate changes in groundwater conditions at dedicated performance monitoring wells RW1 to RW8. Groundwater samples were analyzed for:
  - PHC, general chemistry and metal analyses
  - Compound specific isotope analysis (CSIA)
  - Microbial quantitative polymerase chain reaction (qPCR)
  - Microbial denaturing gradient gel electrophoresis (DGGE) and 16S ribosomal RNA (16S rRNA)

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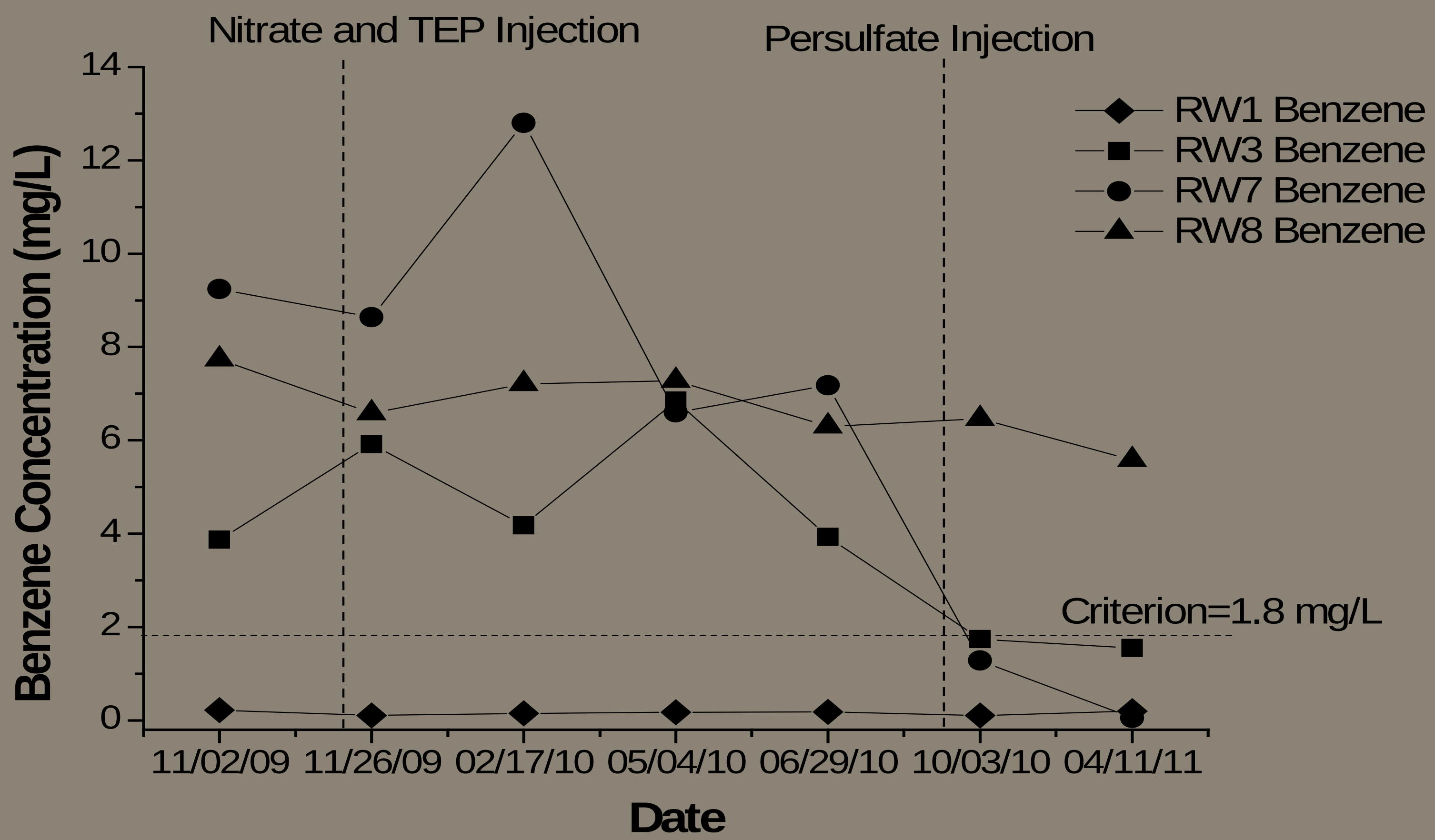
Results

