Effective *In Situ* Treatment of a 1 km PCE Plume in Finland

Successful Demonstration Project Reduces Impacts on Municipal Water Well

Summary

Project Highlights

Problem: A 1 km-long, fast-moving chlorinated solvent plume in Eastern Finland threatens a drinking water supply well

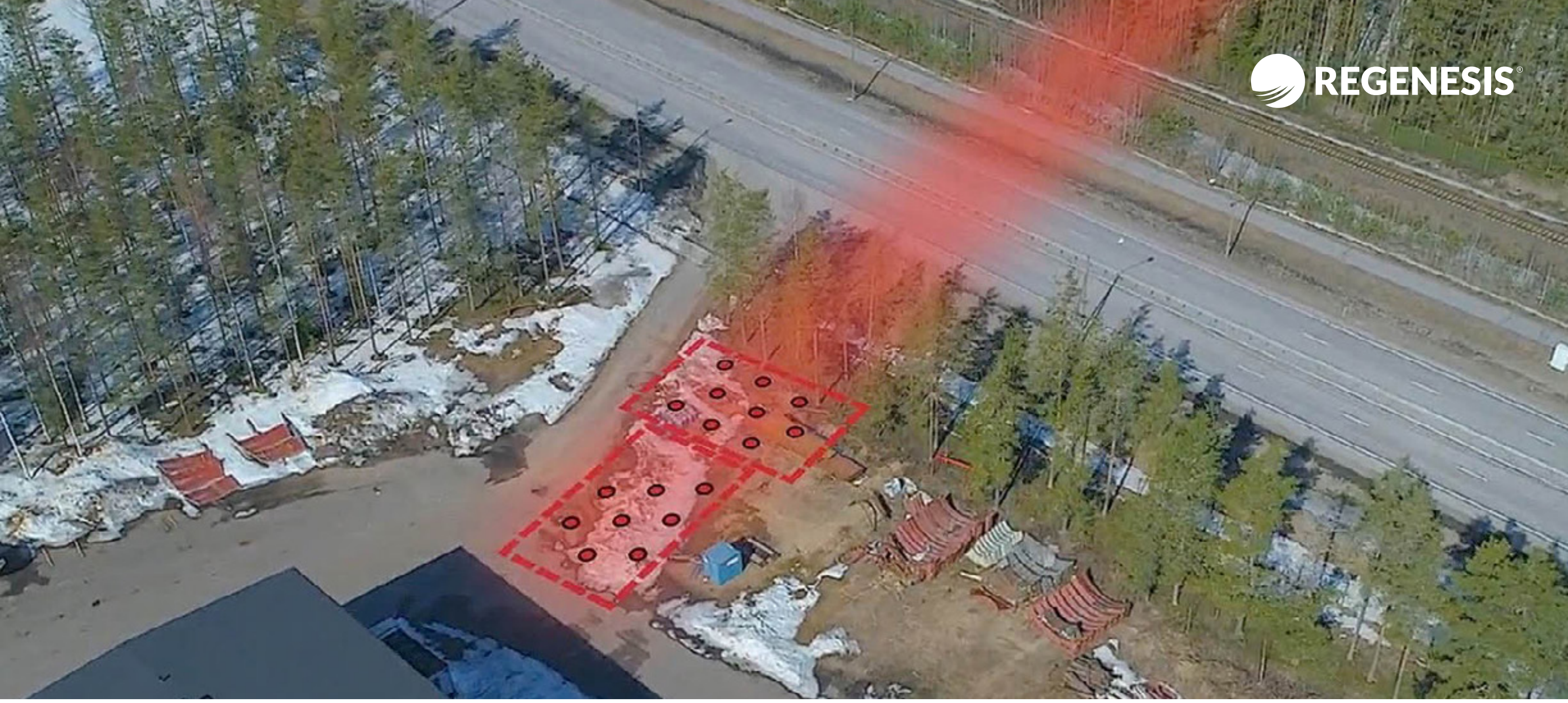
Solution: *In Situ* ERD in source, ERD + Sorption in plume body

Results: PCE concentrations were reduced by 90-95% in the plume and below the drinking water limit at the water supply well, demonstrating the remedy's effectiveness in meeting the site objectives in challenging Finnish conditions.

