



Evaluation of Treatment of MGP-Impacted Soils and Groundwater Co-Mingled with PFAS Using ISCO

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History/Site Activities

History & Investigation Activities

- Former MGP that operated from the late 1890's to the mid 1930's
- Natural gas/propane pumping station from the mid 1940's until 1969
- 1969 to present – municipal fire station
- Site Investigation Activities conducted in 2000
 - Former MGP structures encountered
 - Coal tar encountered in area of former gas holder
 - MGP-related impacts to soil and groundwater

Remedial Activities

- Former MGP structures and ~ 1,500 tons of impacted soil removed in 2002
- ~ 4,000 gallons of coal tar/gw extracted
- Backfilled with sand, stone and ~ 660 lbs. of ORC
- Semi-annual GW monitoring conducted
 - Naphthalene above regulatory criteria
 - Other PAHs periodically above as well
 - PFAS associated with the FTA detected in 2017
 - PFAS co-mingled with residual MGP impacts

Proposed Remedial Approach

- ISCO proposed to address residual MGP impacts to groundwater
- Regulatory authority requested additional information/assessment to evaluate possible ISCO impacts on PFAS
- Bench top treatability study
- Field ISCO pilot testing



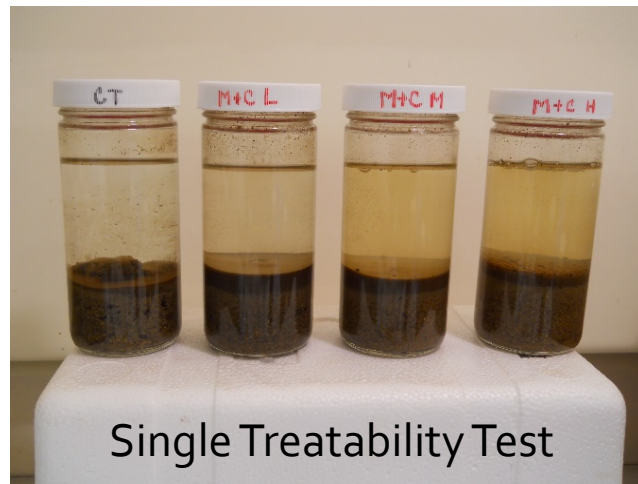
Site Background

- Lithology = Sands and gravel
- VOCs of 4.26 $\mu\text{g/L}$ & 1.20 $\mu\text{g/kg}$
- PAHs of 77 $\mu\text{g/L}$ & 8,573 $\mu\text{g/kg}$
- PFAS up to 7,357 ng/L
 - PFOA up to 2,010 ng/L
 - PFOS up to 2,000 ng/L



Bench-Scale Study Objectives

- Evaluate treatability of MGP-related VOCs & PAHs using ISCO
- Assess the potential impact of ISCO on PFAS
- Three ISCO reagents were evaluated:
 - Modified Fenton's reagent (MFR)
 - Carbohydrate activated sodium persulfate (CHASP)
 - Combination of MFR and CHASP (MFR+CHASP)



Single Treatability Test

Phase I – GW Test

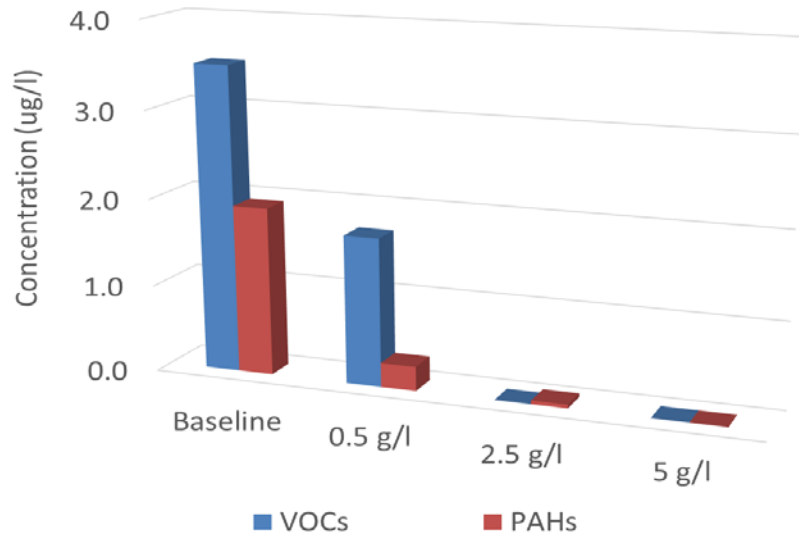
- Two reagents tested
 - MFR only
 - CHASP only
- Test performed on GW sample only
- Tested sample contained:
 - VOCs=3.5 µg/L PAHs=2 µg/L
 - total PFAS= 3,588 ng/L (including PFOA, 140 ng/L & PFOS, 1,980 ng/L)
- MFR and CHASP doses tested at:
 - 0.5 g/L, 2.5 g/L and 5 g/L

