Photon Water

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In-situ Electrochemically Enhanced Nanoremediation for PFAS

Successful Site Trial

Nanoremediation relies on the use of zero-valent iron nanoparticles (nZVI) in reducing water contaminants. An additional electric field enhances the transport of nanoparticles in an aquifer environment and improves the remediation performance of nZVI.

The applied electric field both reduces the adhesion force between nZVI particles and the surfaces of sedimentary rocks and enhances their reactivity and longevity in contaminated groundwater environments. The combination of iron reduction and DC current substantially reduces PFAS concentrations in the aquifer. Large-scale demonstrations at contaminated sites have confirmed the performance of Electro-nanoremediation technology.

The overall costs are reduced substantially thanks to the transfer for chemical reduction from the cathodes to contaminants through nZVI and then increasing its longevity. An additional means of reducing costs is the use of less reactive nanocomposite material of zero-valent iron.

Trial Location

Airport site contaminated by AFFF. Fractured bedrock site. Sandstones and siltstones with lower permeability and dual porosity. The groundwater lever of the aquifer is situated shallow below surface (0-2 m) and the bottom of the shallow phreatic aquifer is situated 4-5 m below ground surface.

Objectives

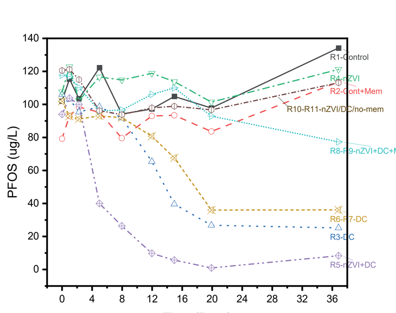
Confirm the applicability of in-situ electrochemical nanoremediation to reduce the PFAS concentration in groundwater and prevent subsequent migration of PFAS contaminants to the surrounding area.

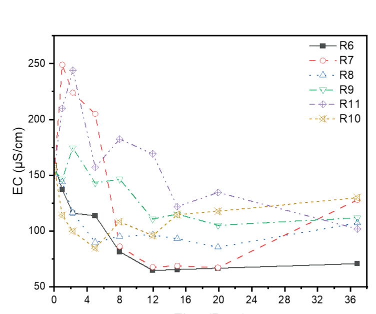
- Delivery of a project with core values of safety, transparency and integrity
- Investigate and confirm PFAS mechanism during electrochemical process
- Meet the standards set for environmental regulatory compliance (NEMP)

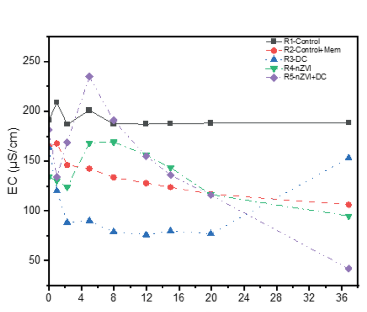
Reactor Test Results

The experimental conditions employed in laboratory-scale tests do not fully replicate the conditions present in the trial site tests. However, these laboratory-scale experiments provide valuable insights into the migration mechanism of PFAS and establish significant correlations between the experimental parameters and the PFAS concentration reduction rate. From the experimental results it can be concluded that direct current in combination with nZVI has significantly improved the concentration reduction of PFOS.

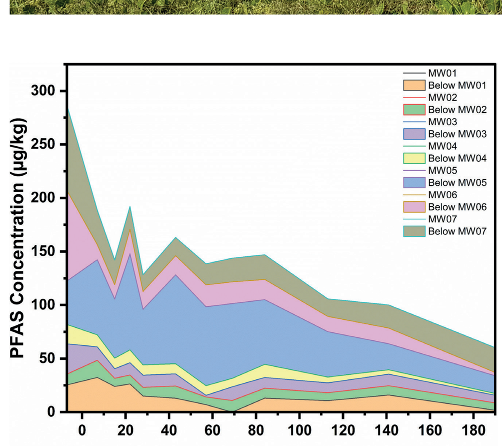
In a singular vessel reactor test, the application of direct current and nZVI led to a remarkable concentration reduction of up to 93%. The reduction in electrical conductivity exhibited a direct correlation with the concentration reduction of PFOS, consistently observed across all reactor test results. Given the absence of PFOS intermediate species over the duration of experiment it can be concluded that mineralization of PFOS did not occur.

