CASE STUDY | KLOZUR® CR

APPLICATION OF KLOZUR® CR ACHIEVES TREATMENT GOALS FOR HYDROCARBONS, BTEX, AND MTBE AT A FORMER PETROLEUM STATION IN BOLOGNA, ITALY

SITE OVERVIEW

KLOZUR® CR is a combined remedy treatment technology consisting of KLOZUR® SP (sodium persulfate) and PERMEOX® Ultra (extended-release calcium peroxide). This technology was successfully applied at a site in a densely populated urban area in Bologna, Italy and which was contaminated with various toxic contaminants. The site, a dismantled former petroleum station, was impacted by the storage of fuels which resulted in groundwater contamination including total petroleum hydrocarbons (TPH) (C<12 ~ 2000 micrograms per liter [µg/L]), benzene (~500 µg/L), ethylbenzene (~380 µg/L)and methyl tert-butyl ether (MTBE) (~13000 µg/L).

Two injection events were carried out fifteen (15) months apart with a total of 4800 kg of KLOZUR® CR (25 percent (%) by weight aqueous slurry) applied at the site. Eighteen (18) months following the first application, the concentrations of contaminants had decreased below the remedial goals in all monitoring piezometers in the treatment area. Total petroleum hydrocarbons were reduced by greater than 90%. Monitoring data confirmed that elevated oxidation-reduction potential (ORP) and dissolved oxygen (DO) levels were sustained to support continued enhanced aerobic bioremediation.

SITE INFORMATION

Site Type:	Confidential Former Petroleum Station
Location:	Bologna City Center, Italy
Contaminants:	TPH ~2000 µg/L Benzene ~500 µg/L Ethylbenzene ~380 µg/L MTBE 13000 µg/L
Soils:	Silty sands to silty clays
Application:	Solid slurry injection of Klozur® CR
Results:	Remedial goals obtained for all contaminants TPH > 80% Reduction MTBE > 90% Reduction

THE APPROACH

Monitoring data from 2017 suggested that the total contaminated area of the site was approximately 350 square meters (m^2) (Figure 1). The groundwater at the site was initially observed at a depth of approximately 3.8 meters (m) below ground surface (bgs), flowing in a northerly direction at a low rate of approximately 4 m/year. Treatment with KLOZUR® CR targeted a 5 m vertical interval of saturated contaminated soil, between depths of 4 m and 9 m bgs. The soil consisted of backfill (gravel in a sandy matrix) up to a depth of 3.5 m bgs, below which were found silty sands, sandy loam, and silty clay lenses, with an effective porosity in the saturated zone of 15% and a hydraulic conductivity of about 4 to 10 cm/second.

THE APPROACH CONTINUED

KLOZUR® CR is a combined remedy technology composed of a 50/50 blend of KLOZUR® SP (sodium persulfate) and PERMEOX® Ultra (slow-release calcium peroxide). The KLOZUR® CR technology was selected by the design engineers for groundwater remediation to sequentially promote:

- In situ chemical oxidation (ISCO) via alkaline and hydrogen peroxide activated sodium persulfate
- Enhanced aerobic bioremediation, due to slow-release oxygen in bio-available form (PERMEOX® Ultra)
- Enhanced anaerobic bioremediation (anaerobic oxidation), due to the interaction of sulphate and residual hydrocarbons in groundwater

The remediation goals were calculated through industry standard risk analysis (AdR) corresponding to the site-specific risk threshold concentrations (CSR) (Table 1).