Phase II – Soil & GW Test

- Two reagents tested
 - MFR only
 - MFR followed by CHASP
- Tested on slurry consisting of soil mixed with GW at 1:1 ratio by weight
- Majority contamination in soil phase
 - PAHs (1.3 µg/L and 3,810 µg/kg)
> 99% of the COCs
- MFR and MFR+CHASP doses tested at:
 - 2 g/kg, 10 g/kg and 20 g/kg

Phase I: VOCs/PAHs Treatment

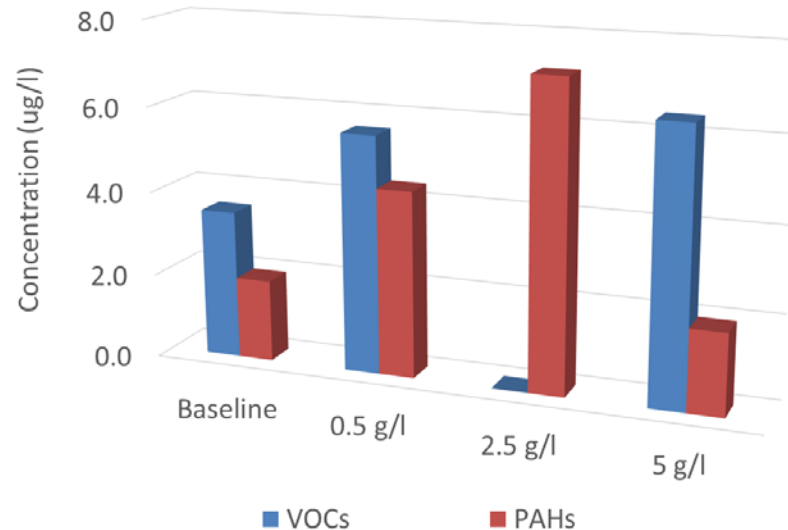
VOCs/PAHs remaining using MFR



MFR Treatment

- VOC reduction = 51%-100%
- PAH reduction = 51%-100%
- Oxidant consumption = >99%

VOCs/PAHs remaining using CHASP

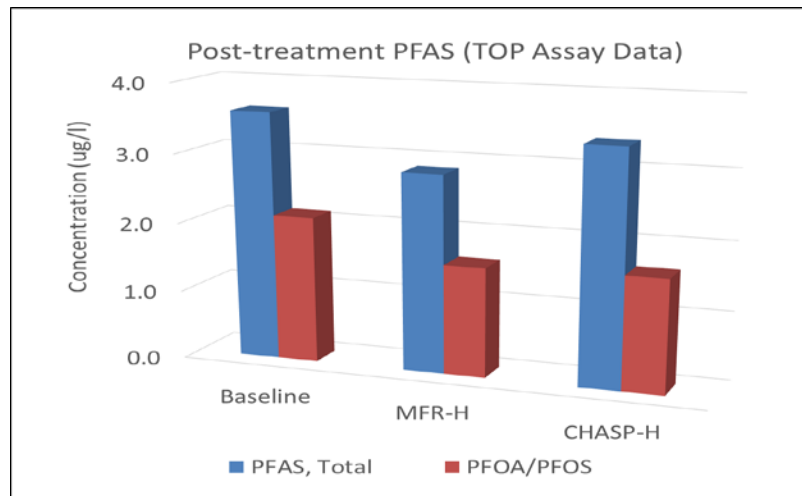


CHASP Treatment

- VOC reduction = 100% (medium dose)
- Ineffective for PAHs
- Oxidant consumption = 35%-57%