In Eastern Finland, a fast-moving PCE (perchloroethene) plume beneath a metal-processing facility was remediated to reduce impacts on a municipal drinking water source. The demonstration project achieved PCE concentration reductions of approximately 80% in the plume within months and 90 to 95% by 18 months, ultimately reducing PCE to below the drinking water limit at the municipal water supply well.

The *in situ* remedy applied enhanced reductive dechlorination (ERD) beneath the source area at the industrial building, combined with downgradient plume area treatment comprising ERD plus adsorption, facilitated by PlumeStop®, to form an injectable permeable reactive barrier (IPRB).

The progressive approach uses relatively few injection points to reduce the contaminant flux into the plume and to impede contaminant migration downgradient, resulting in the effective and economical treatment of a 1-km-long chlorinated solvent plume to mitigate the potential exposure risk.

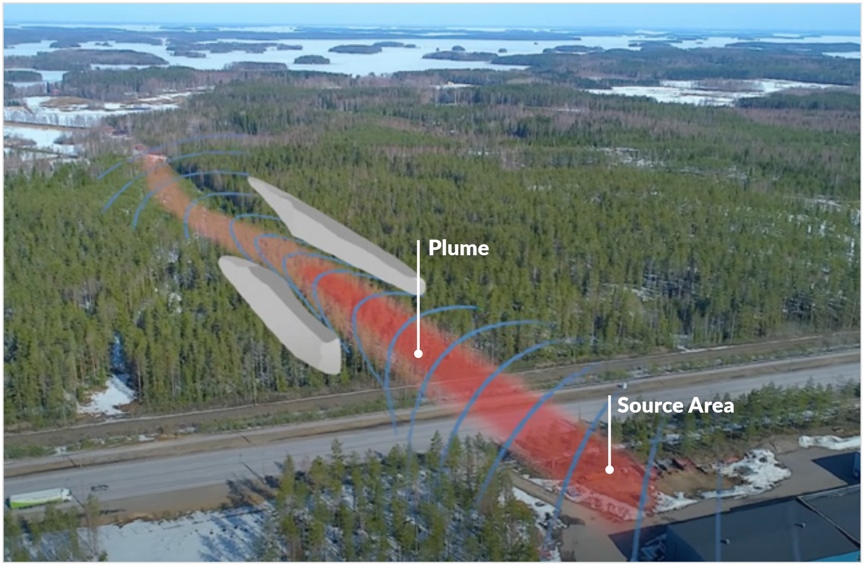


Case History

In Eastern Finland, the groundwater beneath a metal processing industry became contaminated with PCE. Due to an underlying pebble ‘ridge’, the PCE plume migrated rapidly, impacting a municipal drinking water source approximately 1 km downstream. The coarse, permeable materials in the ridge were part of an esker formation, resulting in a long, narrow plume with groundwater velocity estimated at several thousand m per year. Figure 1

Figure 1 PCE Source and Plume Prior to Treatment

Aerial depiction of PCE plume in groundwater emanating from metal processing industry.



Project Site Details

Demonstration Project Site
Metal processing industry in Eastern Finland

Contamination
PCE in groundwater, with concentrations ranging from 250 to 330 µg/L

Geology
Esker formation with high groundwater velocity, estimated at several thousand metres per year

Groundwater Conditions
Aerobic, no PCE daughter products detected, temperatures ranging from 7 to 9° C

Impact
Plume approaching drinking water well 1 km downstream

Objective
Demonstrate effectiveness of *in situ* ERD treatment approach in Finland

This project was one of four governmental demonstration projects to show that *in situ* remediation of chlorinated solvents via ERD could be effective in Finland, where cold groundwater and low organic carbon concentrations, conditions known to reduce the approach's effectiveness, are found in many aquifers.

The *in situ* remediation of chlorinated solvents using electron donors that release hydrogen (e.g., 3-D Microemulsion®) to promote ERD is a well-established method that has proven effective at thousands of sites globally. Still, few *in situ* ERD remedies have been conducted in Finland, partly due to regulator concerns about the approach's effectiveness in cold groundwater conditions. Due to its high-latitude geography, Finland's groundwater temperatures are often in the single-digit Celsius range; at this site, they range from 7 to 9° C.

Although ERD of chlorinated ethenes using electron donors and microbial consortia containing *Dehalococcoides sp.* has been reported with temperatures as low as 4° C, relatively few studies are available.[1,2,3] Therefore, this field demonstration project gives valuable insight into this approach's effectiveness in cold water aquifers like those seen in Finland.