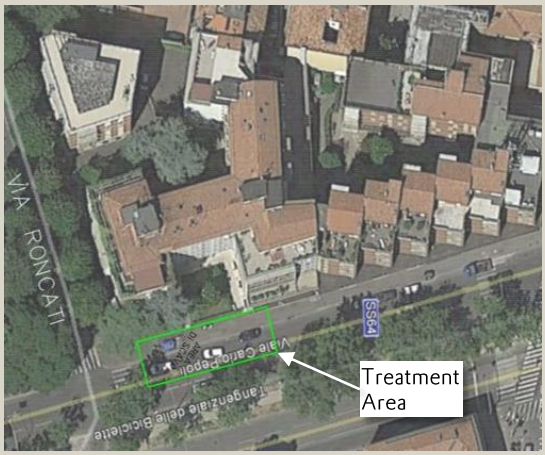

Figure 1 | Site Location

Table 1 | Site-specific risk threshold concentration remediation goals

Contaminant of Concern	Remedial Goals (CSR) (µg/L)
Benzene	18.24
Toluene	6.85
Ethylbenzene	53.04
p-Xylene	2.31
Total Hydrocarbons	350*
MTBE	74.66

*CSR=CSC (Contamination Threshold Concentration D.Lgs. 152/06)

FIELD APPLICATION

Two injection events were carried out in February 2018 and April 2019, with 2380 kg and 2400 kg of KLOZUR® CR used, respectively. The KLOZUR® CR was injected, as a 25% slurry, through 18 injection points (Figure 2) which were distributed with a regular triangular mesh of about 5 m side (sphere of influence ~ 2.5 m) in the region of the source area. The injections targeted the impacted saturated zone from 4 to 9 m bgs. The injections were performed bottom-up using Manchette tubes, with injections every 30 cm increments.

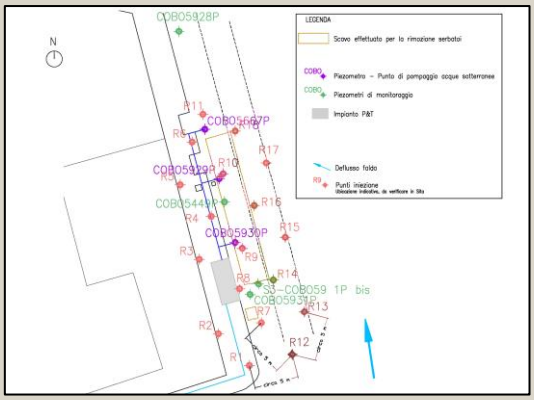

Figure 2 | Grid of the 18 injection points (in red) and 4 monitoring locations (in green) together with the direction of flow S to N

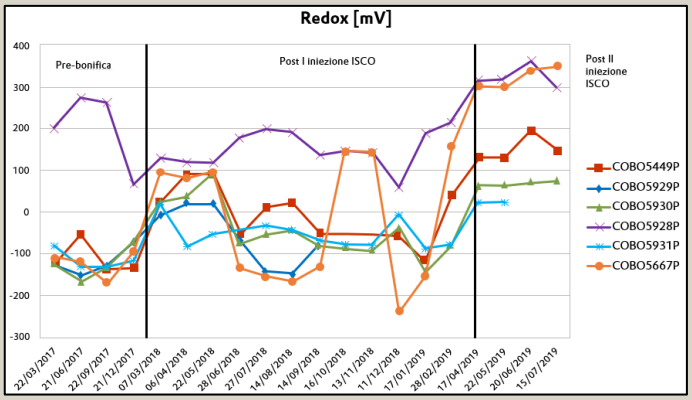

Figure 3 | Redox potential and dissolved oxygen values at monitoring locations before and after KLOZUR® CR treatment

RESULTS

KLOZUR® CR generated oxidative conditions by alkaline activation of the sodium persulfate in the product and sustained conditions supporting aerobic bioremediation. An increase in ORP was observed at all monitoring locations in the treatment area, as well as higher DO concentrations (Figure 3). Most of the pre-application ORP values were about -100 millivolts (mV) and increased up to +100 mV after the first application. Two locations showed an increase in ORP values of greater than +300 mV after the second application of KLOZUR® CR. Similarly, DO concentrations increased from less than 5 mg/L to 45 mg/L after the first application, and three locations exceeded a DO of 30 mg/L after the second application of KLOZUR® CR. This data confirmed that KLOZUR® CR was effective in creating and maintaining conditions necessary to remediate the contaminants found at this site.

