

In Situ Bioreactor: A new tool to help improve biostimulation and bioaugmentation

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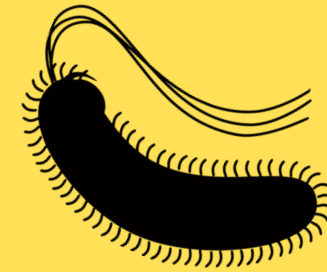
Enhanced Bio: Potential Challenges



Inhibitory
contaminant
concentrations



Contaminant
concentrations
below threshold
required for
growth



Missing the right
degraders



In Situ Bioreactor Design

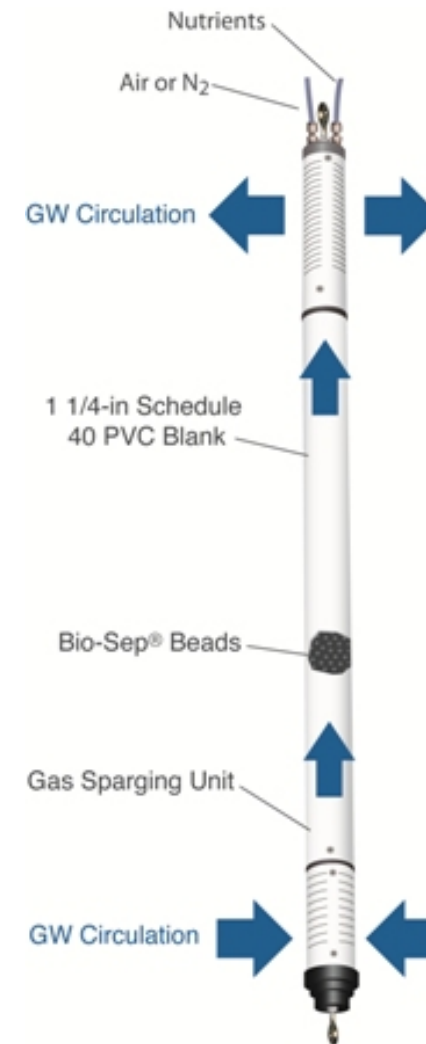
Adapting Bio-Sep for Remediation

- Bio-Sep beads long used as diagnostic tool for microbial sampling
- High surface area
- Rapid formation of biofilms
- Adsorptive surface
 - Concentrates contaminants at low concentrations
 - Reduces high aqueous phase concentrations
- Release new microbes into the aquifer



Bioreactor Design

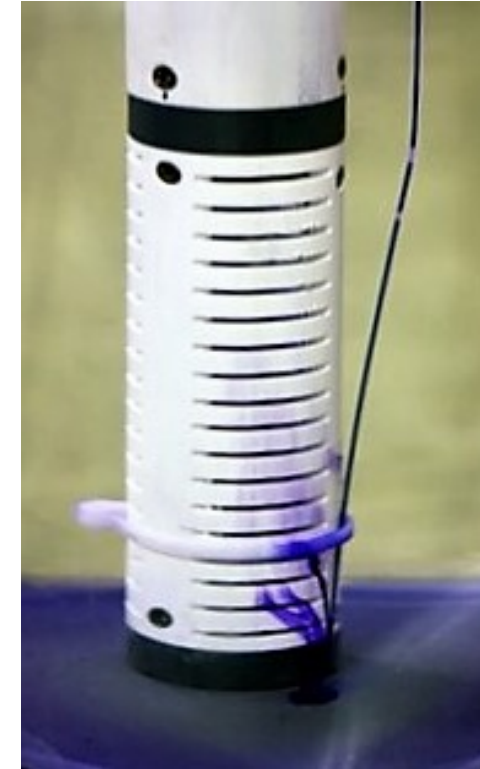
- Fits in standard 2" monitoring well
- Bio-Sep beads, nutrient addition, air or nitrogen sparging
- Groundwater treated as it moves through column of beads
- Exiting water carries degraders into the aquifer
- Continual monitoring and adjustments possible



