



# Advanced *In Situ* Barrier Treatment Secures NFA Status in Italy

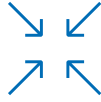
S-MicroZVI and PlumeStop drive multi-year ISCR treatment success, meeting stringent regulatory levels



# Highlights



**Site Type:**  
Green Space - church oratory garden



**Project Driver:**  
Regulatory compliance to achieve NFA status, ensuring community and environmental safety offsite.



**Contaminants:**  
Tetrachloroethene (PCE) - 300 micrograms per litre (µg/L), trichloroethene (TCE) 10 µg/L, and trichloromethane (TCM) 10 µg/L



**Treatment:**  
*In situ* chemical reduction (ISCR) combined with *in situ* sorption (ISS).



**Technologies:**  
PlumeStop and S-MicroZVI

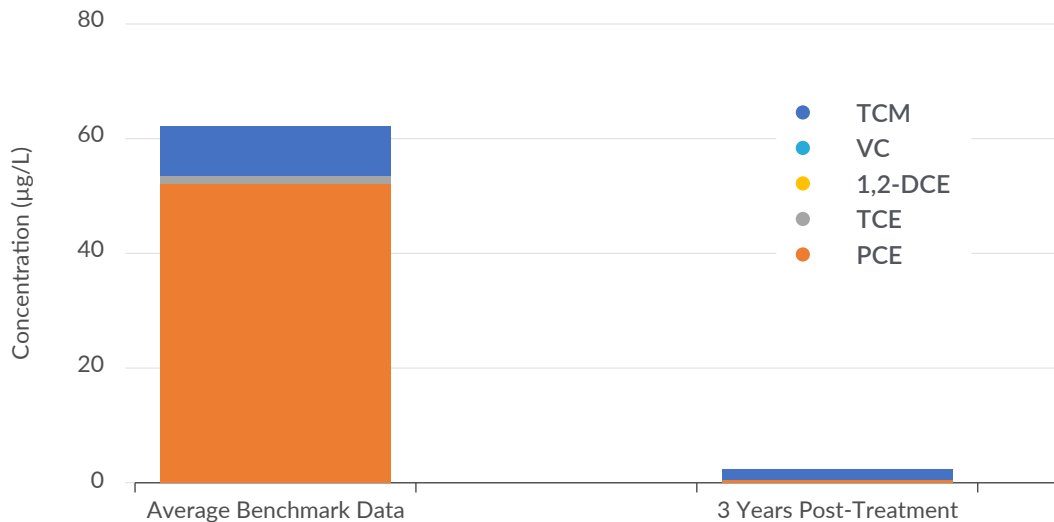


**Geology:**  
Sandy gravel. The remediation area featured a challenging geological setting, with pre-coring required to reach >20m depth through cemented soil.

# Summary

A permeable reactive barrier for *in situ* groundwater plume treatment, implemented in a church oratory garden, has achieved No Further Action (NFA) status as part of a broader initiative to address groundwater contamination from tetrachloroethene (PCE) at a manufacturing plant in Italy. Using a combination of S-MicroZVI® and PlumeStop®, the project successfully reduced PCE concentrations below the target level of 100 µg/L, with consistent results observed over multiple years of bi-monthly monitoring.

## PC17 - Average Well Concentrations Before & 3 Years After Treatment





## Background

In a major Italian city, a manufacturing facility has been the source of a widespread tetrachloroethene (PCE) plume affecting the underlying aquifer. The highly aerobic conditions of the aquifer have hindered natural attenuation, leading to an absence of detectable daughter products over many years.

TAUW, a leading environmental multinational consulting firm, had already established hydraulic containment within the factory grounds, as mandated by law. Nonetheless, the persistent plume extended beyond the site boundary, spread across a densely populated residential area with limited access. To address this challenge, a comprehensive Master Plan was developed by Tauw in collaboration with the University La Sapienza of Rome and local authorities, to install a network of barriers throughout the city, aimed at reducing plume concentrations effectively. The PRB discussed in this case study is located in a church oratory garden, and forms part of the broader strategy to remediate the persistent and extensive PCE plume.