Benzene Removal from Groundwater



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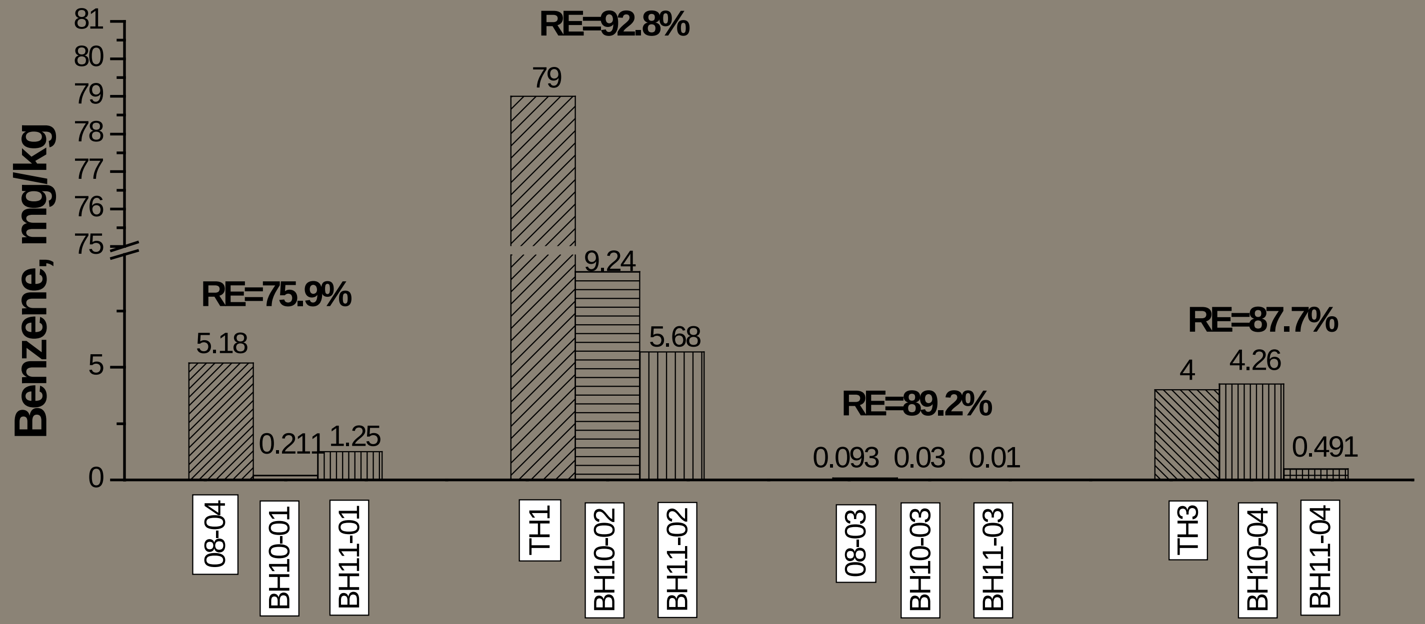
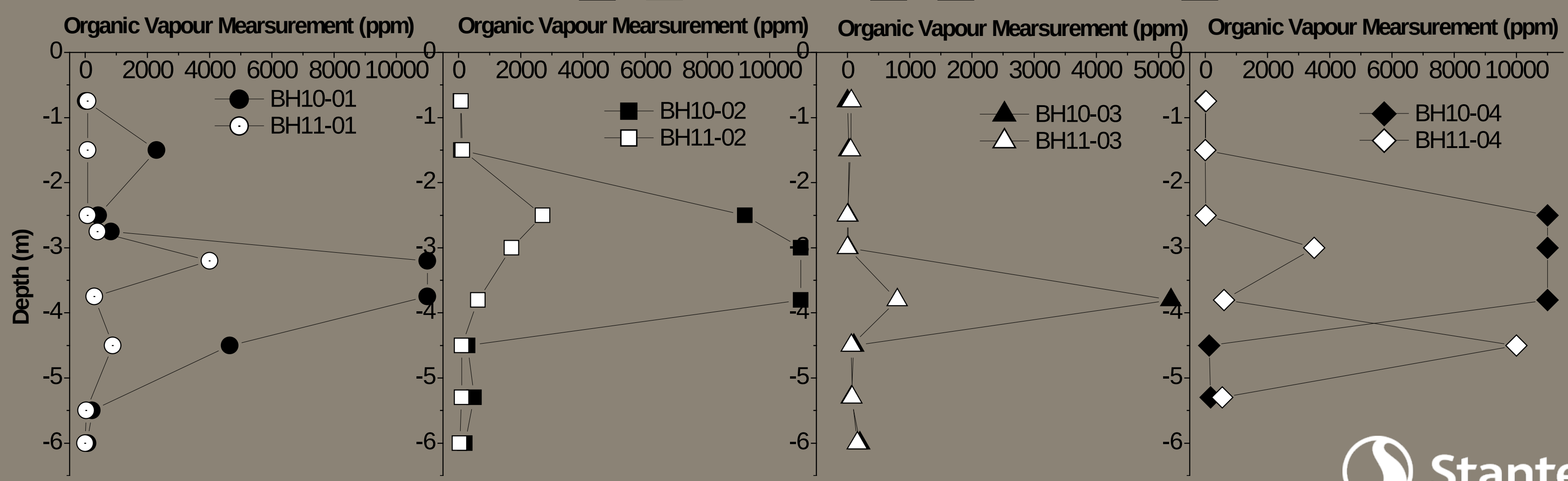
Results