Bioreactor Design



Topside Equipment



GW Circulation

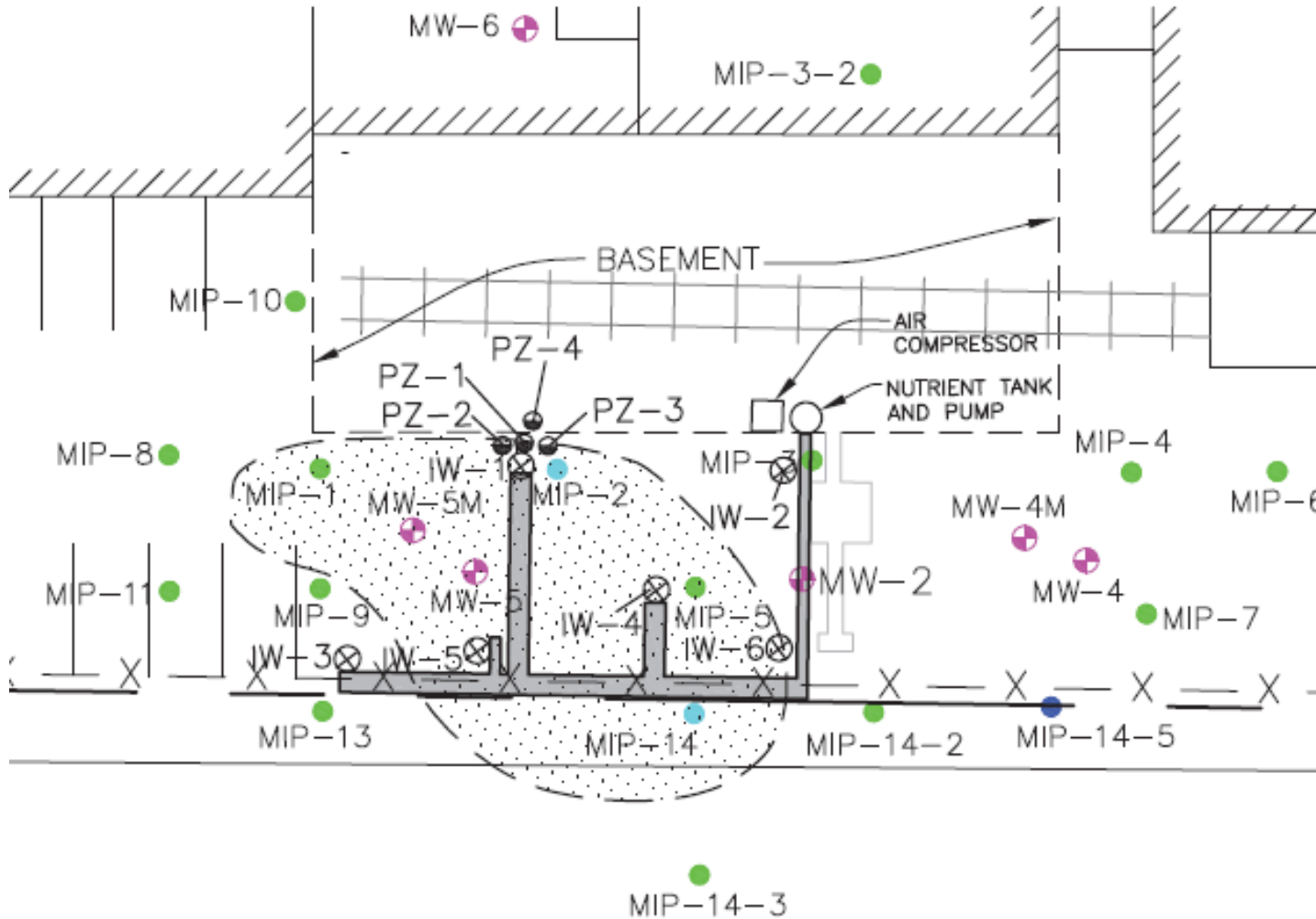


Case Studies

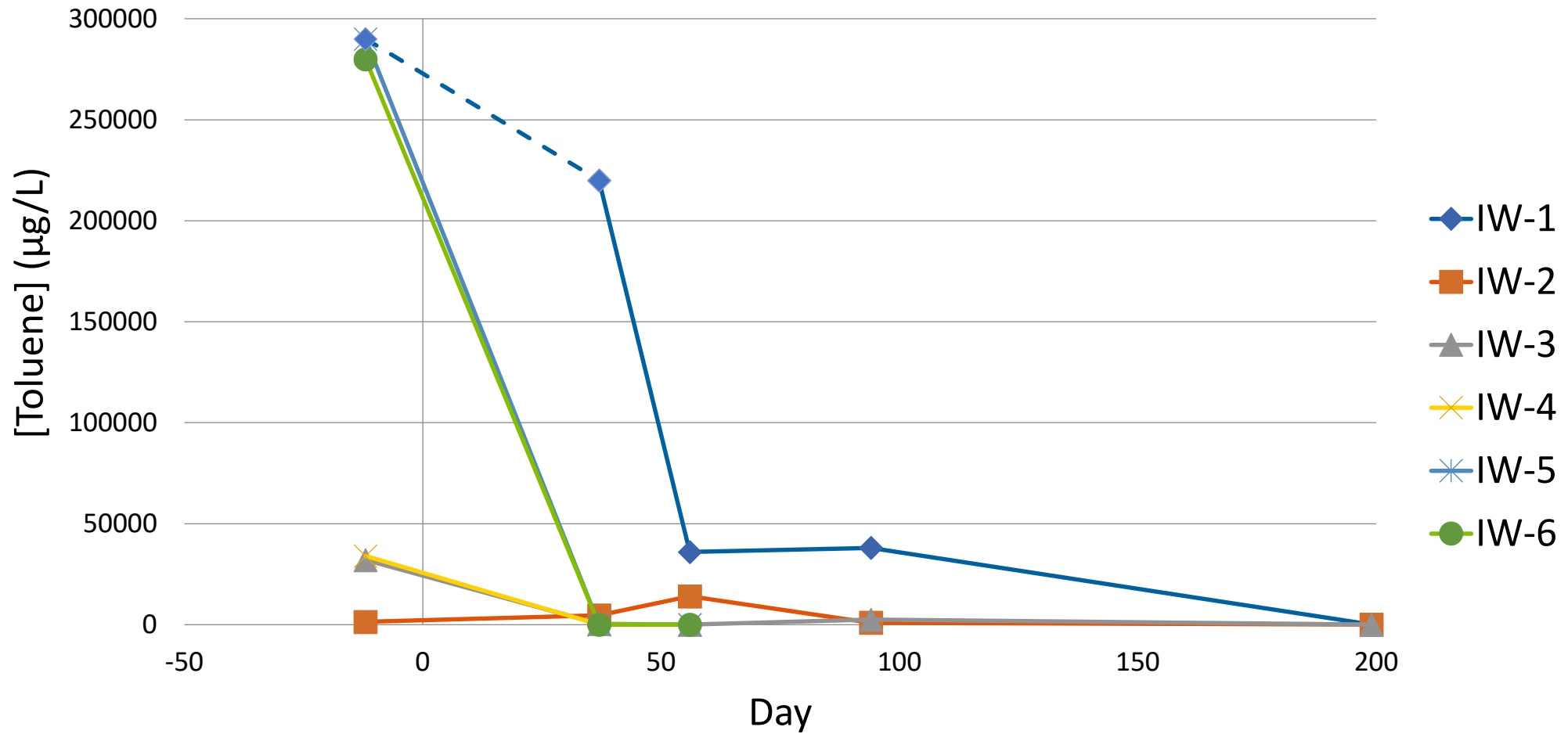
Free phase toluene at an industrial site

- Former industrial site in northern NJ
- Toluene UST removed in 2001
- Previous remedial efforts failed to meet site cleanup goals
- Free phase toluene observed in the pilot study area
- Potentially inhibitory concentrations up to 430 ppm