Phase I: Treatment Effect PFAS

- Standard PFAS analysis shows
 - Slight PFAS fluctuations with each reagent, but within expected laboratory deviations
- TOP assay data shows:
 - PFAS precursors reduction
 - PFOA+PFOS reduction

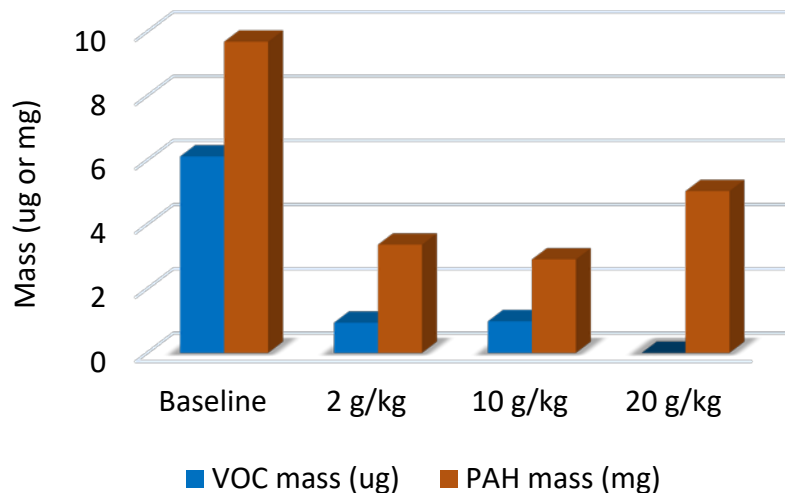


PFAS Top Assay Results

Sample ID	Control	MFR-H	CHASP-H
Oxidant used	none	H ₂ O ₂	Na ₂ S ₂ O ₈
Activator used	none	Cat	CH
Oxidant added (by weight)	0 g/l	5 g/l	5 g/l
PFAS (ng/l)			
PFBA	242.00	191.00	256.00
PFPeA	318.00	225.00	389.00
PFBS	15.40	9.76	ND
PFHxA	252.00	183.00	223.00
PFPeS	26.60	17.10	16.60
PFHpA	116.00	94.00	69.10
PFHxS	503.00	363.00	413.00
PFOA	140.00	114.00	37.70
PFHpS	31.10	23.70	14.80
PFNA	198.00	161.00	351.00
PFOS	1700.00	1470.00	1600.00
PFAS, Total	3542	2852	3370
PFOA/PFOS	1840	1584	1638
PFAS, Total (% Reduction)		21%	6%
PFOA/PFOS (% Reduction)		25%	23%

Phase II: VOCs & PAHs Treatment

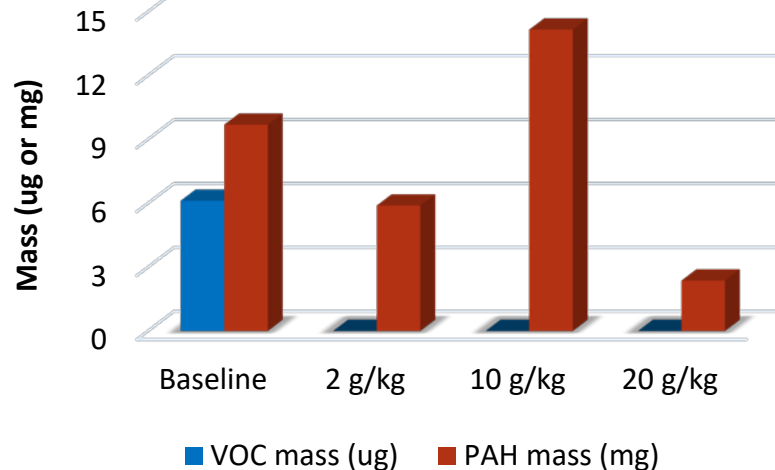
VOCs/PAH Mass Remaining using MFR



MFR Treatment

- VOC reduction = 84%-100%
- PAH reduction = 48%-70%
- Oxidant consumption = >99%