Removal from Benzene Groundwater





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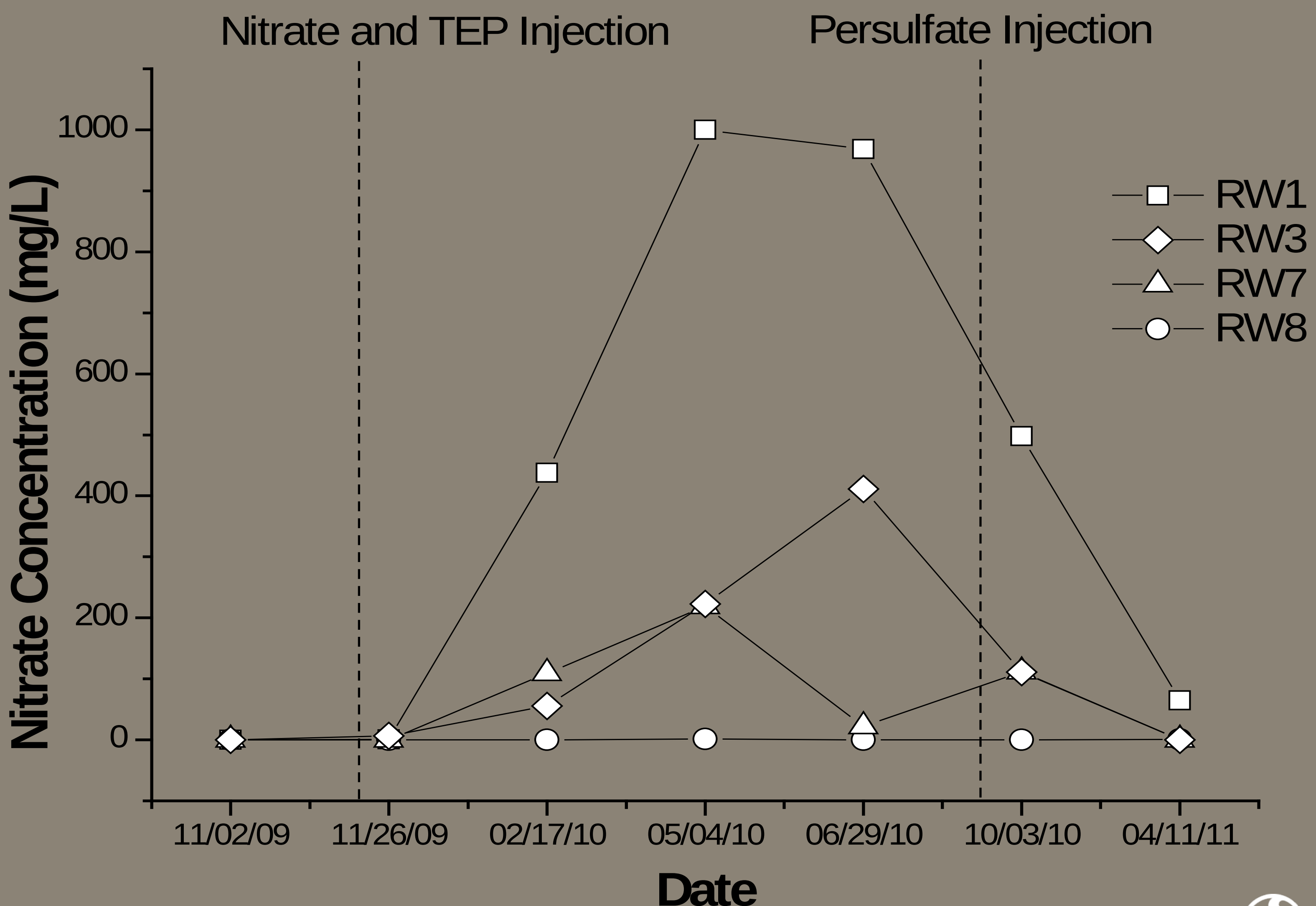
Results