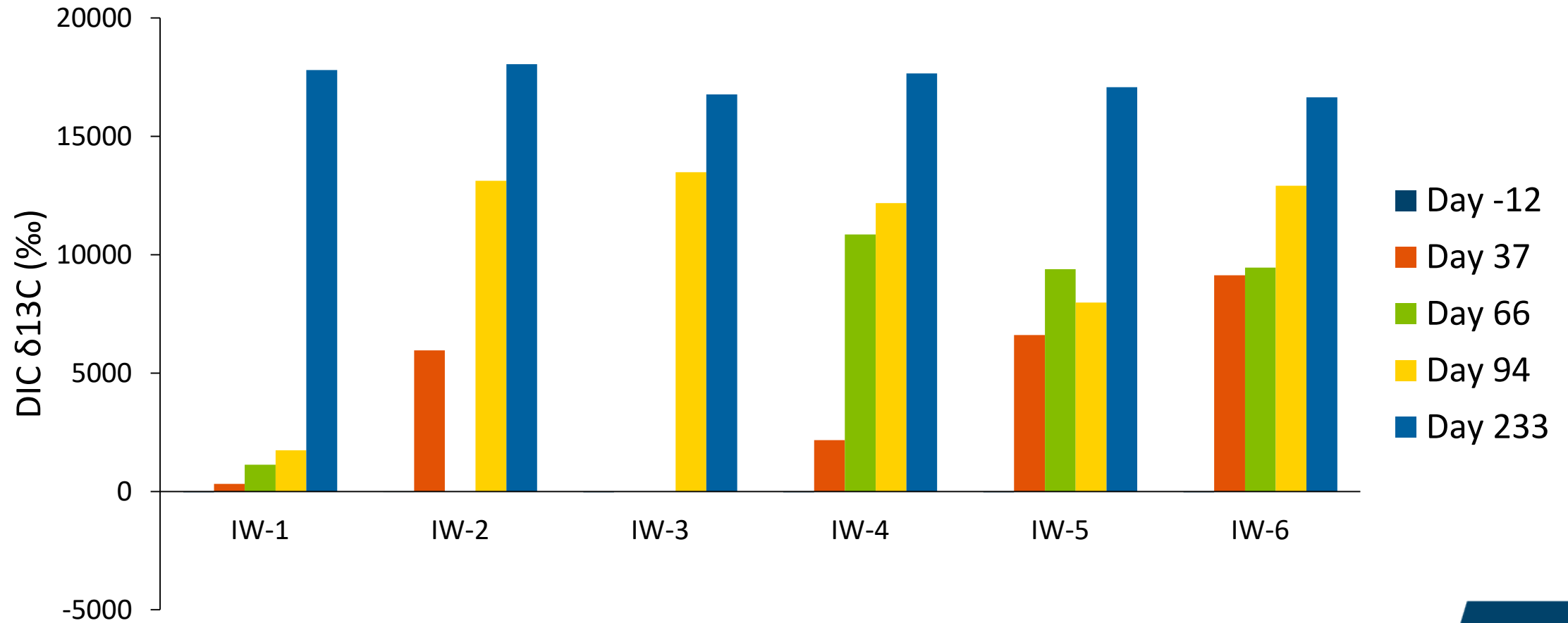
Site Map



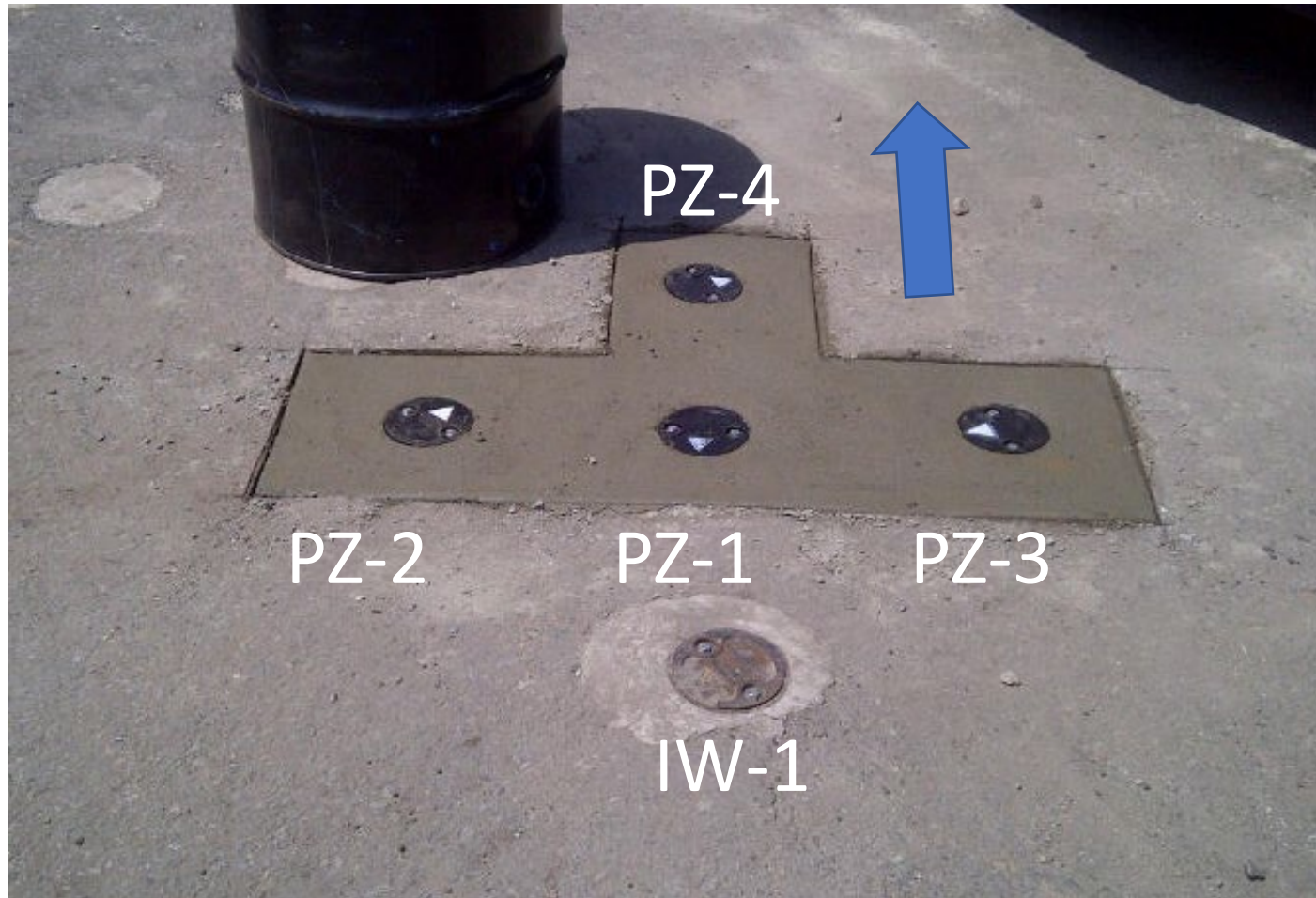
Toluene Data – ISBR Wells



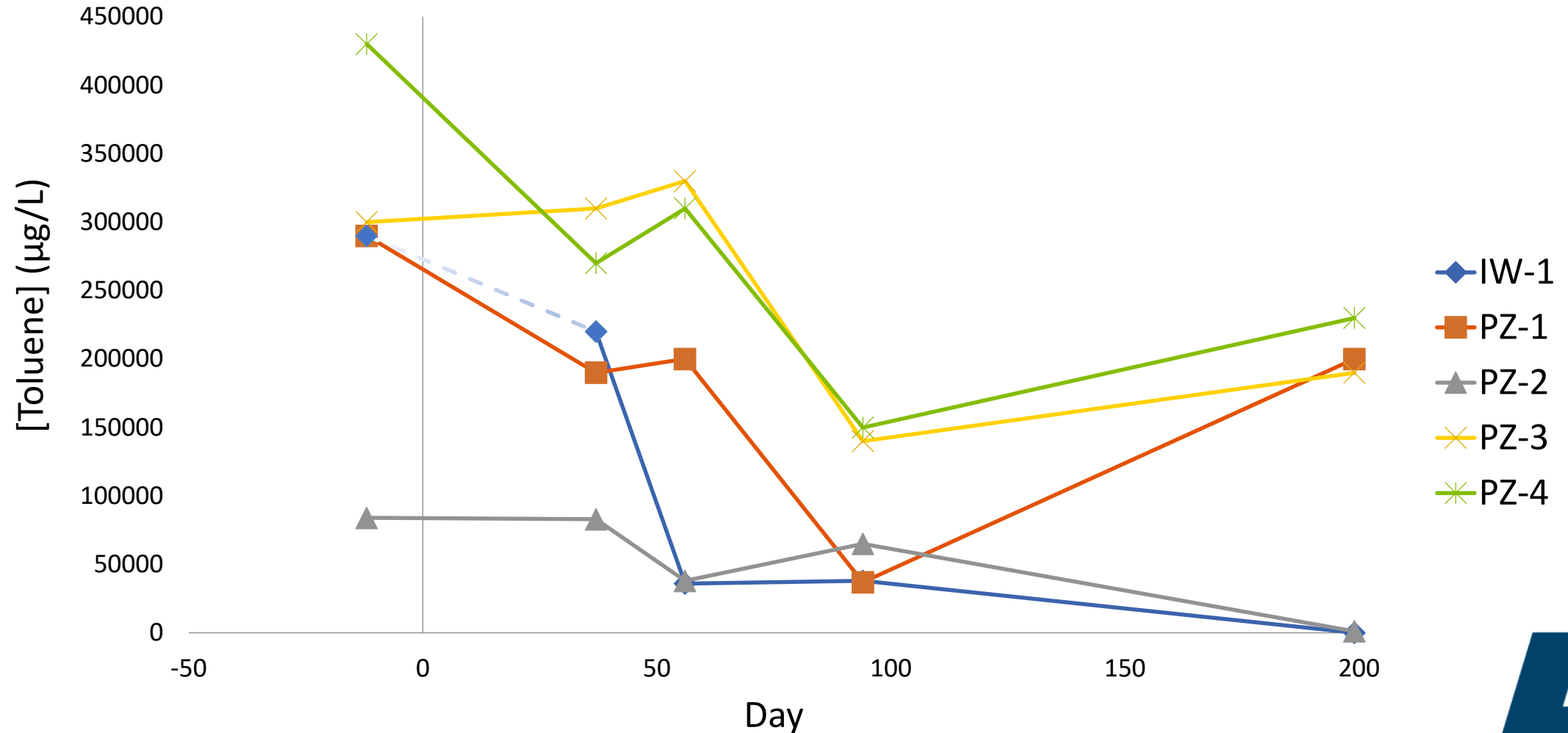
Stable Isotope Probing – ISBR Wells



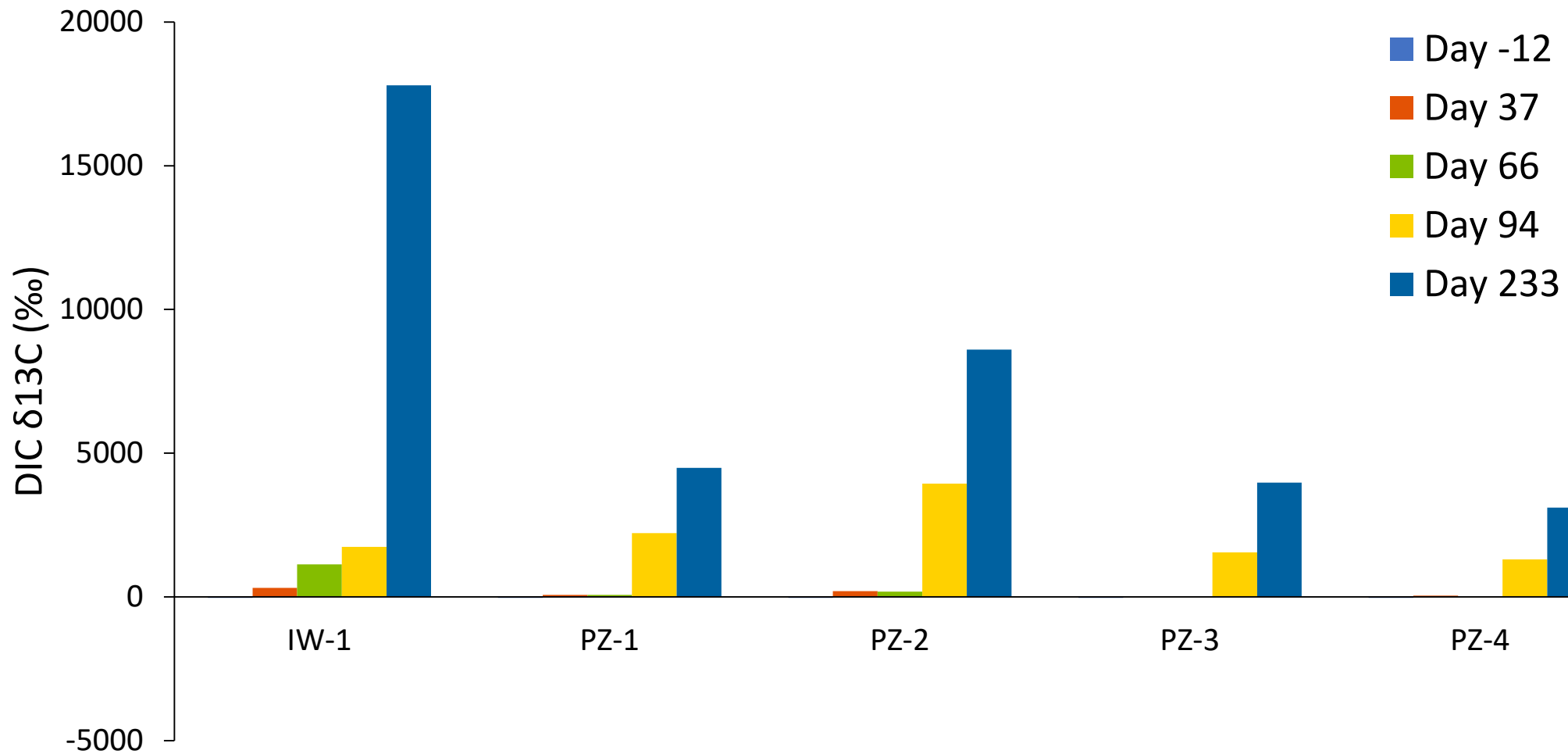
IW-1 and Piezometers



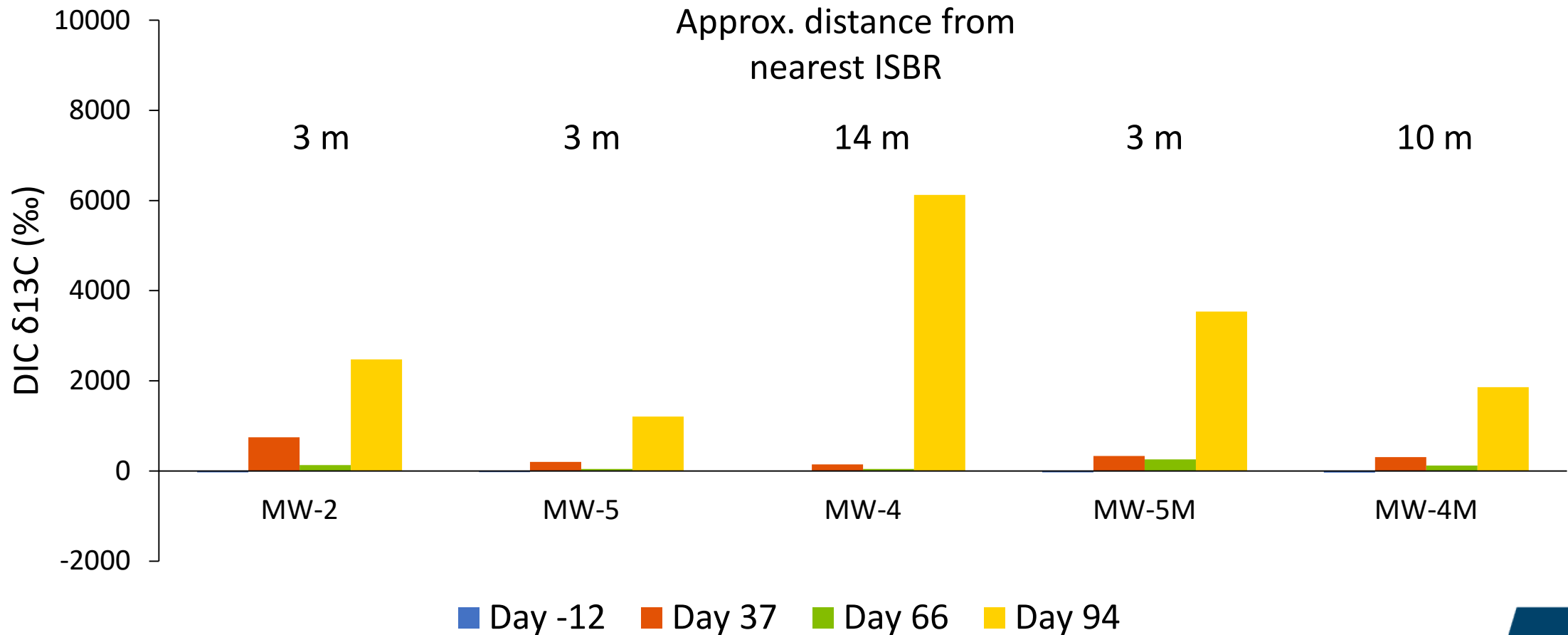
Toluene Data – IW-1 and Piezometers



Stable Isotope Probing – IW-1, Piezometers



Stable Isotope Probing – Monitoring Wells



Site Summary

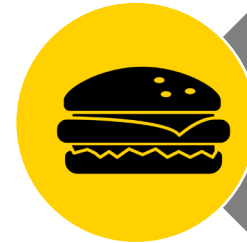
- After 200 days, toluene concentrations in all bioreactor wells met NJDEP groundwater standards
- 99% toluene reduction in PZ-2 and 30-50% reduction in PZ-1, -3, and -4
- SIP data provided direct evidence of increased toluene mineralization throughout the site