The PCE concentrations before remediation were approximately 250 µg/L in the source area and 330 µg/L in the plume body. Due to the high flow rate, the groundwater in the plume was aerobic, and there were no traces of degradation products. These conditions present further challenges in effectively deploying an ERD treatment strategy.

Remediation

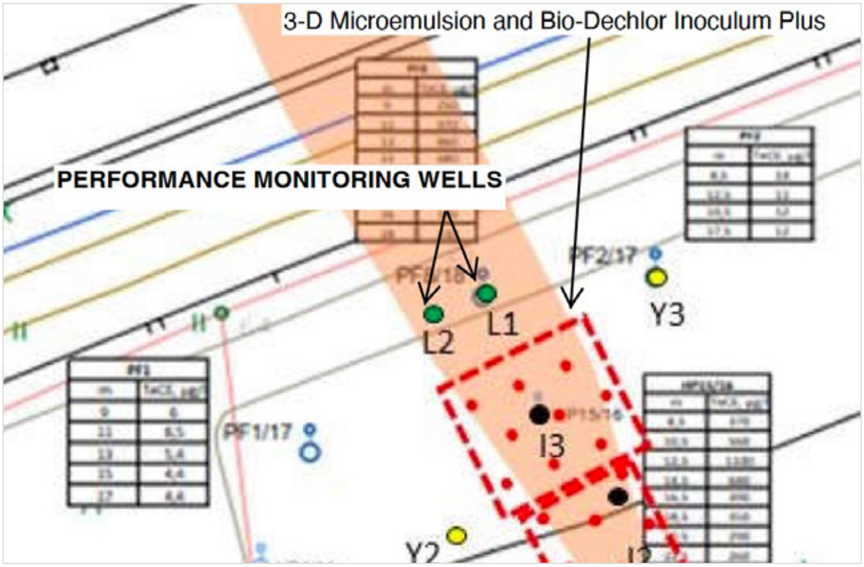
Design

The ERD design strategy used at this site involved injecting 3-D Microemulsion and Bio-Dechlor INOCULUM Plus (BDI)® in the source zone to reduce the PCE influx into the plume Figure 2 and placing a PlumeStop-ERD permeable 'barrier' in the plume, approximately 700 m downgradient, to stop further PCE migration toward the municipal drinking water supply well. Figure 3 Monitoring wells were positioned downgradient of each demonstration area to assess remedial performance.

Figure 2

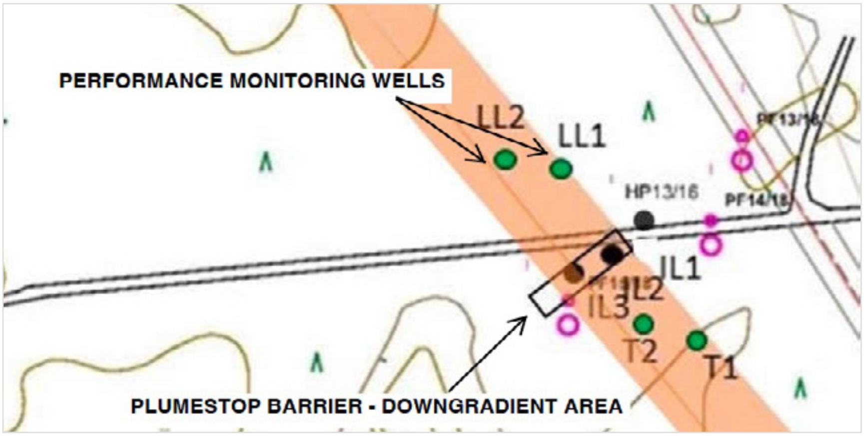
ERD Source Area Treatment

Depiction of ERD treatment in the source area. Injection points are shown by red circles.



REGENESIS, RGS Nordic (now Sortera, i.e., the injection contractor), and Nordic Envicon (i.e., the consultant) collaborated on the remediation design for the integrated source zone/plume barrier treatment strategy, commonly employed to treat long, chlorinated solvent plumes such as at this site.

Figure 3 PlumeStop-ERD Barrier Treatment



Depiction of PlumeStop-ERD barrier treatment in the downgradient plume.

