Successful Site Trial of In-Situ Electrochemically Enhanced Nanoremediation for PFAS

Photon Water

Australian Government
Department of Defence

Ian Phillipps, Emily Brown, Petr Kvapil, Jaroslav Nosek
With thanks to Namuun Ganbat, Cassandra Perron, Tomáš Pluhař and Vojtech Antos
Photon Energy Group (Photon Water), 219-241 Cleveland St, Redfern, NSW, 2019 AUSTRALIA





Successful demonstration of a novel application of in-situ electrochemical nano-remediation to reduce PFAS concentrations in groundwater, within a contamination hotspot.

BACKGROUND

The Australian field trial site, within a PFAS contamination hotspot, features an upper aquifer into which this in-situ remediation solution was applied. The site is located within a particularly sensitive geographic location, with potential influence on nearby communities. The site owner has diligently undertaken extensive remediation options and action planning and is now working closely with community stakeholders to support remediation activities. These activities include proven technologies and approaches, but also the application of unique emerging solutions to ensure an effective, completely integrated remediation solution is applied. The impact on both the environment and local community is likely to be both extensive, and positive.

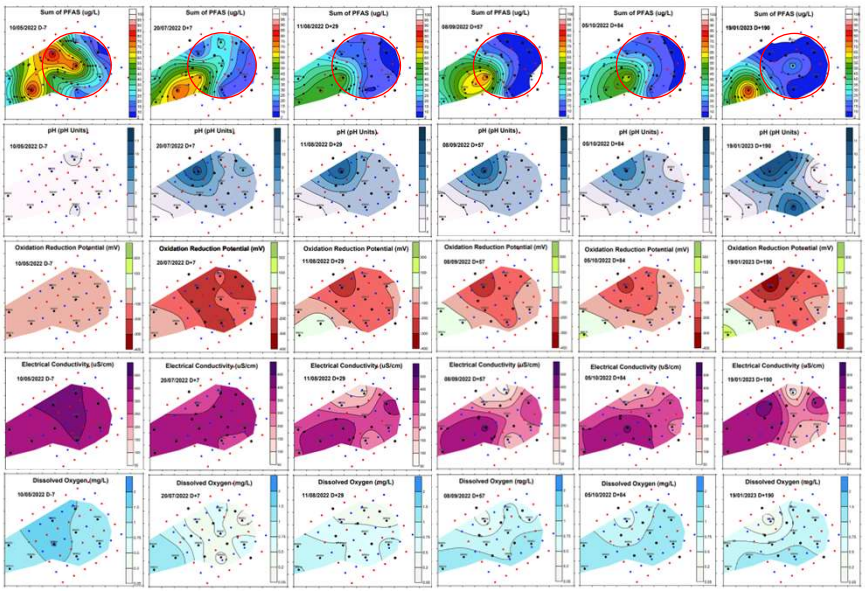
APPROACH AND ACTIVITIES

The project approach was to confirm at field scale, the applicability of in-situ electrochemical nano-remediation to reduce the concentration and mass of PFAS present in the groundwater and to prevent further migration of PFAS contaminated groundwater. The collected data from both sampling and ongoing monitoring was used to assess the efficacy of the applied technology and to characterize physical and chemical trial observations.

Efficient operation of this remediation strategy through measurement of PFAS concentration reductions, with understanding of hydrogeological conditions and the broader environmental and physiochemical impacts was defined within the project scope.
The field trial involved the installation and subsequent operation of groundwater monitoring and injection wells, a low powered direct current voltage control system, powered electrodes, monitoring electrodes, and an autonomous water sampling and analysis system. A liquid suspension of iron nanoparticles was dosed into the groundwater, with low direct current and voltage applied to the application electrodes, supporting a voltage differential between an anode and cathode. Within the trial specific and identified groundwater conditions, PFAS compounds were reduced within the treatment area.







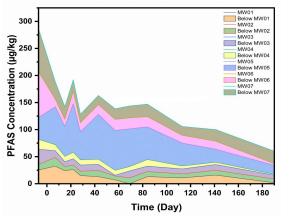
Extrapolated Surfer plots of Sum of PFAS, pH, oxidation reduction potential, electrical conductivity and dissolved oxygen of trial wells 1-10. D-7, D+7, D+29, D+57, D+84 and D+190 displayed.

