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ELECTRO-NANO-BIO-REMEDIATION TECHNOLOGY FOR IN-SITU CHC DEGRADATION FROM LOW PERMEABLE CLAY AQUIFER

Technology Description

Electro-Nano-Bio-Remediation represents an integrative technology for in-situ application that combines **nanoremediation and bioremediation** with the **use of electrical current**. The process of nanoremediation involves the application of zero-valent iron (nZVI) for the remediation of contaminated soils. The implementation of an electrokinetic system serves to enhance the process of chemical reduction of target contaminants, extend the lifetime of nanoiron, and simultaneously facilitate **effective pH control** to maintain optimal conditions for bioremediation.

Bioremediation is defined as the stimulation of microbial communities with the objective of facilitating the degradation of contaminants. The combination of both with electrokinetic treatment, which is the application of low-voltage direct current across a section of contaminated aquifer material, has been demonstrated to further improve their efficiency. The application of an electric field affects the surrounding environment, primarily modifying the pH value of the groundwater. This can be employed to advantage in enhancing the reactivity of nZVI and the microbial environment.

Pilot site - Spain

The pilot site is located in Spain. The area is characterised by industrial activity and complex geological conditions. The site is **contaminated with chlorinated hydrocarbons,** with **perchloroethylene** representing the dominant pollutant. A total of 20 piezometers are present within the designated area, of which 12 are located within the application zone.

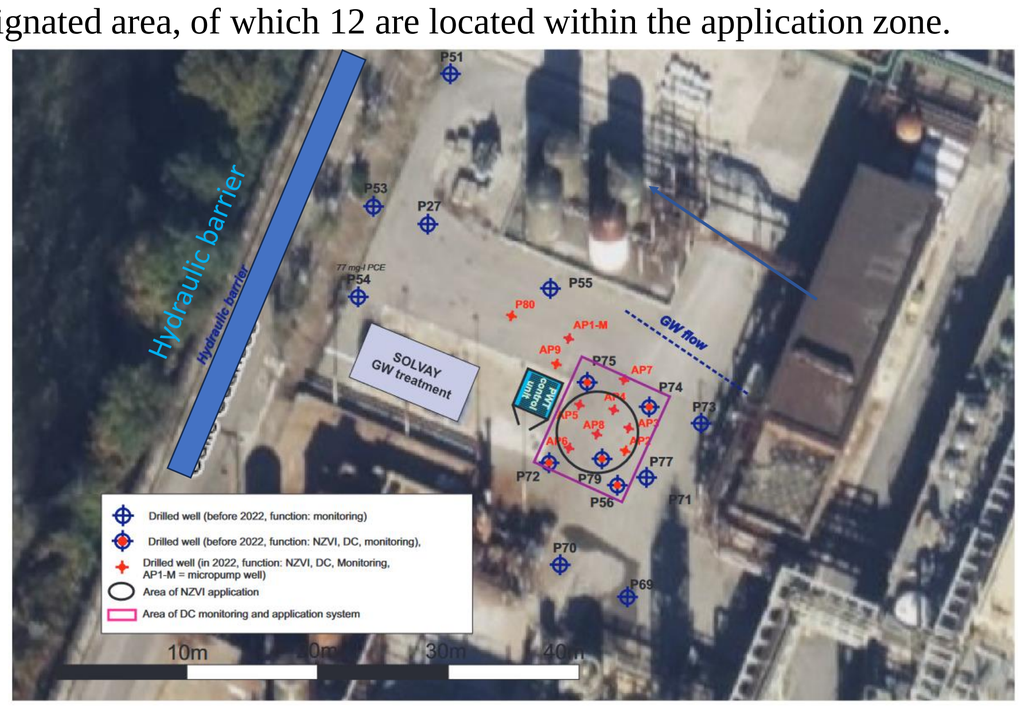

Figure 1: Pilot site with well position and application zone outlines

DC System upgrade - Power Unit

In February 2024, a new **stand-alone unit** was introduced to supplement the existing DC monitoring system. The aforementioned upgrade enables the **remote monitoring** of the polarity of the power electrodes at the pilot site. The power electrodes may be deactivated in their entirety or their polarity may be altered to that of the anode or cathode.