Application Details

Source Area

Treatment Volume	3,500 m³
Injection Depths	7 to 20 m bgl
Products Applied	3-D Microemulsion and BDI Plus

Downgradient Plume Barrier

Treatment Dimensions	6 m wide x 20 m long
Injection depths	13 to 20 m bgl
Products Applied	PlumeStop, HRC/HRC-X

Application

The application was completed in November 2018 in the source area and between the months of April and August 2019 in the downgradient plume area. The climate and remote location presented challenges to the injection program, particularly in the barrier area, where a new access road had to be constructed in a densely forested area during the spring snowmelt.

RGS Nordic completed the injections using a high-powered, direct-push drill rig, successfully achieving the 20 m target injection depth through dense, coarse-grained materials.

Results

Source Area

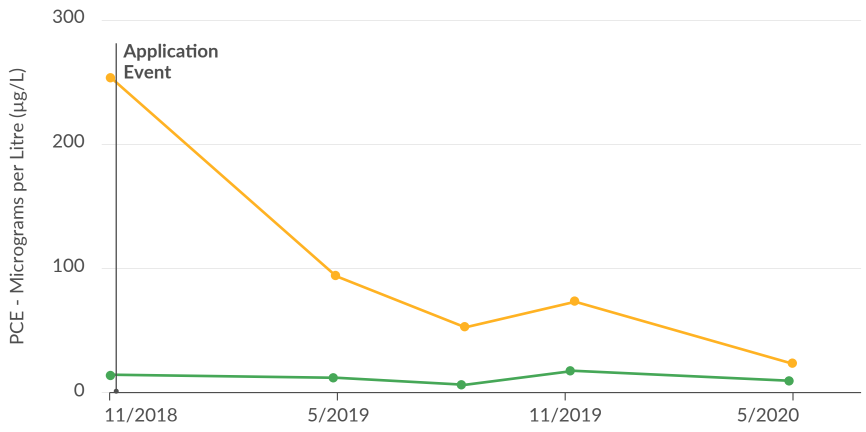
After injection into the source area, the maximum PCE concentration was reduced from approximately 250 µg/L to 50 µg/L (75% reduction) within 6 months. Treatment continued until a 90% reduction was achieved by the end of the 18-month demonstration period. Figure 4 Additionally, ethene was detected, indicating PCE transformation into non-toxic end products through full reductive dechlorination.

Figure 4 PCE Downgradient of Source Area Treatment

PCE concentrations in monitoring wells immediately downgradient of the source area treatment.

L1

L2

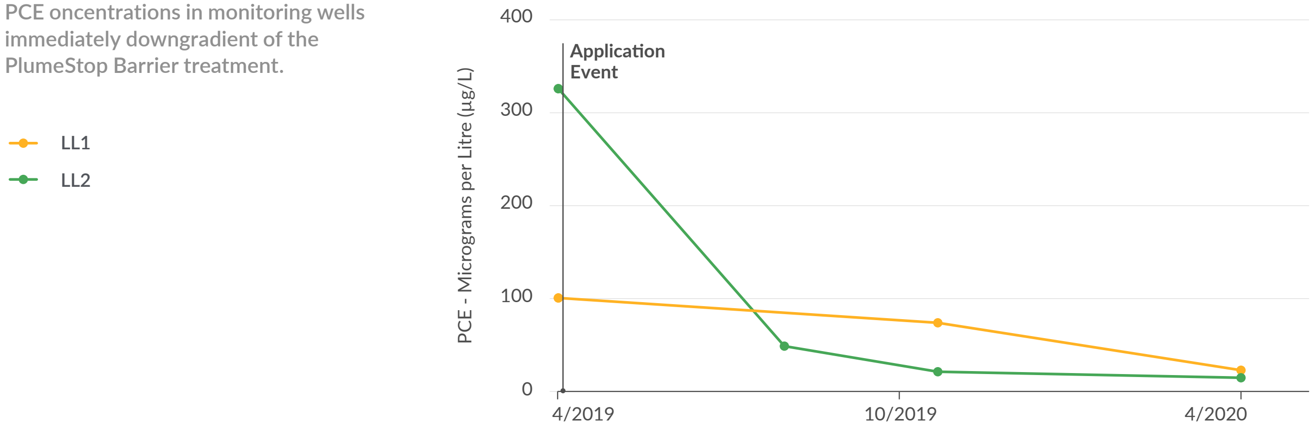


Downgradient Plume Barrier

Following the installation of the PlumeStop-ERD barrier in the downgradient plume area, the maximum PCE concentration was reduced from 325 µg/L to 50 µg/L (85% reduction) within 4 months (i.e., by the first monitoring event). The PCE concentration was reduced by 95% within 18 months. Figure 5

Figure 5 PCE Downgradient of PlumeStop Barrier Treatment

PCE oncentrations in monitoring wells immediately downgradient of the PlumeStop Barrier treatment.