Heating Oil-Impacted Residence

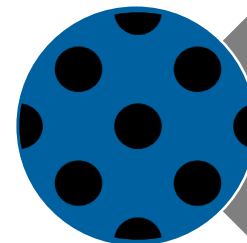
- Low, but persistent BTEX
- 1 bioreactor and 4 monitoring wells installed in basement
- Three-phase system startup



1st Month
Air Sparging

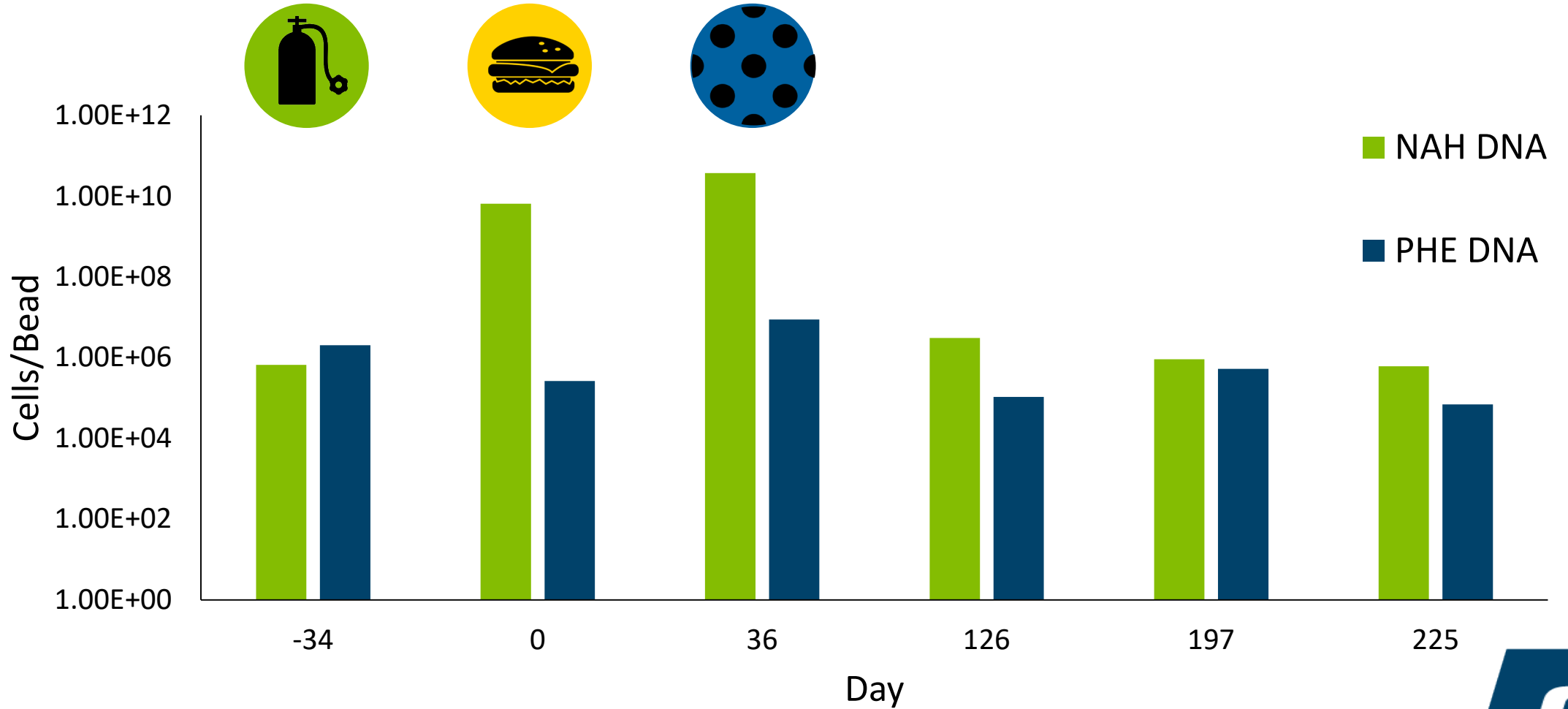


2nd Month
Air + Nutrients

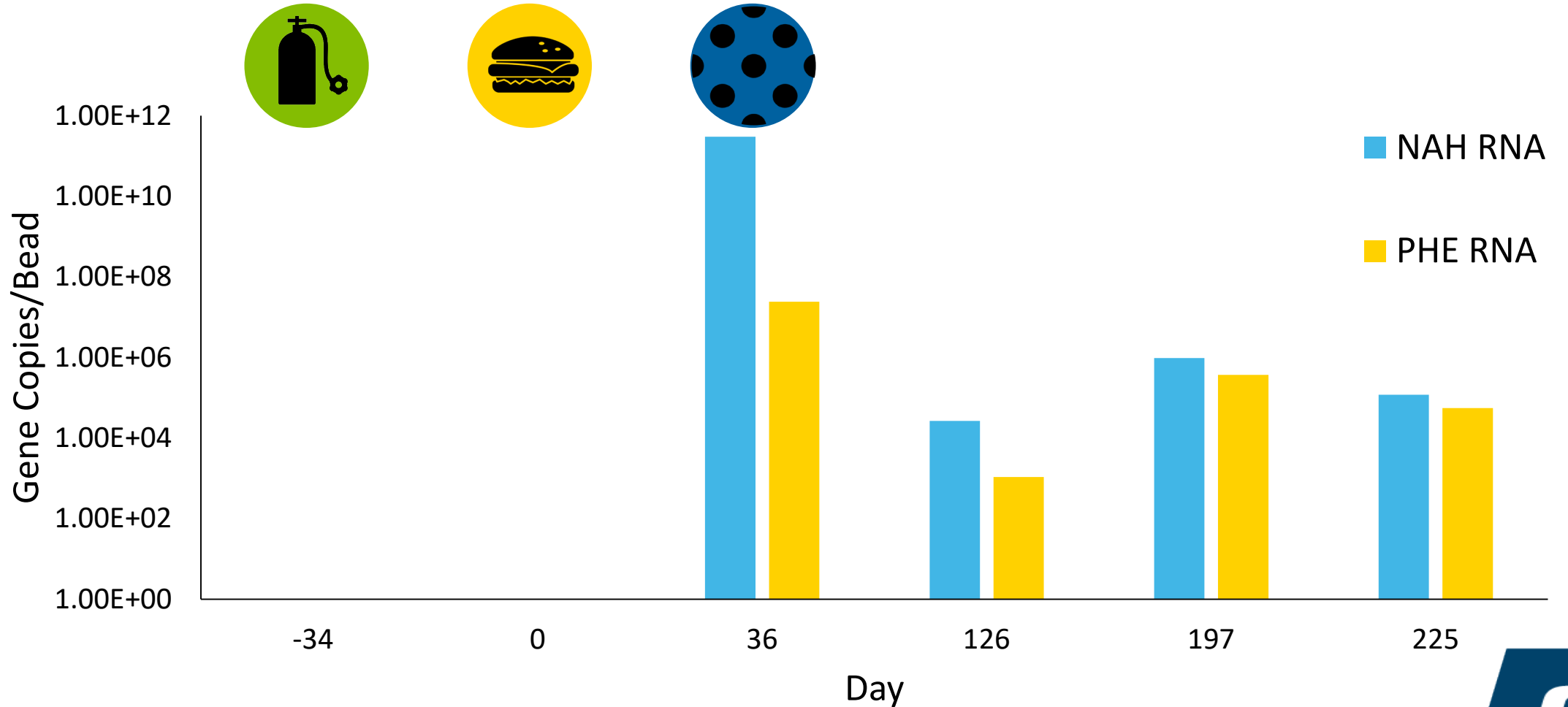


3rd Month
Bio-Sep Beads