VOCs/PAH Mass Remaining using
MFR+CHASP

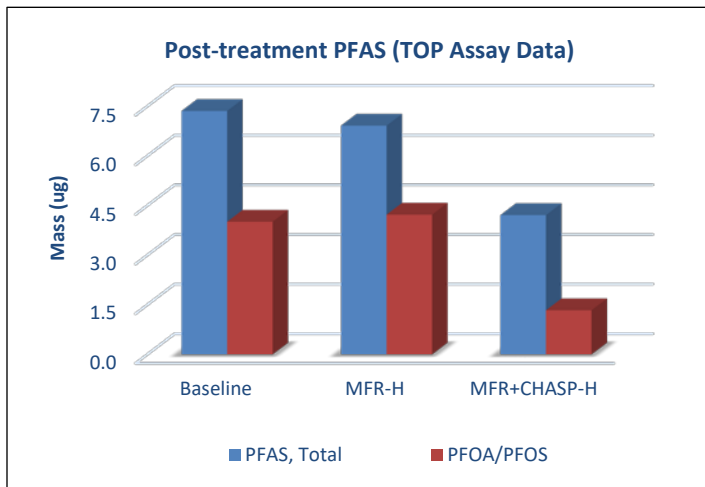


MFR+CHASP Treatment

- VOC reduction = 100% (all 3 doses)
- PAH reduction = 39% & 76%
- Oxidant consumption = 77%-98%

Phase II: Treatment Effect PFAS

- Standard PFAS analysis shows
 - Slight PFAS fluctuations with MFR and MFR+CHASP but within expected laboratory deviations
- TOP assay data shows:
 - PFAS total reduction
 - PFOA+PFOS reduction

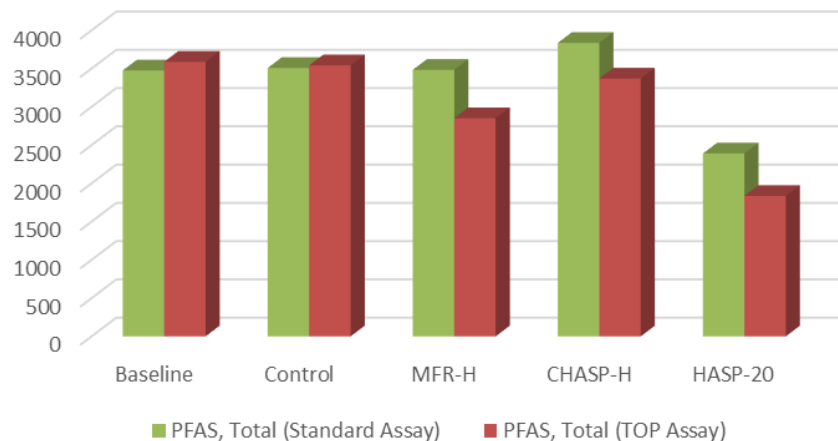


PFAS Top Assay Results

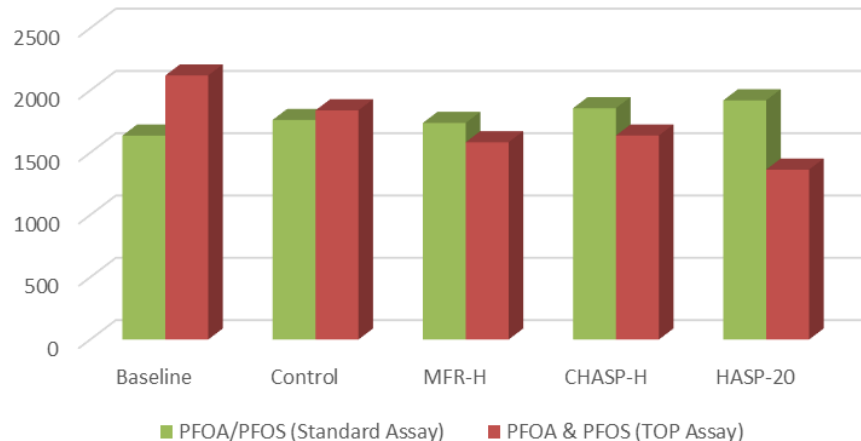
Sample ID	Control	MFR-20	MFR+CHASP-20
Oxidant used	none	H ₂ O ₂	H ₂ O ₂ +Na ₂ S ₂ O ₈
Activator used	none	Cat	Cat+CH
Oxidant added (by weight)	0 g/kg	20 g/kg	(15+5) g/kg
PFAS (ng/l)			
PFBA	457.00	274.00	252.00
PFPeA	752.00	591.00	843.00
PFBS	ND	ND	17.70
PFHxA	996.00	696.00	998.00
PFPeS	ND	31.00	29.30
PFHpA	327.00	178.00	126.00
PFHxS	495.00	793.00	543.00
PFOA	1810.00	783.00	184.00
PFHpS	ND	64.90	53.10
PFNA	ND	61.80	13.90
PFOS	2450.00	3440.00	1150.00
PFAS, Total	7287	6913	4210
PFOA/PFOS	4260	4223	1334
PFAS, Total (% Reduction)		5%	42%
PFOA/PFOS (% Reduction)		5%	69%