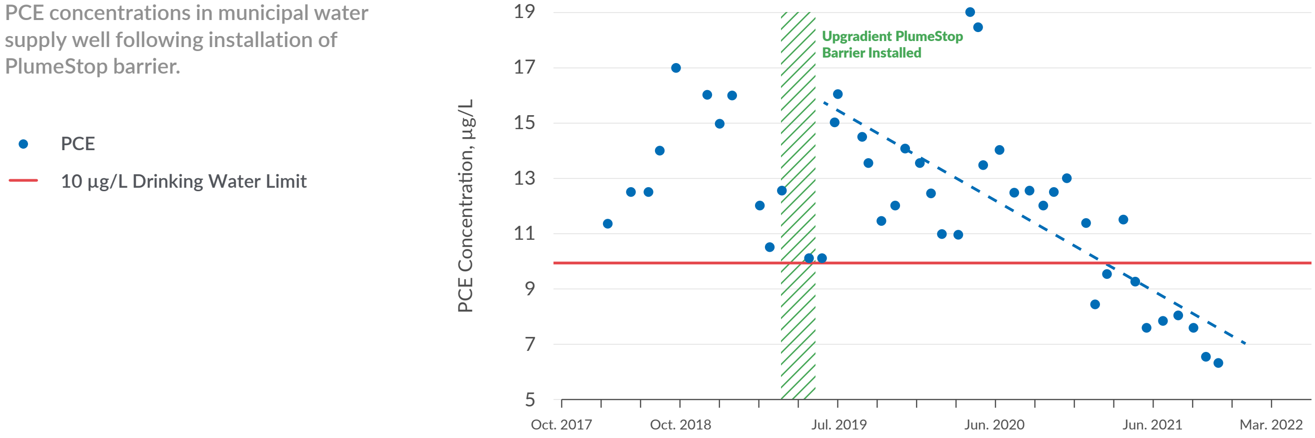
Municipal Water Supply Well

A declining trend in PCE concentrations began at the municipal water supply well shortly after the PlumeStop-ERD barrier was installed. PCE eventually fell below the 10 µg/l drinking water limit as the influence of the source/plume remediation completed upgradient reached the well. Figure 6

Figure 6

PCE in Municipal Water Supply Well

PCE concentrations in municipal water supply well following installation of PlumeStop barrier.



Conclusion

The *in situ* remediation demonstration project completed for the PCE plume in Eastern Finland reveals the following:

- The *in situ* ERD remedy surpassed the project goals, achieving a 90 to 95% reduction in maximum PCE concentrations in both the source area and the downgradient plume, and reducing PCE in the municipal water supply well below the drinking water limit. These results indicate that the ERD approach implemented at this site can be successfully applied in cold groundwater aquifers with low organic carbon content, which are predominant in Finland.
- The integrated source area/PlumeStop-ERD barrier treatment is an effective strategy for treating elongated chlorinated solvent plumes. However, in a typical full-scale design, additional barrier transects would likely be added in a PCE plume of this length (1 km) to achieve even more rapid and pronounced results.
- The detection of ethene indicates that PCE is undergoing a complete microbial transformation in this aerobic, fast-moving, cold-water aquifer. This corroborates laboratory testing results, showing the *Dehalococcoides sp.*-based microbial culture maintains growth in water temperatures as low as 4° C.