Nitrate Utilization



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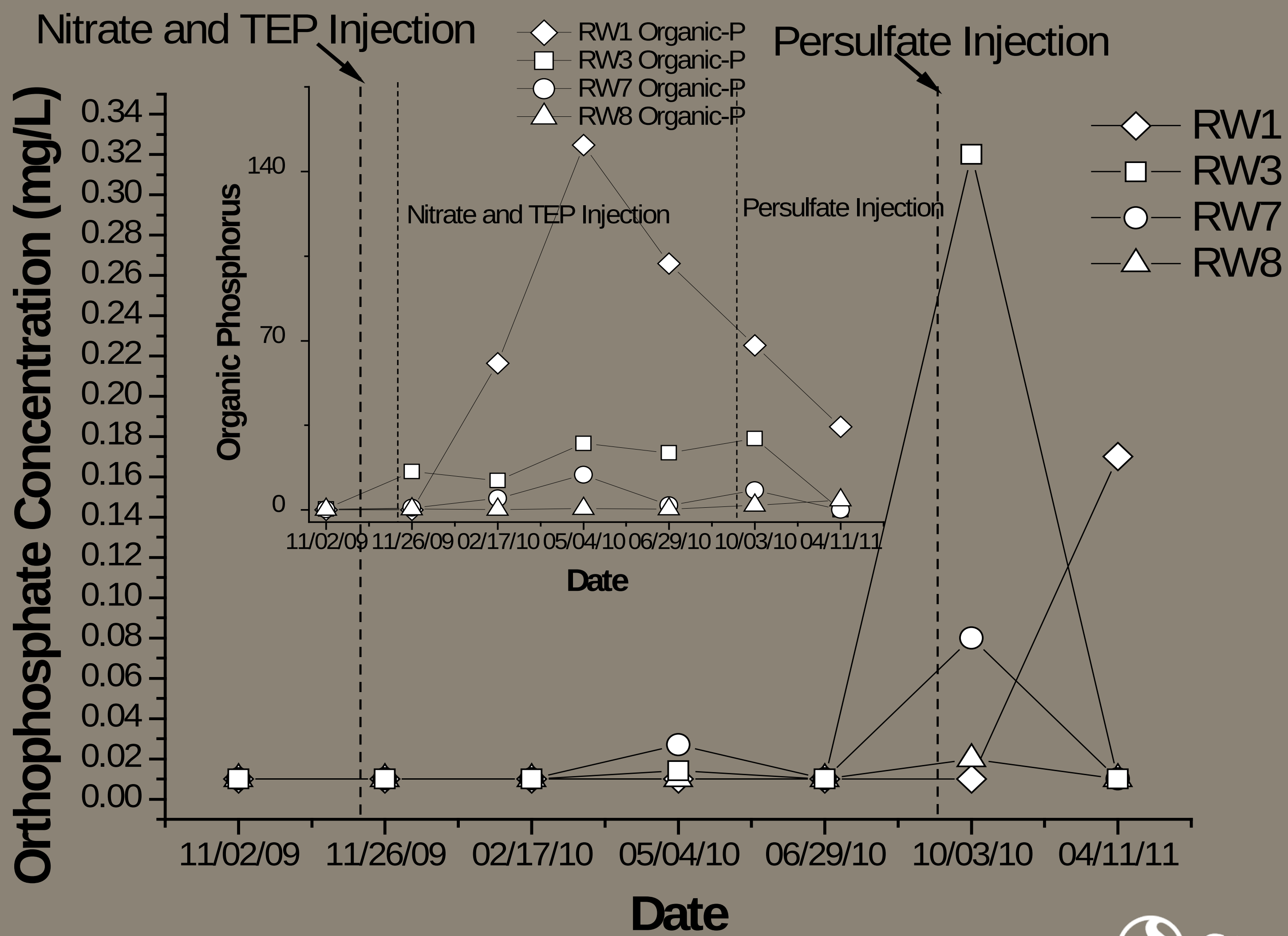
Phosphorus Uptake