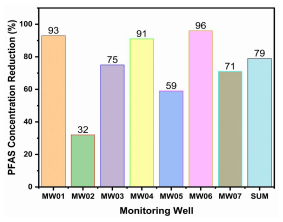
RESULTS

Under strict sampling and analysis quality criteria, the trial results indicated an average PFAS mass reduction of 79% across the active trial site (circled in red) and trial duration. This includes hydraulically disconnected well areas, and locations with lower or no applied voltage. PFAS mass concentration was reduced in the trial area by up to 100% at specific locations with reference to the lowest concentrations recorded during the sampling regime. Areas of aquifer that were influenced to design with DC current and nanoparticle suspension, an average concentration reduction of 93% was documented. This percentage reduction is represented by an average shift of approximately 42.65 µg/L to 2.15 µg/L in wells 1, 4 and 6. As a consequence of the in-situ technology, changes of an increased groundwater pH, negative oxidation reduction potential and decreased electrical conductivity were noted with statistical significance, to correlate to the observed PFAS reduction.

Additional laboratory reactor testing was undertaken in late 2022 to define were possible PFAS migration mechanisms, quantify degradation products, and to support technical conclusions. The environmental considerations of risk, efficiency of mass reduction and waste generation have been fundamental to the success of this remediation trial. No evidence of mineralization, intermediates and short chain formation was recorded. This was confirmed through reactor testing and principal component analysis of site data confirming a positive correlation between all PFAS species present.
Analogous mass reduction is noted in a connected downstream control well. This indicates, in accordance with modelled aquifer velocities a reduced pollutant mass flux leaving the aquifer. An upstream influent control well remained consistent at a concentration of approximately 243 µg/L.

Monitoring wells 1 to 7, post trial, compile with the 0.56 µg/L PFOA drinking water concentration requirement. PFOS & PFHxS concentrations significantly reduced towards the 2.0 µg/L recreational water guideline levels (NEMP 3.0).





Trial Sum of PFAS results and percentage reductions (including post SAQP to date). All results are presented as µg/L.

PFOA, PFOS and PFHxS results for MW01-MW10 according to NEMP guidelines.

	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	12/8/20	GHD153	0.83	11.70	17.30	29.00	29.83
	24/6/20	GHD106	5.30	62.00	160.00	222.00	227.30
d - 7 Sampling	10/5/22	MW01	0.49	5.60	17.00	22.60	23.09
		MW02	0.18	2.20	7.00	9.20	9.38
		MW03	0.56	6.30	19.00	25.30	25.90
		MW04	0.40	4.70	11.00	15.70	16.10
		MW05	0.84	9.80	26.00	35.80	36.60
		MW06	1.60	19.00	56.00	75.00	76.60
		MW07	1.50	18.00	53.00	71.00	72.50
		MW08	0.65	7.50	16.00	23.50	24.15
		MW09	1.80	24.00	50.00	74.00	75.80
		MW10	0.62	7.30	19.00	26.30	26.92
d + 190 Sampling	19/1/23	GHD153	0.62	7.90	15.00	22.90	23.52
		GHD106	5.60	89.00	270.00	359.00	364.60
		MW01	0.03	0.29	1.30	1.59	1.62
		MW02	0.20	2.20	3.70	5.90	6.10
		MW03	0.21	2.30	3.60	5.90	6.11
		MW04	0.03	0.31	1.10	1.41	1.44
		MW05	0.32	3.90	11.00	14.90	15.22
		MW06	0.06	0.65	2.00	2.65	2.71
		MW07	0.43	4.90	16.00	20.90	21.33
		MW08	0.87	12.00	12.00	24.00	24.87
		MW09	1.40	20.00	54.00	74.00	75.40
		MW10	1.40	16.00	19.00	35.00	36.40

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

CONCLUSIONS AND NEXT STEPS

Safe PFAS Concentration Reduction by ECNR
Significant decreases in all PFAS species were observed in the laboratory reactor and at the reactive site area. An average mass concentration reduction of 93% observed in highly influenced areas, or from an average of 42.65 µg/L. to 2.15 µg/L. 100% mass reduction or nil-detect results were recorded during discrete sampling intervals in these areas. The active trial site averaged a 79% mass reduction over the trial duration.

No Mineralisation
Absence of short chain or intermediate PFAS confirm mineralisation did not occur. No volatile or potentially harmful by products were noted in the analytical suites. PCA and statistical analysis confirm a positive correlation of all PFAS suites.

Regulatory Compliance
NEMP drinking water PFOA requirements (<0.56 µg/L) meet with significant improvement towards recreational water quality guidelines in sulfonic PFAS species.

Sustainability
The trial demonstrated alignment of the in-situ ECNR solution with a decreased environmental risk of reduced concentration and mass flux. The downstream control well recorded a similar 72% mass reduction analogous to aquifer concentrations. An innocuous injection suspension was utilised, and minimal waste was removed from site. An energy treatment efficiency of 75W-h/L was calculated for the 190-day trial duration. This efficiency value could be optimised to nil-detect values or be operated with small scale off grid photovoltaics for CO_2 neutrality.

NEXT....
Commercial roll out. Continued research into the mechanisms, surface chemistry and interactions. Examination of in-situ electrokinetics and PRBs for PFAS soil remediation.