S-MicroZVI and PlumeStop were applied as a permeable reactive barrier (PRB) to facilitate *In Situ* Chemical Reduction (ISCR) and *In Situ* Sorption (ISS). The simultaneous application of these technologies was designed to rapidly remove contaminants from the groundwater and to ensure they are fully degraded with minimal daughter product generation.

## Remedial Approach

The PRB was configured using PlumeStop colloidal activated carbon and S-MicroZVI colloidal sulfidated zero-valent iron. These colloidal technologies are characterized by their low viscosities, allowing them to be co-applied into the subsurface under low pressure. This method ensures a uniform distribution of the amendments within the flux zones where contamination migrates, thereby enhancing the efficacy of remedial performance.

### PlumeStop-Enhanced ISCR: Advanced Barriers for Long-Term Chlorinated Solvent Plume Treatment

PlumeStop and S-MicroZVI are micron-scale, colloidal liquid amendments that are co-injected into PRBs, resulting in a synergistic sorption-enhanced ISCR process that rapidly eliminates chlorinated solvents like PCE and TCE. These amendments combine PlumeStop's high adsorption efficiency with S-MicroZVI's unique sulfidation chemistry to create self-regenerating *in situ* PRBs that stop contaminant movement over the long term.





## Mechanism of Action:

**Adsorption:** PlumeStop's <2-micron-size activated carbon particles coat the aquifer matrix, create an extensive carbon filter that immediately begins halting contaminant flow upon injection.

**Transformation:** S-MicroZVI's <4-micron-size, sulfidated ZVI particles have 30x the reactivity compared to commodity ZVI, quickly transforming the adsorbed contaminants into non-toxic compounds such as ethene and ethane.

**Regeneration:** With terminal byproducts (such as ethene and ethane) that are minimally sorptive, adsorption sites are cleared and regenerated continuously, sustaining the ISCR process.

This PlumeStop-enhanced ISCR process outperforms traditional barrier methods by preventing treatment gaps and avoiding the production of harmful byproducts like vinyl chloride. PlumeStop's and S-MicroZVI's engineered properties ensure complete ISCR treatment of contaminants, reduce the frequency of re-injections, and decrease life cycle costs for PRB remediation approaches.

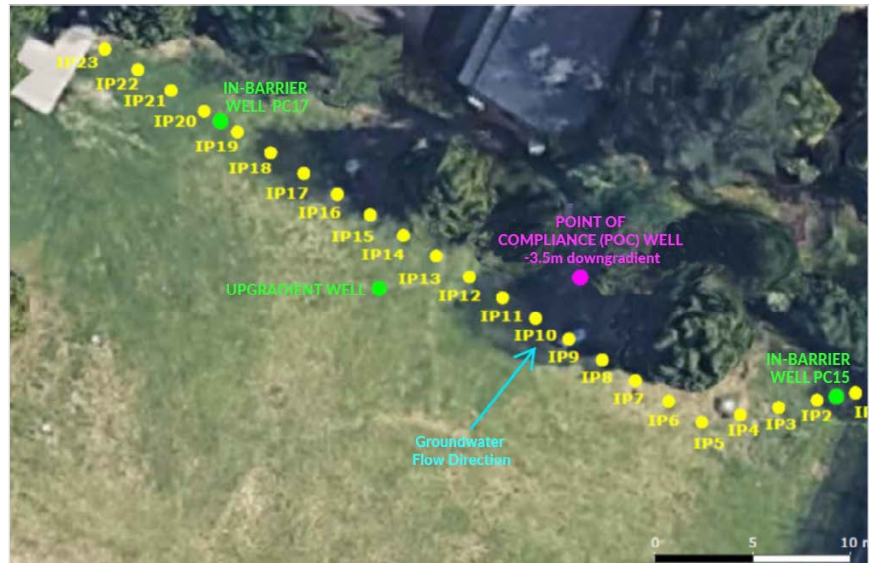
## Application

REGENESIS Remediation Services installed the PRB within the green area of a church oratory over an eight-day period. The application, designed to minimise communal disruption, was executed in a single mobilisation using direct-push injection technology. The 46-meter-length ISCR-ISS barrier was constructed via 23 direct push injection points spaced 2 meters apart. S-MicroZVI and PlumeStop were mixed and co-applied into each point.