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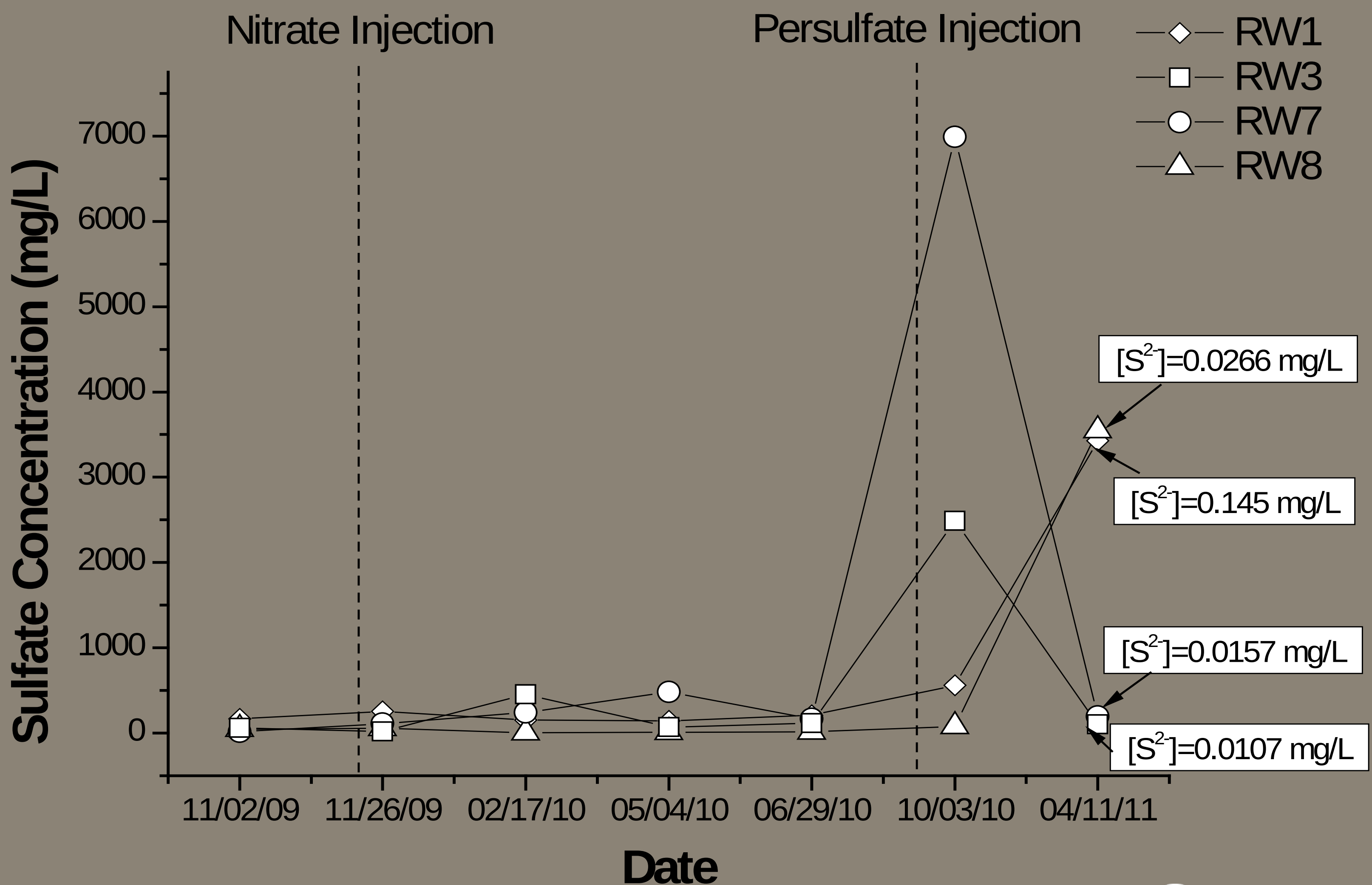
Sulfate Utilization



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Results

qPCR Analytical Results

Sample	bssA	DSR	nirS	nirK
RW7	<9.00E-1	7.00E-01	2.92E+03	1.96E+01
RW8	1.11E+02	1.41E+04	2.22E+01	2.15E+04
MW08-07	1.80E+00	1.12E+03	5.03E+05	6.07E+04