With this upgrade, it will be possible to better **influence the pH** in the application zone to be in a range suitable for the bacteria that will be used in the next stage - bioremediation. This step was taken to better control the pH at the application site so that it would be within a suitable range to support and improve the effectiveness of the next stage of remediation - bioremediation.

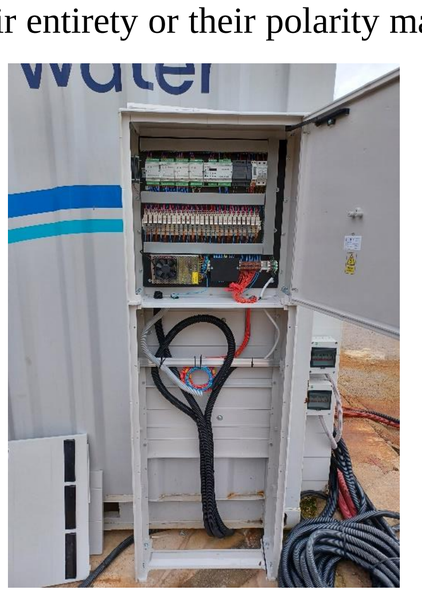

*Figure 2: DC system upgrade – **Power Unit***

Results from the monitoring of the pilot site

This chapter presents the results obtained from regulatory monitoring of chlorinated hydrocarbons and end products. A **comparison of the baseline concentrations** of CHC´s in piezometers in the application zone before and after the first phase - nanoremediation - is presented. The results of molecular genetic analyses of the pilot site are also shown, which characterize the second phase - biodegradation.

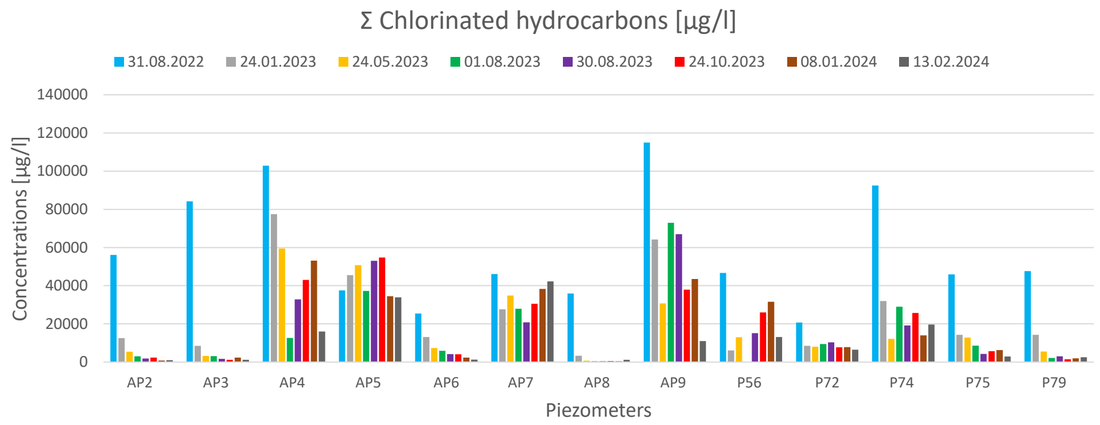

Figure 3: Concentration of the CHC´s in the site before and after the first phase - nanoremediation