References

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2. Vainberg S, Steffan RJ Effect of common site conditions on chlorinated solvent biodegradation by a bioaugmentation consortium. Lawrenceville (GA): RNAS Remediation Products, 2014. http://rnasinc.com/wp-content/uploads/Battelle-poster-2014-CBI_PosterSession_rev-5-rjs.pdf.
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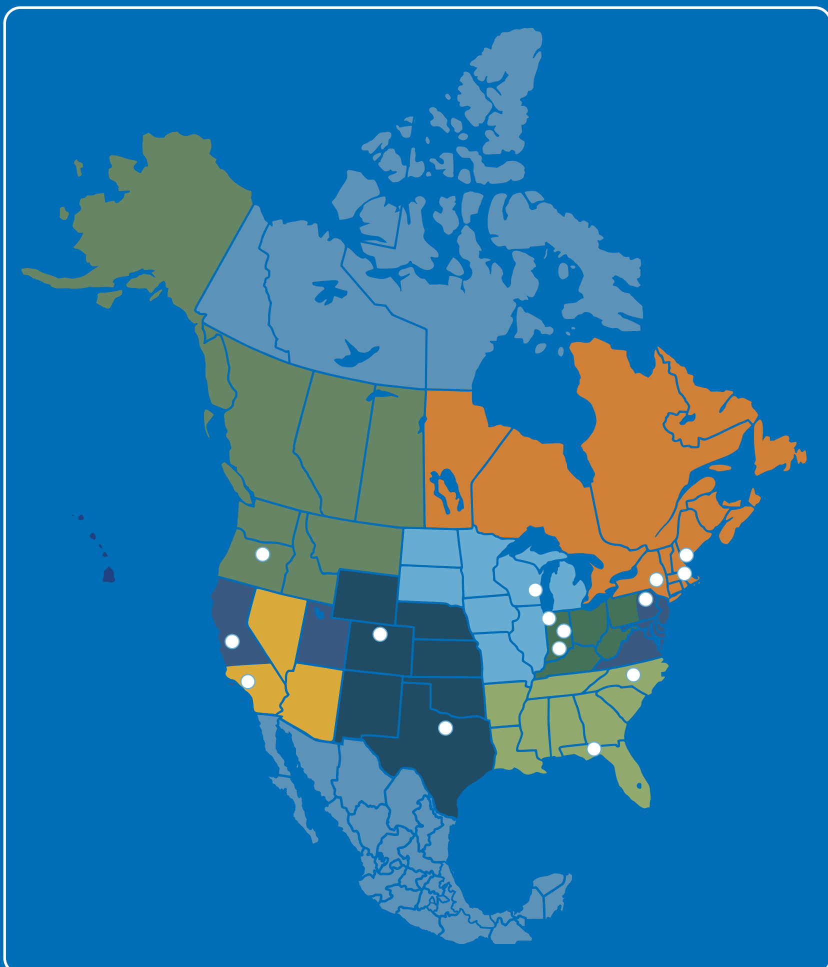

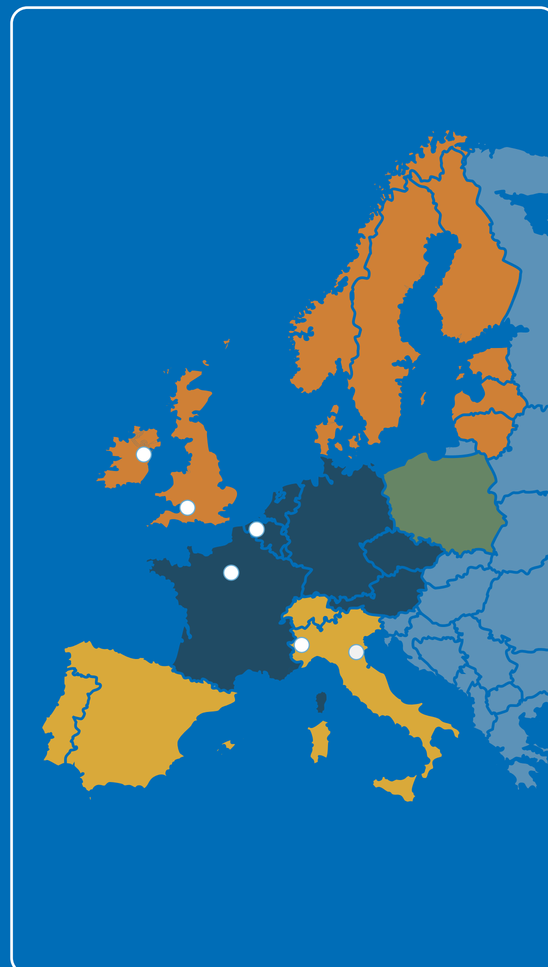

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