Less than 12 months after the initial injections of KLOZUR® CR the site remediation goals were achieved in all monitoring locations present in the treatment area except for benzene levels at one location (piezometer COBO5449). A second application of KLOZUR® CR occurred in April 2019. Six months after the second application, benzene concentrations were below the risk threshold concentrations at all monitoring points present in the treatment area.

Figure 4 shows that less than 18 months after the first injection of KLOZUR® CR, the remediation goals were achieved in all principal monitoring piezometers present in the treatment area without any subsequent rebound of the contamination levels, demonstrating the effective and complete degradation of contaminant mass.

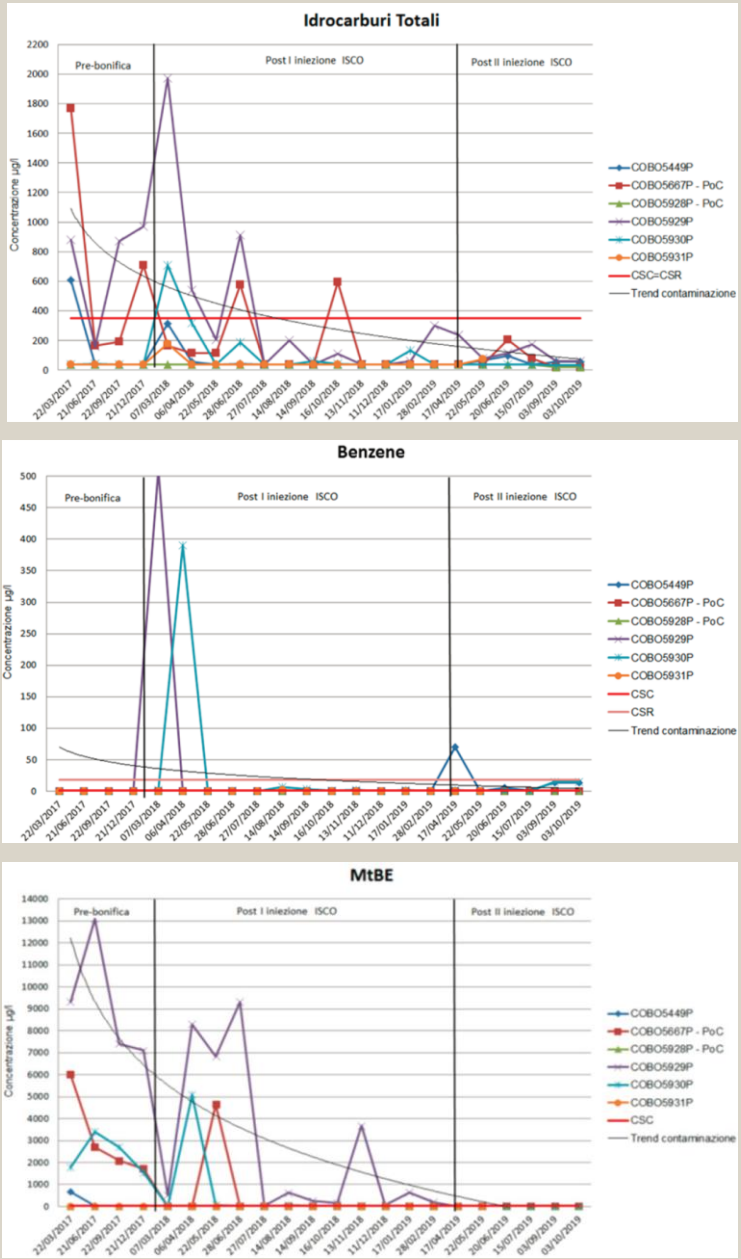

Figure 4 | Total hydrocarbon, benzene, and MTBE concentrations in groundwater before and after KLOZUR® CR treatment

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