Standard vs. TOP Observations

PFAS Total - Standard vs. TOP Assay Comparison



PFOA & PFOS - TOP vs. Standard Assay Comparison



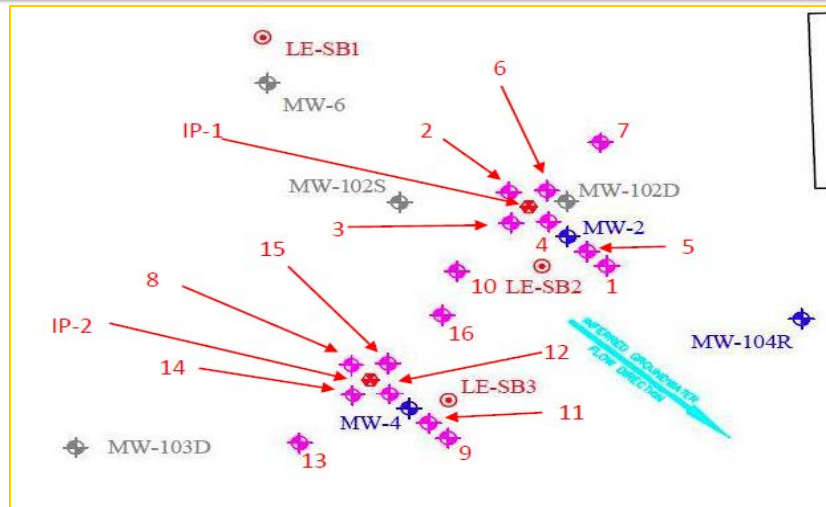
- Standard assay doesn't tell the whole story
- TOP assay illustrates some treatment PFAS, increases PFOS/PFOA in Baseline sample and confirms slight reductions seen in PFAS data

Bench Study Conclusions

- Both MFR and MFR+CHASP are amenable for treating VOCs & PAHs. Combination of MFR & CHASP produced better results than MFR.
- No significant adverse impacts were noted on PFAS following MFR or MFR+CHASP.
- Decreases were noted for total PFAS and PFOA & PFOS, based on TOP assay data using MFR+CHASP combined technology.

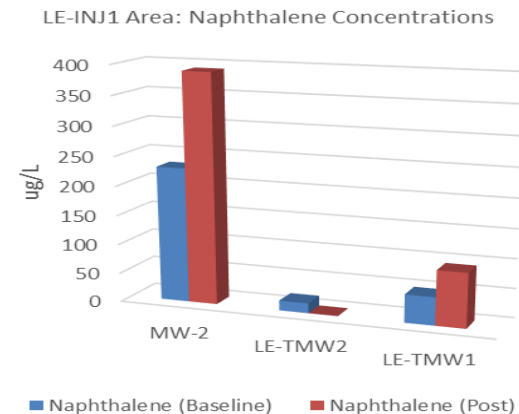
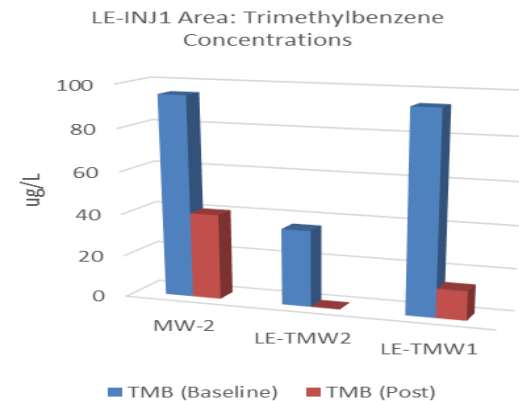
Pilot Study Details