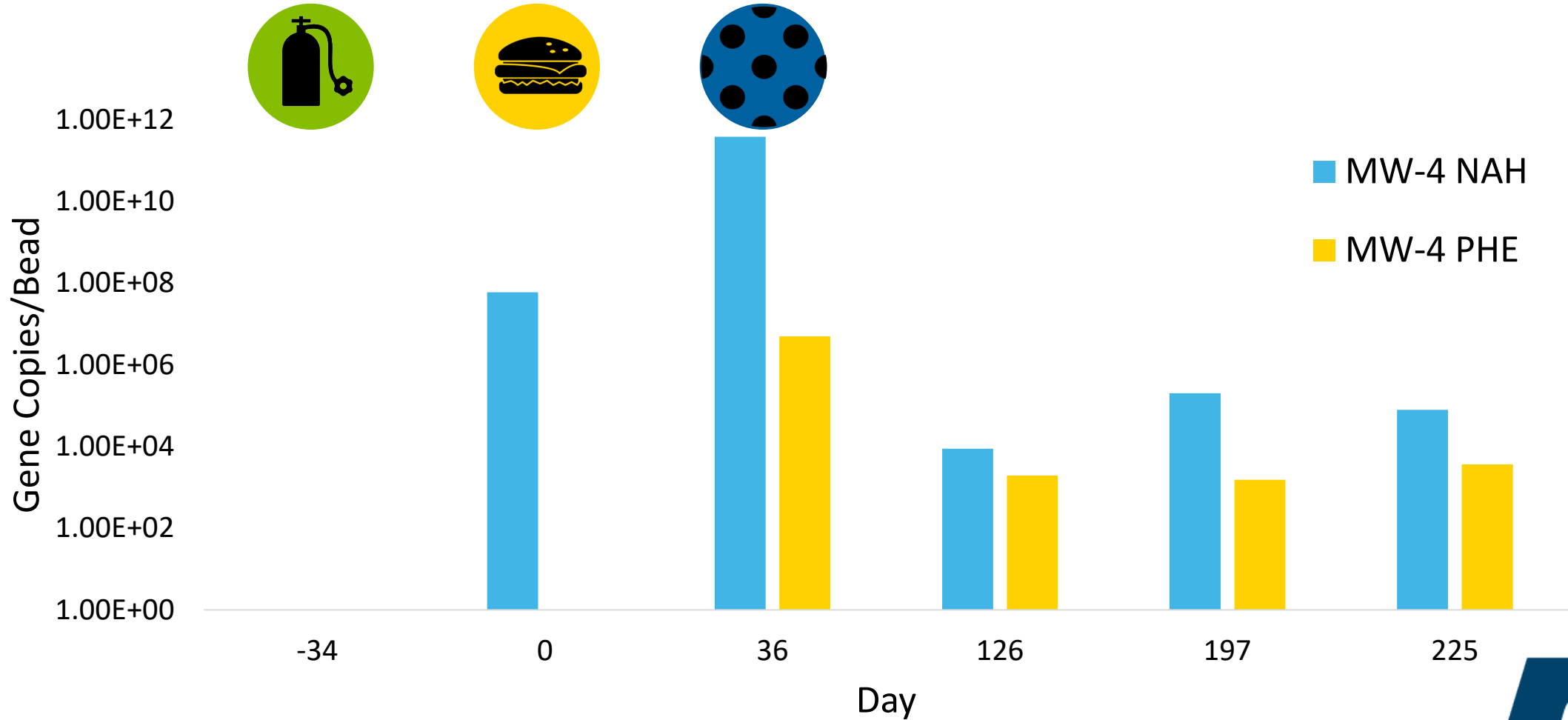
BR1 qPCR Analysis – Genetic Potential



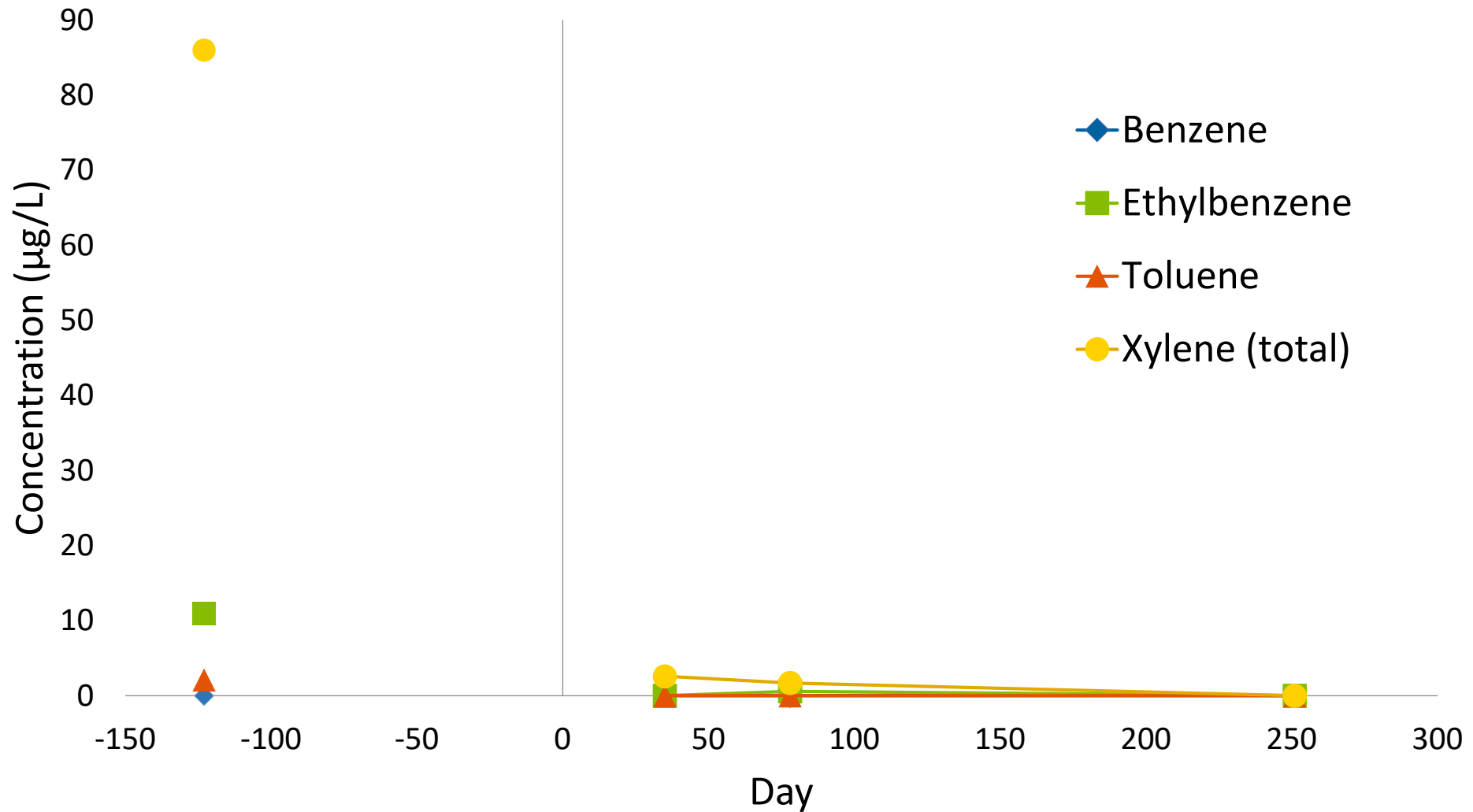
BR1 RT-qPCR Analysis – Gene Expression



MW4 RT-qPCR Analysis – Gene Expression



BTEX Concentrations



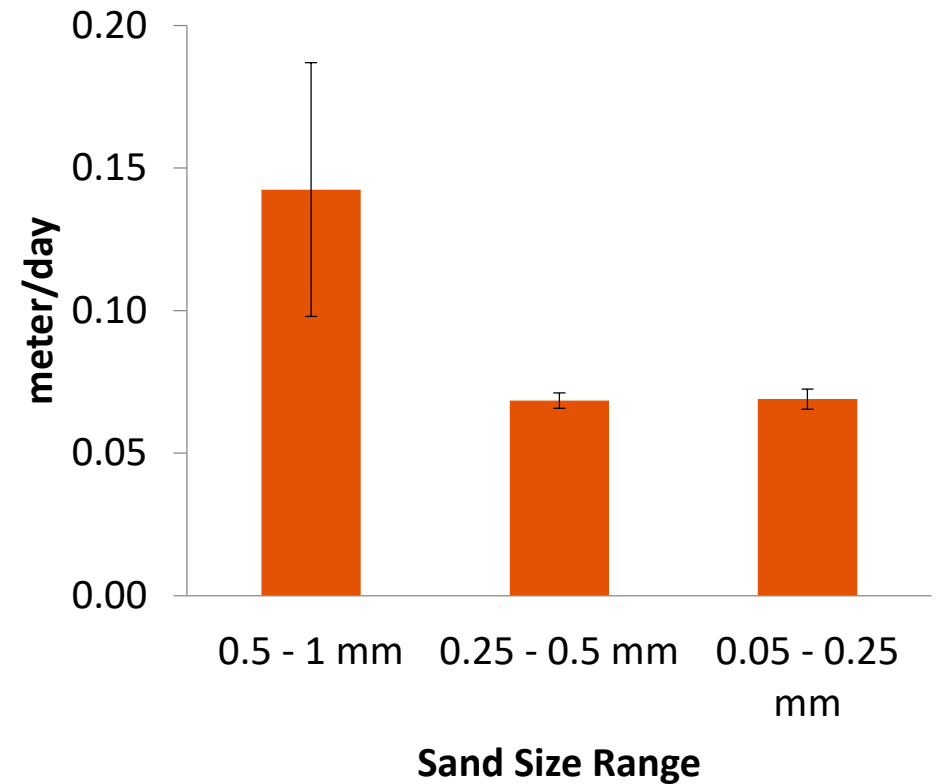
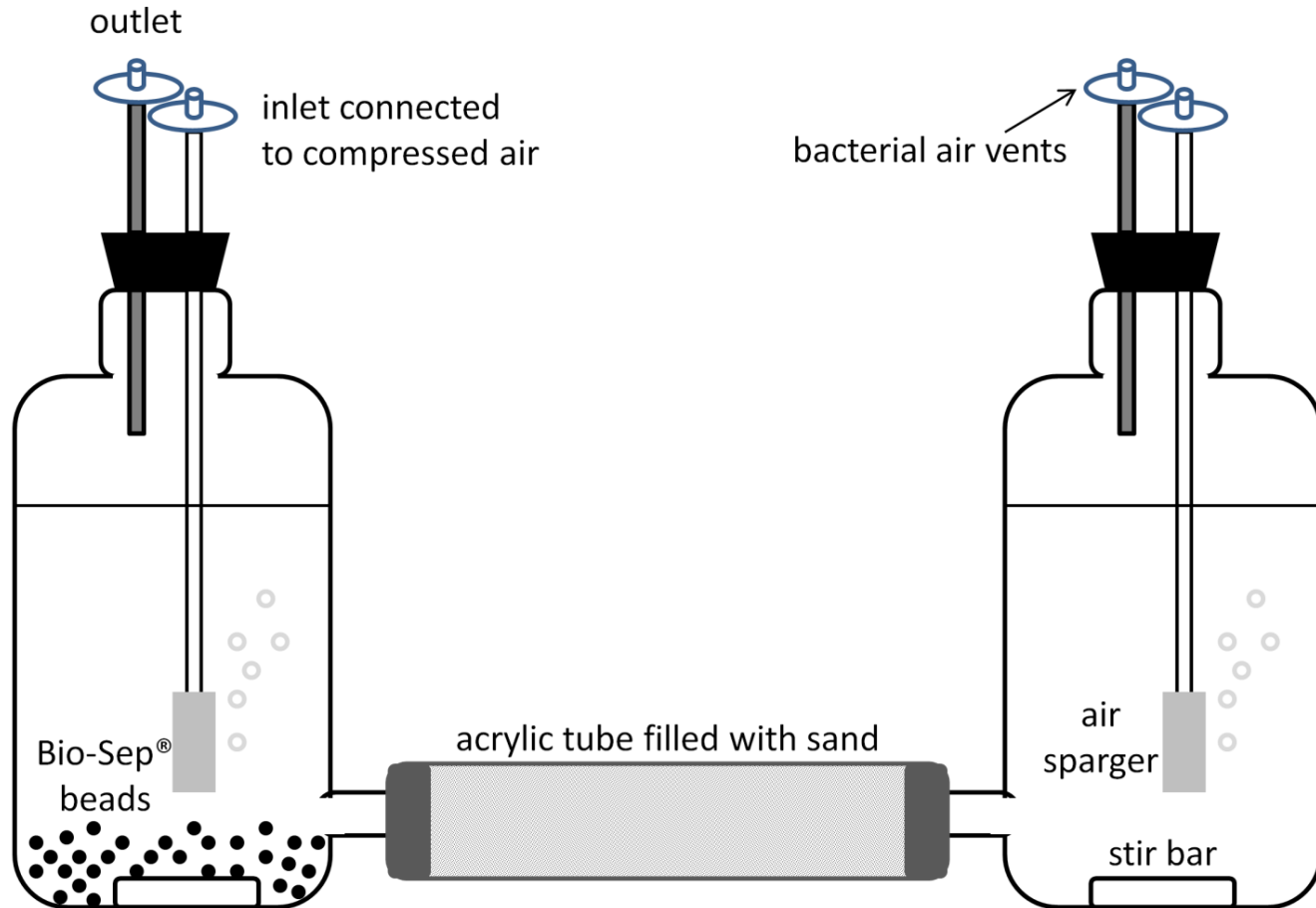
Site Summary

- Biodegradation stimulated at low hydrocarbon concentration
- Increased degraders and expression of hydroxylase genes after Bio-Sep beads added
- Microbial community responded to changes in treatment; effect seen in both the bioreactor well and the monitoring wells
- All constituents of concern were either not detected or below groundwater quality criteria by the end of the study