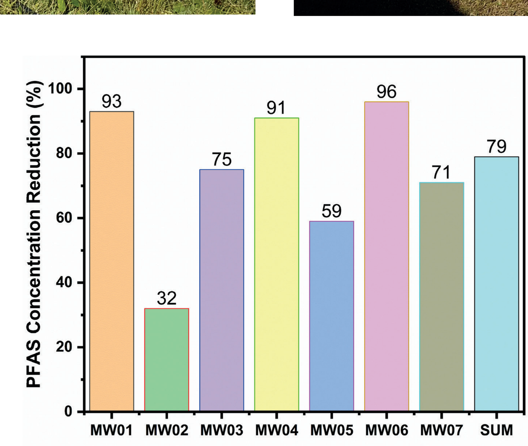






Trial





	Date	Monitoring Well	PFOA (µg/L)	PFHxS (µg/L)	PFOS (µg/L)	Sum (PFHxS + PFOS)* (µg/L)	Sum (PFHxS + PFOS + PFOA)* (µg/L)
Pre-Trial	12/08/20	GHD153	0.83	11.7	17.3	29	29.828
	24/06/20	GHD106	5.3	62	160	222	227.3
d - 7 Sampling	10/05/22	MW01	0.49	5.6	17	22.6	23.09
		MW02	0.18	2.2	7	9.2	9.38
		MW03	0.56	6.3	19	25.3	25.86
		MW04	0.4	4.7	11	15.7	16.1
		MW05	0.84	9.8	26	35.8	36.64
		MW06	1.6	19	56	75	76.6
		MW07	1.5	18	53	71	72.5
		MW08	0.65	7.5	16	23.5	24.15
		MW09	1.8	24	50	74	75.8
		MW10	0.62	7.3	19	26.3	26.92
d + 190 Sampling	19/01/23	GHD153	0.62	7.9	15	22.9	23.52
		GHD106	5.6	89	270	359	364.6
		MW01	0.03	0.29	1.3	1.59	1.62
		MW02	0.2	2.2	3.7	5.9	6.1
		MW03	0.21	2.3	3.6	5.9	6.11
		MW04	0.03	0.31	1.1	1.41	1.44
		MW05	0.32	3.9	11	14.9	15.22
		MW06	0.06	0.65	2	2.65	2.71
		MW07	0.43	4.9	16	20.9	21.33
		MW08	0.87	12	12	24	24.87
		MW09	1.4	20	54	74	75.4
		MW10	1.4	16	19	35	36.4

Description	PFOA	Sum (PFHxS + PFOS)*
Tolerable daily intake (TDI)	0.16 µg/kgbw/day	0.02 µg/kgbw/day
Drinking water quality guideline value	0.56 µg/L	0.07 µg/L
Recreational water quality guideline value	10 µg/L	2 µg/L

Results

Looking from left to right; 7 days before injection we define a highly acidic site, with low oxidation reduction potential. Dissolved oxygen was observed up 2mg/L and the Sum of PFAS concentrations in sampling wells measured average over site 43 µg/L and maximum over 84 µg/L. These surfer generated plots represent extrapolated concentrations and provide a compelling visual to examine the shift physiochemical properties and decreasing PFAS mass concentrations over the site.

Showing the technology can be applied and optimized for recreational and drinking water requirements, trial findings reinforced that despite preferential patterns of reduction (aforementioned C-C > C-S) all present species show a decrease in mass concentration. This notion of complete mass reduction is exemplified in the exponential detailing the bulk mass reduction of the reactive trial site. All findings (trial and reactor tests) of mass reduction are consistent with conclusions from post-trial reactor tests and experimental results.

Desktop dilution studies previously distributed establish that this concentration reduction as reflective of a complete bulk reduction as opposed to a dilution affect from injection. While analysis and correlation factors can be found well by well and as a trial site, the positive correlation for all PFAS species, confirms that reduction in long chain species does not result in short chain PFAS and that precursors or intermediates are not created.

Where wells performed well/influenced we saw reduction of PFAS concentrations over 90%.

Conclusion

The combination of iron reduction and DC current substantially reduces PFAS concentrations in the aquifer.

In-situ Electrochemical Nanoremediation in this trial demonstrated the ability to reduce the mass and flux of PFAS in groundwater, at a very low environmental impact compared to traditional treatment methods.

- Significant concentration reduction of PFAS: average 93%; up to 100% at specific wells
- Compliance with NEMP 3.0 drinking and recreational water standards were made
- No related by-products and intermediates were detected
- The immediate effect of concentration reduction of PFAS delivered a sustainable value to the environment and a local community

T A Č R

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