- Two Pilot Study Areas = ~20' x 15' each
 - LE-INJ1 Area
 - LE-INJ2 Area
- Treatment Interval = 8-16 ft bgs
- Pilot Study Approach
 - Inject 750 gallons MFR + CHASP into single injection point.
 - Two intervals (8-12' and 12-16')
 - Monitor from 8 piezometers & 1 existing well
- LE-INJ1 had higher VOC and PAH and lower PFAS concentrations than LE-INJ2 treatment area

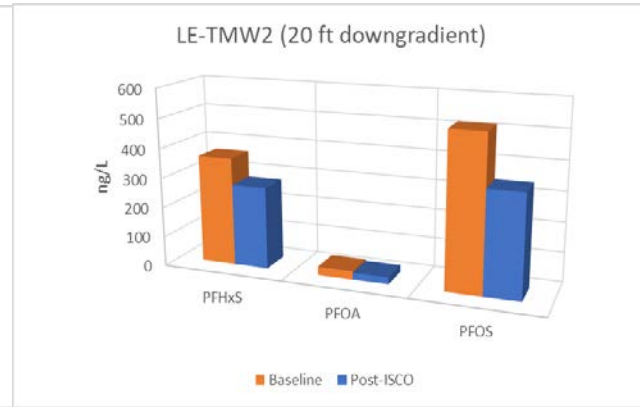
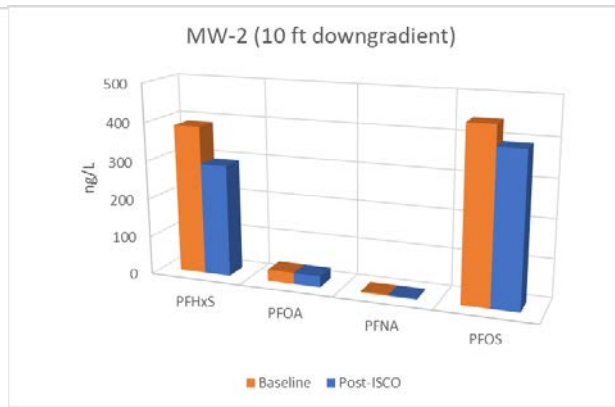
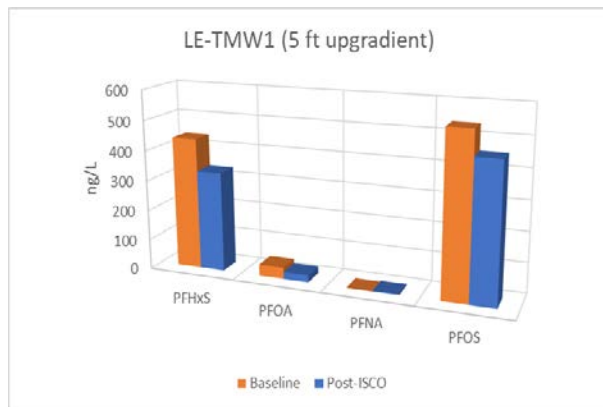


LE-INJ1 Pilot Study Results (Post 3-Months VOCs & PAHs)

- VOCs and PAHs decreased significantly
- Naphthalene increased compared to baseline
- Radius of influence up to 20 ft (TMW1) based on field monitoring (conductivity & DO)



LE-INJ1 Pilot Study Results (Post 3-Months PFAS TOP Assay)

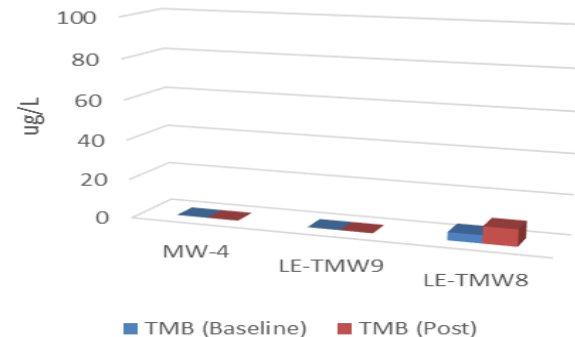


- PFAS concentrations decreased overall at 5 ft, 10 ft and 20 ft radial distance from injection well
- TOP assay results indicate PFAS concentrations were not adversely impacted from ISCO