Transfer and Maintain Degraders

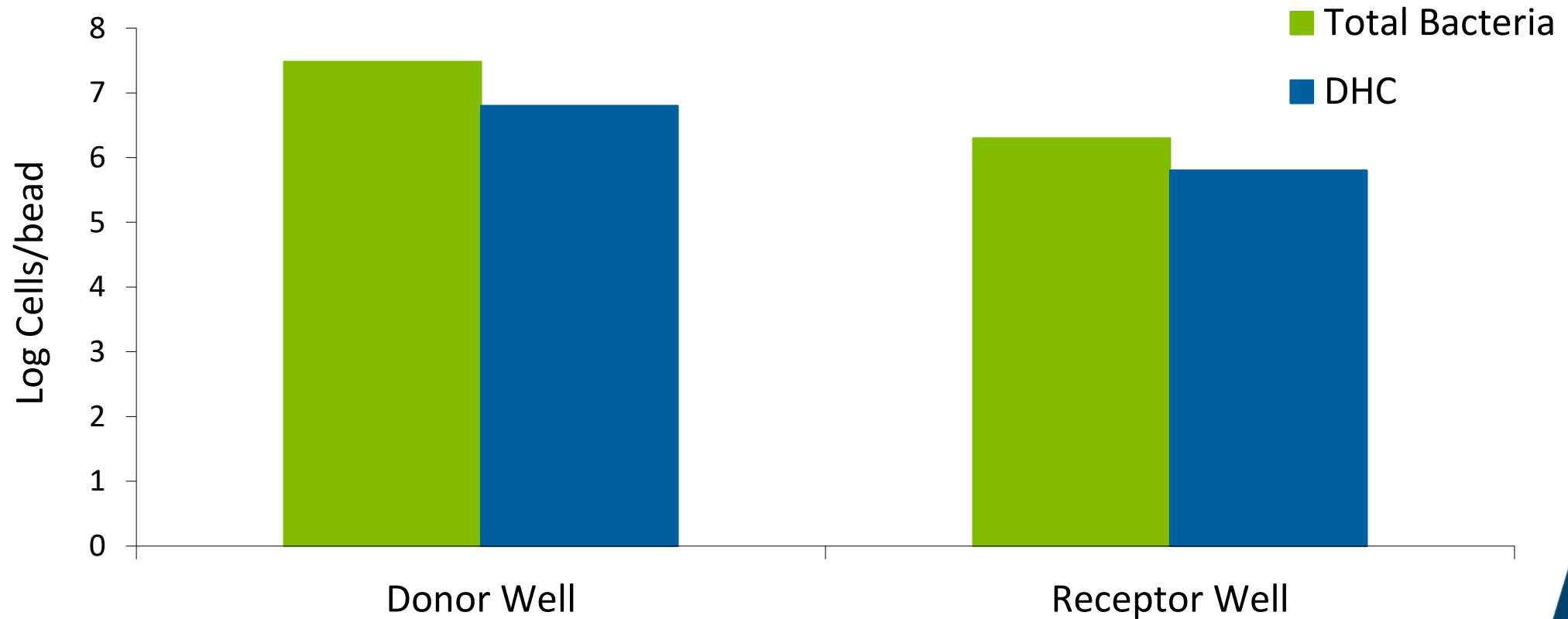
- Colonize degraders from active area of a site and transfer to another area
- Bio-Sep beads pre-inoculated prior to installation increase culture survivability

Microbial Release and Transport Study

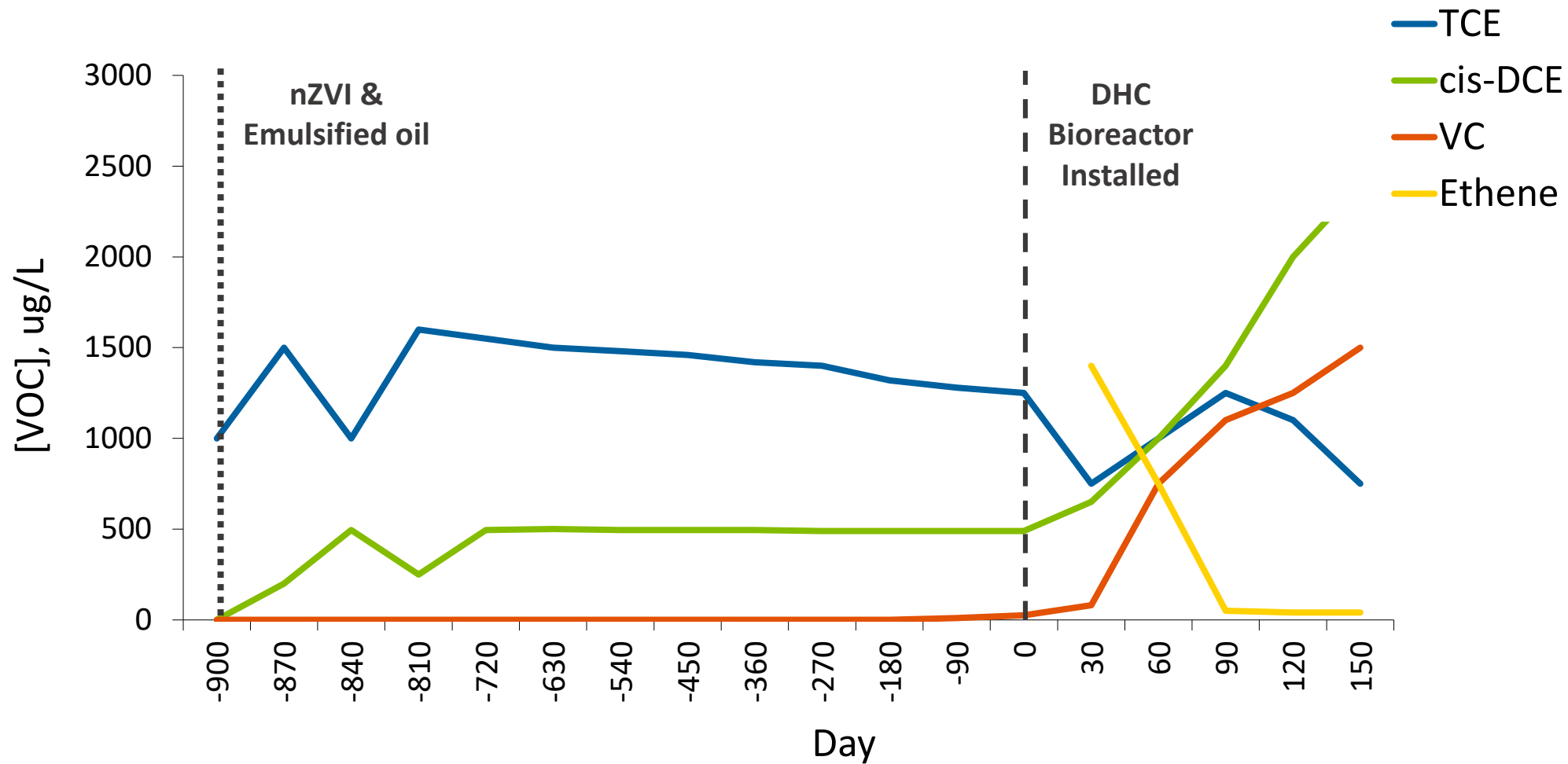


Transfer of DHC in a TCE Plume

qPCR Results from Donor and Receptor Wells after One Month



Transfer of DHC in a TCE Plume



Conclusions

In situ bioreactors shown to effectively stimulate biodegradation

- Potentially inhibitory contaminant concentrations
 - Toluene degradation documented at least 12 m away from bioreactor in silty clay aquifer
- Dilute plumes
 - Increased gene expression following Bio-Sep bead addition
- Heterogeneous distribution of degraders
 - Successful transfer and maintenance of indigenous *Dehalococcoides*



Thank you for your time

Are there any questions?