**Figure 1**

Aerial plan view showing the injection points that form the PRB and the monitoring wells. Image modified from TAUW.

### Aerial Plan View



### Pre-Coring for Deep Injection

The vertical treatment zone encompassed a thin (approx. 1 m) aquifer at a depth of 24 m below cemented soil. Due to these conditions, conventional direct push techniques were insufficient. To overcome this, a standard rig with a 101 mm diameter was used for pre-coring. The coring holes were then backfilled, cement was used in the unsaturated zones, and sand in the areas designated for injection. Following this preparation, the direct push (DP) rig successfully penetrated through the cement to carry out the injection process.



## Testing and Verification

Low-pressure injection techniques (<2 bar) were employed to suit the site’s challenging geology, facilitating the substrates’ integration into the flux zones. The suitability of these conditions was confirmed through design verification testing, which helped optimize the pressure and volume settings for the injections.

Injection confirmation testing was conducted to verify the interlocking radii of influence, ensuring the barrier’s integrity and effectiveness over its entire length.

## Application Details

|                    |  |
|--------------------|--|
| Injection Points   | 23   |
| Spacing            | 2 meters   |
| Injection Depth    | ±23.8 m to 24.8 m based on pre-coring findings, adjusted onsite according to the specific saturated layers encountered at each injection point.                |
| Products Injected  | PlumeStop and S-MicroZVI with point-by-point dosages tailored to the local geology, thickness of treatment interval and contamination levels                   |
| S-MicroZVI         | 39 kg to 80 kg per point   |
| PlumeStop          | 52 to 100 kg per point   |
| Injection Duration | 8 working days   |
| Injection Volume   | Approximately 620 L/point, with adjustments made up to 1200 L/pt where necessary to ensure thorough substrate penetration and effective contaminant treatment. |

## Results

The injected barrier has demonstrated remarkable efficacy in contaminant management, achieving and sustaining regulatory compliance over an extended period. The following are the key outcomes:

**PCE Reduction:** The barrier rapidly lowered PCE concentrations in the downgradient compliance well to consistently below the regulatory target of 100 µg/L, reducing baseline concentrations by 2 orders of magnitude.

Reductions to non-detect were achieved immediately after application, however these reverted to a steady reduction of '96%', well below the target concentrations and showing that full degradation was occurring.

**Sustained Results:** These concentrations were maintained below threshold levels throughout three years of post-application monitoring.

**Absence of Daughter Products:** No reductive dechlorination daughter products, such as cis-DCE and VC, were detected, underscoring the synergistic effects of sorption and chemical reduction.

**TCM Reduction:** Trichloromethane levels were also reduced following the barrier application.

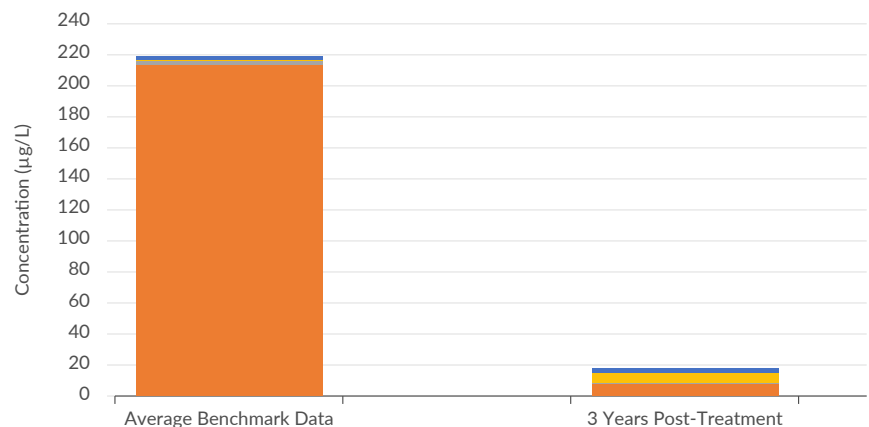
**NFA Status Granted:** The successful outcomes led the local regulatory authority to grant No Further Action (NFA) status, validating the effectiveness of the ISCR-ISS approach.