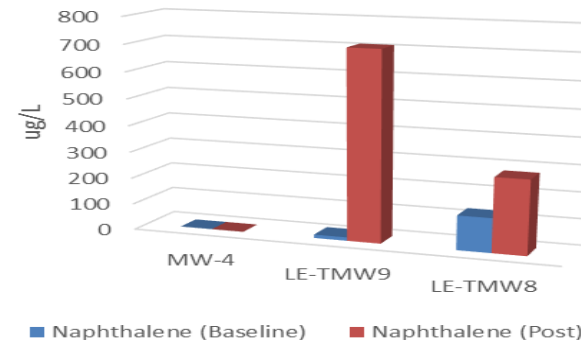
LE-INJ2 Pilot Study Results (Post 3-Months VOCs & PAHs)

- Post-treatment results indicate VOCs and PAHs generally remained stable
- Increase noted for naphthalene
- Radius of influence up to 20 ft based on field monitoring (conductivity & DO)

LE-INJ2 Area: Trimethylbenzene Concentrations

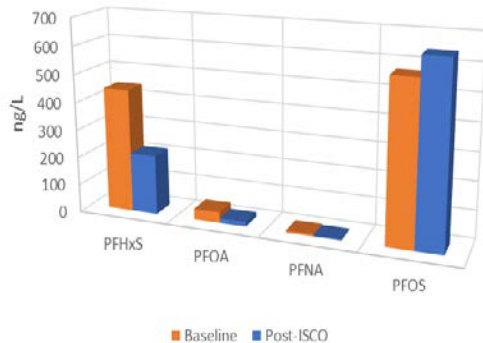


LE-INJ2 Area: Naphthalene Concentrations

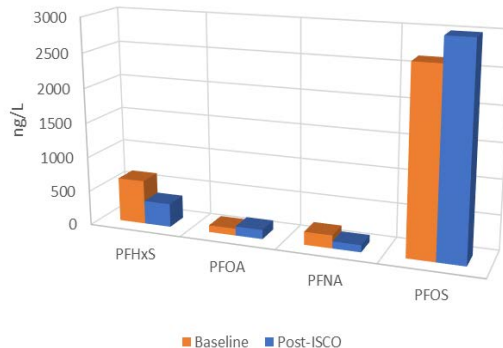


LE-INJ2 Pilot Study Results (Post 3-Months PFAS TOP Assay)

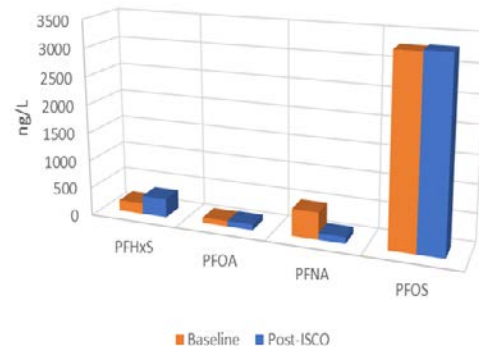
LE-TMW9 (5 ft upgradient)



MW-4 (10 ft downgradient)



LE-TMW8 (20 ft downgradient)



- 5 ft upgradient: PFHxS decreased by 52%, PFOA by 56%, PFNA by 47%. PFOS remained stable.
- 10 ft downgradient: PFHxS decreased by 46% and PFNA by 45%. PFOA and PFOS increased.
 - Historical concentrations of PFOS & PFOA much higher 10,000 ng/L and 130 ng/L, respectively.
- 20 ft downgradient: PFNA decreased by 75%. PFHxS increased by 70%, PFOA and PFOS increased slightly.

Pilot Test Conclusions

- Combination of MFR and CHASP is a viable technology for treatment of MGP-related contaminants in the presence of PFAS
- No significant adverse impacts were noted for PFAS following ISCO
 - Evidence of decreases in PFOA and PFOS concentrations noted during bench-scale study as well as in one pilot study area
- Good radial effect achieved during pilot study even though injection was performed into only one well



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