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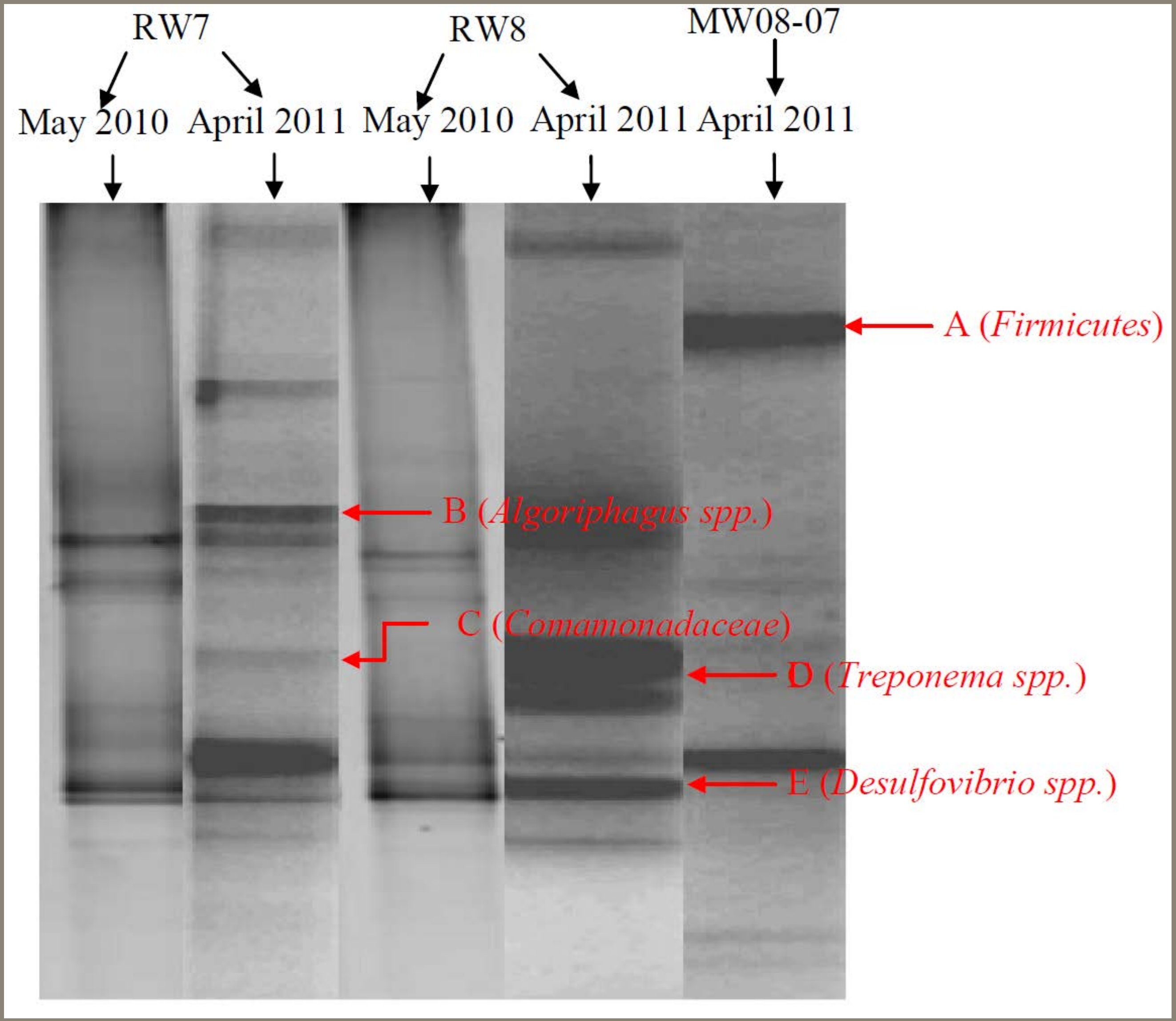
Results

DGGE Profile



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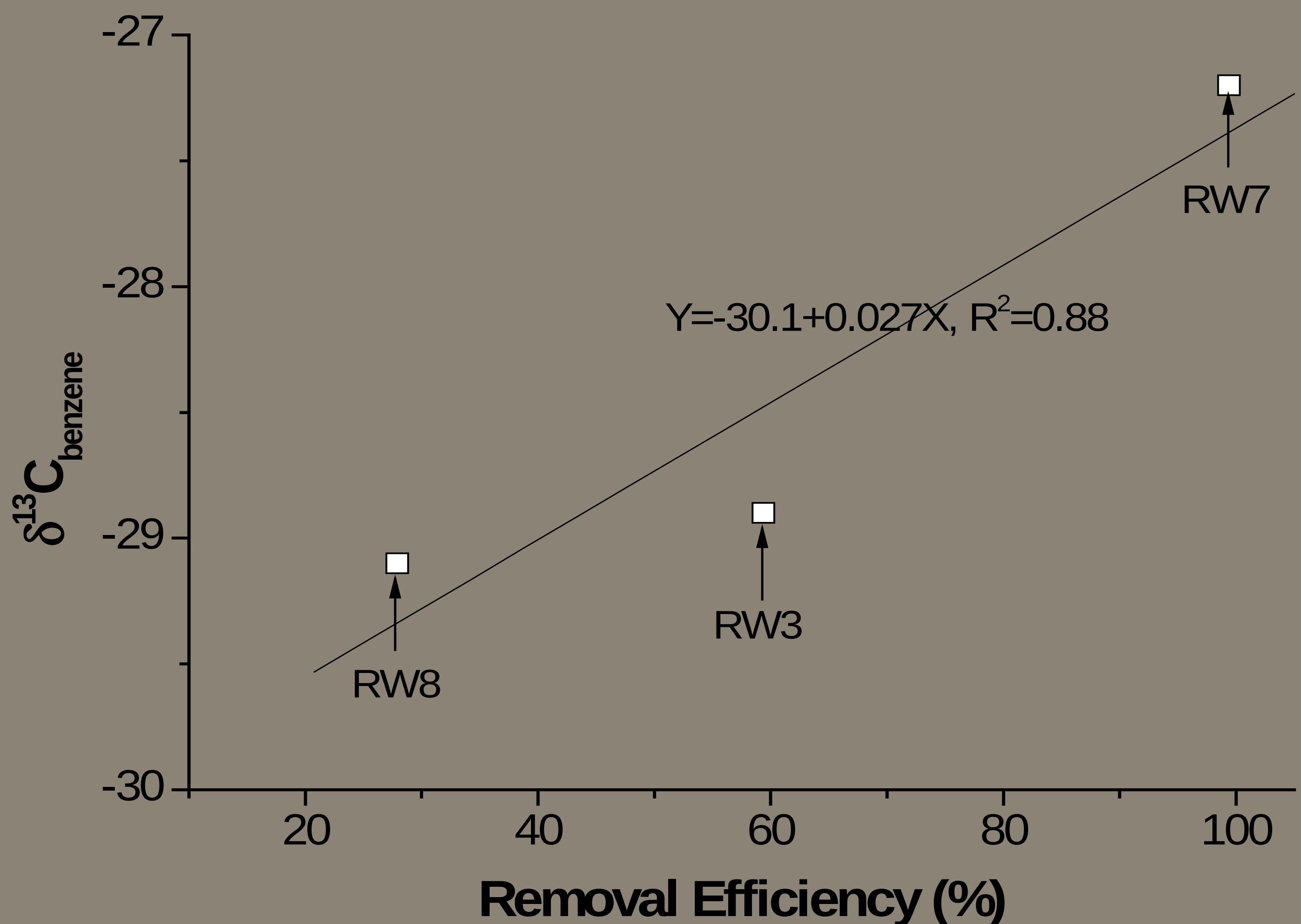
Results