			Well/Sample												
	unit	Method	AP2 Result	AP3 Result	AP4 Result	AP5 Result	AP6 Result	AP7 Result	AP8 Result	AP9 Result	P56 Result	P74 Result	P75 Result	P77 Result	P79 Result
March 2024 before Glycerol Injection	Eubacteria	qualitative PCR			+		+	+					+		
	Dehalococc	qualitative PCR			-		-	-					-		
	Desulfuron	qualitative PCR	n.s.	n.s.	-		-	-	n.s.	n.s.	n.s.	n.s.	-	n.s.	
	Desulfomo	qualitative PCR			-		-	-					-		
	Dehalobac	qualitative PCR			-		-	-					-		
	Desulfitoba	qualitative PCR			+		+	-					+		
August 2024 after Glycerol Injection	Eubacteria	qualitative PCR	+	+	+	+	+	+	+	+	+	+	+	+	+
	Dehalococc	qualitative PCR	-	-	-	-	-	(+)	-	+	-	-	-	-	-
	Desulfuron	qualitative PCR	+	-	-	-	+	-	+	+	-	-	-	-	-
	Desulfomo	qualitative PCR	-	-	-	-	-	-	-	-	-	-	-	-	-
	Dehalobac	qualitative PCR	+	+	+	+	+	+	+	+	+	+	+	+	-
	Desulfitoba	qualitative PCR	+	+	-	+	+	+	+	+	+	+	+	+	-

n.s. not sampled in monitoring

Figure 4: Molecular biological analysis of field pilot test

Molecular biological analysis

Low biomarker concentrations
- Before start of firts phase – nanobioremediation (nZVI application 10/2022)
- During nanobioremediation (August 2023 and March 2024)

Increasing biomarker concentrations
- After start bioremediation (biosubstrate injection 4/2024)

Increasing number of positive results after biosubstrate injection demonstrates growth of **organohalide respring bacteria** under presence of auxiliary substrate.

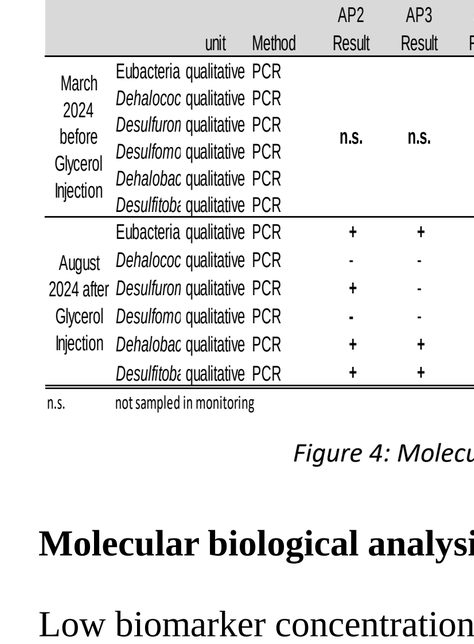

*Figure 5: **Groundwater Sampling Unit** for sampling all piezometers*

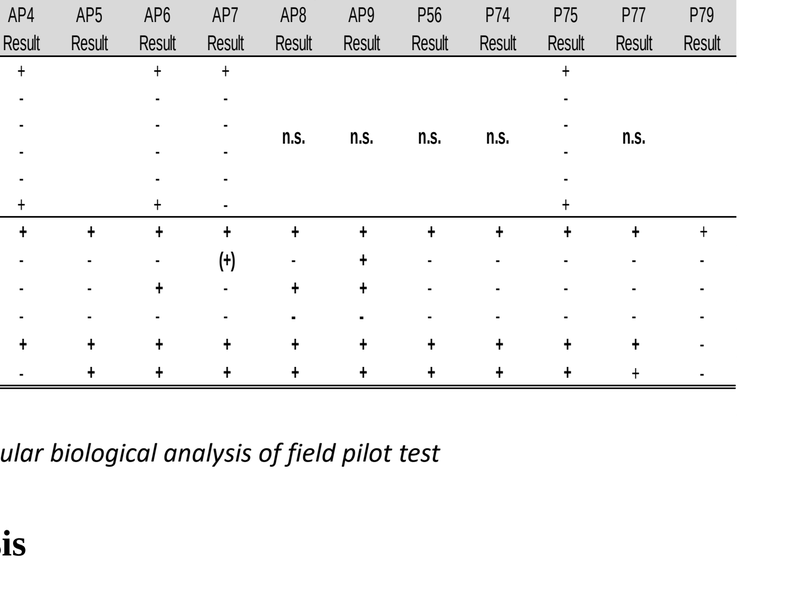

Figure 6: Photon Water Technology team at the pilot site

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