

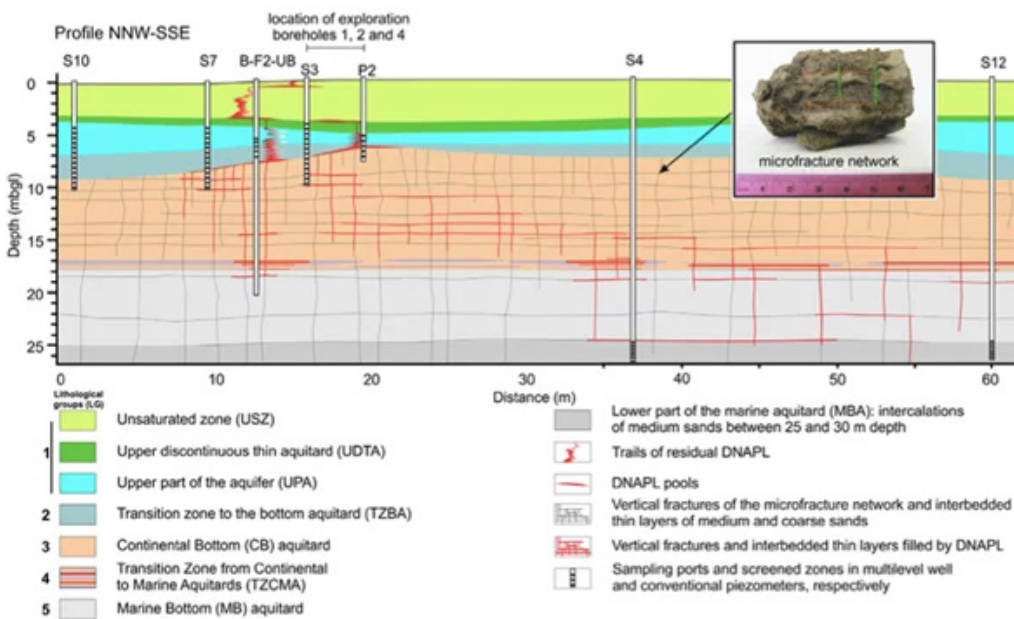
Injection of zerovalent iron (ZVI) in fractured aquitard at greater depth (35 m-bgl)



Context

As part of a study on the degradation of chlorinated solvents conducted by a Catalan university in collaboration with the Catalan Water Agency (ACA), INJECTIS was contacted to perform injections into a fractured and highly compacted marine aquitard, reaching depths of up to 35 meters below ground level.

When aquitards are fractured, pollutants in general and chlorinated solvents in this particular case also spread into these natural fractures, as free phase (Dense Non-Aqueous Phase Liquid; DNAPL) or in dissolved state. As a result, these natural fractures constitute preferential migration pathways of the free and dissolved phase of chlorinated solvents and often lead to contamination of the underlying aquifers.



The aquitard, impacted by PCE, is uniquely affected at great depths (>35 m), as PCE was able to percolate freely vertically through diffusion and gravity, migrating into the microfractures of the highly compacted aquitard.

With such characteristics, few injection techniques can reach these depths while injecting ZVI into a highly impermeable soil. The university extensively characterized the marine aquitard and had a specific request to inject into natural fractures identified at certain depths. Additionally, they aimed to fill these fractures with sand and ZVI to maintain degradative activity (both abiotic and biotic) within them. To achieve this, INJECTIS collaborated in developing the injection protocol and provided its SPIN® technology to take on this university research challenge.

Reaction and reagents

The studies conducted on the site have tested both biotic (Enhanced Reductive dechlorination (ERD) with combined injection of lactic acid) and abiotic (chemical reduction by zerovalent iron; ZVI) degradation processes. Several studies are ongoing to monitor degradation mechanisms, including biological degradation markers such as the presence of specific bacteria (by PCR) as well as isotope analysis.

For the present pilot test, it was decided to inject microscale ZVI along with sand, which serves only as a so-called propant. Since the ZVI contains a low concentration of guar gum, the biological degradation processes are also enhanced in combination with the chemical reduction induced by zerovalent iron.

Geology

The site's geology features a superficial layer of medium sand with slight silt content between 0 and 5 m-bgl, followed by an aquitard approximately 10 meters thick, composed of fine silty sand with both horizontal and vertical fractures. Below this, from around 17-18 meters depth, lies the marine bottom aquitard, which is highly compact and micro-fractured. This structure allowed the slow but deep vertical migration of the PCE contamination, reaching layers at depths exceeding 50 m-bgl.

The SPIN® injection tests with sand and ZVI were planned within this marine bottom aquitard between 24 and 35 m-bgl.

Results

The main goal of this pilot test was to identify an injection technique and protocol capable of reaching 35 meters depth while effectively delivering ZVI into this highly compact soil. Therefore, it has been decided to perform this pilot test with the SPIN® Injection Technology which was the only technique available able to reach these depths in a compacted soil. Three injection points were performed within the source zone. After an initial unsuccessful attempt, which was blocked and obstructed – mainly due to the presence of the coarse sand as propant in the injected solution – it has been decided to remove the sand from the solution. This adjustment facilitated the injection process and prevented precipitation of sand in the injection rods. As a result, the second SPIN® injection reached a depth of 27 m-bgl, while **the third injection successfully reached 35 m-bgl**. The injection was carried out both top-down and bottom-up. A total volume of **2.800 liters was injected** into the fractured zone, with injection volumes per meter depending on the presence of natural fractures, ranging from 50 liters to 440 liters per fracture.

Location:	North Spain
Geology:	Fractured Pliocene marine aquitard (silty sand)
Pollutant(s):	PCE (DNAPL)
Reaction:	In Situ Chemical Reduction (ISCR) + Enhanced Reductive Dechlorination (ERD)
Reagent(s):	microscale ZVI
Application type:	Pilot test
Surface/length:	ND
Number of points:	3
Depth interval:	24,0 – 35,0 m-bgl
Dosage:	300 l/m

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