Isotopic Analytical Results



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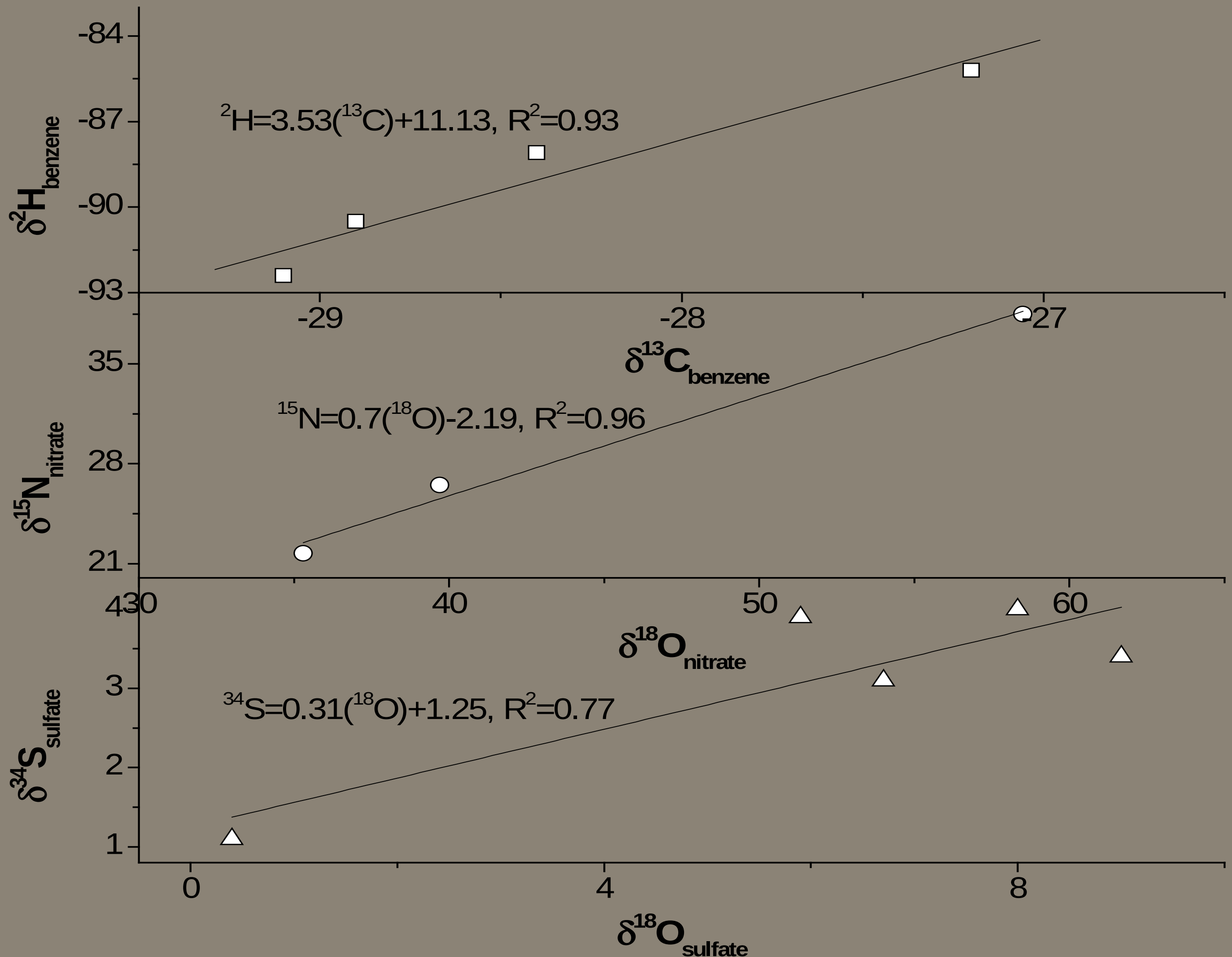
Results

Isotopic Analytical Results



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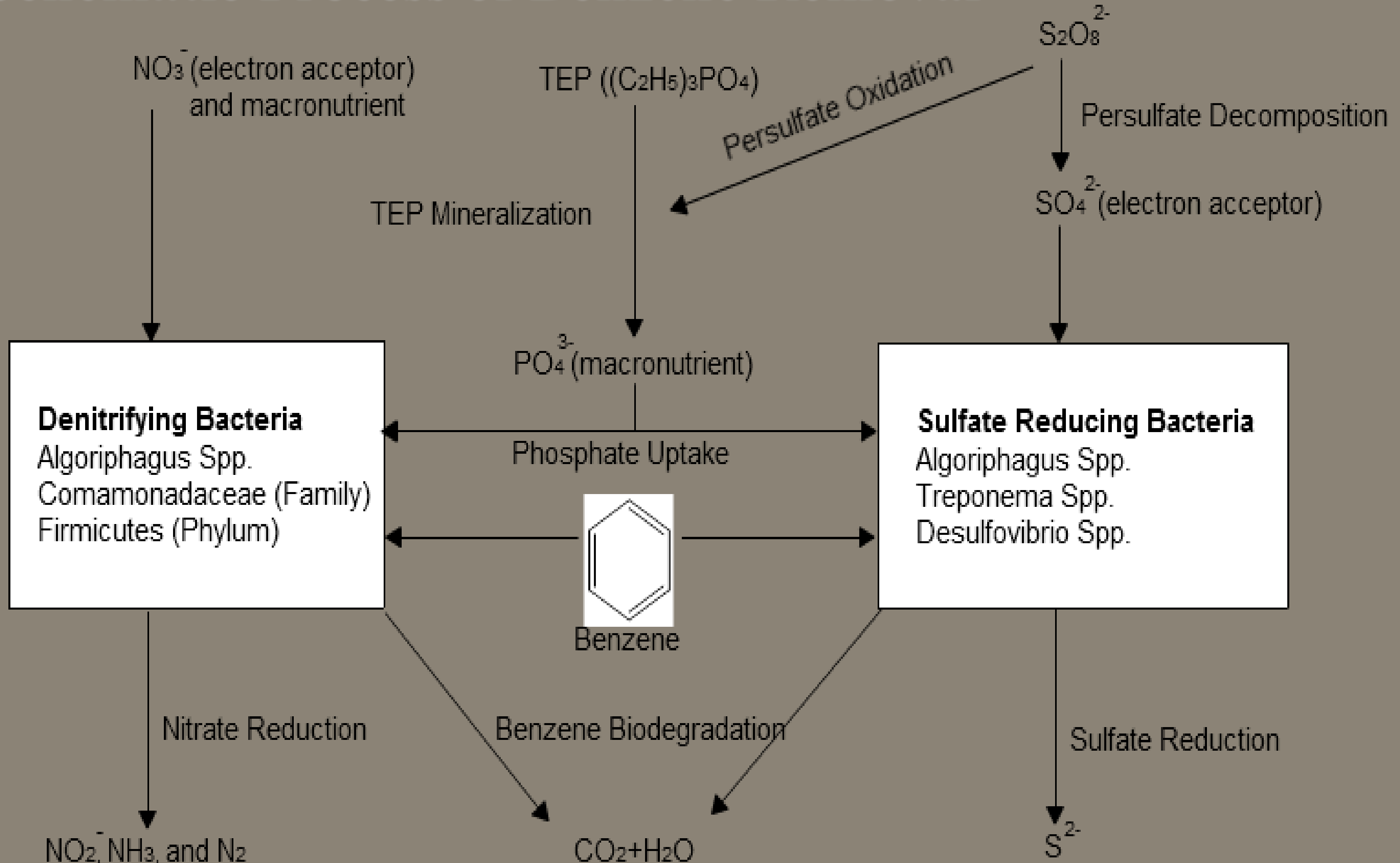
Results

Schematic Process of Benzene Removal



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Conclusion

- Removal of PHC, including benzene, in the subsurface was optimized through a novel EAB approach integrating nitrate and TEP injection with the subsequent addition of non-activated persulfate
- Injected persulfate broke down organic phosphorus into inorganic orthophosphate, thereby stimulating nitrate and sulfate reduction
- CSIA analysis provided further direct evidence for the occurrence of PHC degradation by nitrate and sulfate reduction
- Dominant EAB mechanism to date appears to be nitrate reduction, although sulfate reduction also appeared to play an important role on portions of the study site

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Thank you

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