**Figure 2**

**POC Well - Average Concentrations Before & After**

TCM and chlorinated ethenes concentrations at POC well before and after S-MicroZVI and PlumeStop application.

- TCM
- VC
- 1,2-DCE
- TCE
- PCE



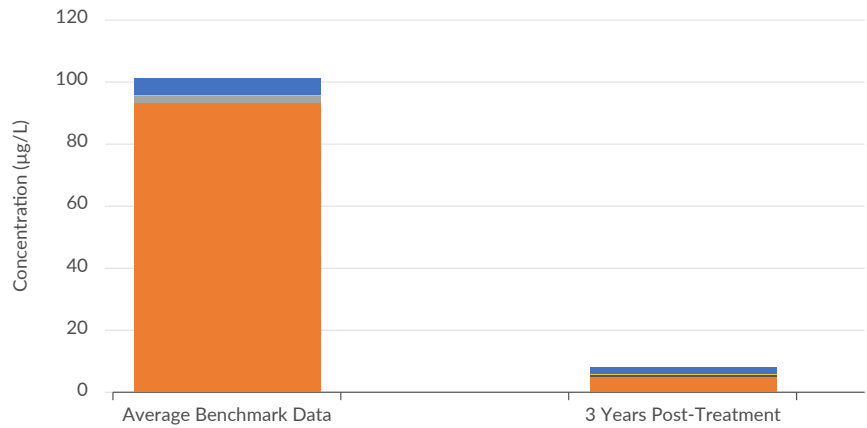


**Figure 3**

**PC15 - Average Well Concentrations Before & After**

TCM and chlorinated ethenes concentrations within in-barrier well PC15 following S-MicroZVI and PlumeStop application.

- TCM
- VC
- 1,2-DCE
- TCE
- PCE

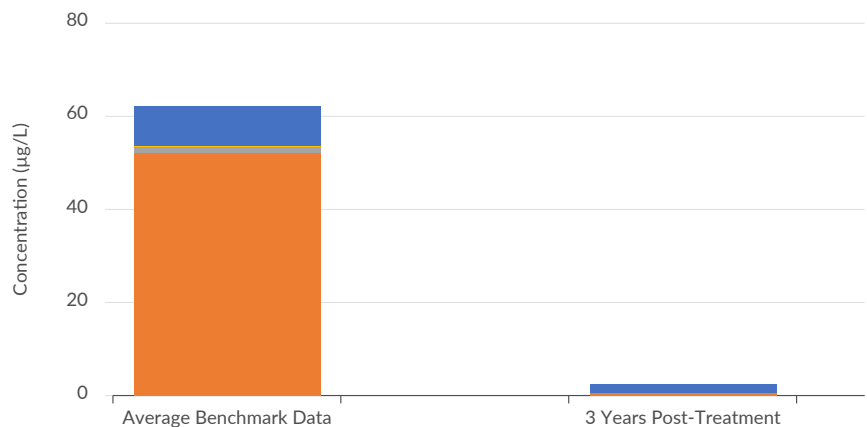


**Figure 4**

**PC17 - Average Well Concentrations Before & After**

TCM and chlorinated ethenes concentrations within in-barrier well PC17 following S-MicroZVI and PlumeStop application.

- TCM
- VC
- 1,2-DCE
- TCE
- PCE



## Conclusion

This precisely managed application of S-MicroZVI and PlumeStop, conducted by TAUW and REGENESIS, rapidly met and maintained regulatory standards, whilst effectively minimising disruptions to the church oratory’s daily operations. The *in situ* barrier operates without the need for power or maintenance and, owing to its self-regenerative capabilities, is expected to continue treating the chlorinated solvent plume for years following this single application.



## About the Consultant

TAUW is a European consultancy and engineering firm with a strong position in environmental advice and the sustainable development of the living environment. From offices in the Netherlands, Belgium, Germany, France, Spain and Italy, more than 1,200 dedicated employees work on a beautiful, clean, safe and sustainable living environment.

TAUW Italia has been active since 1990 acting as reference point for industrial clients, real estate developers and investment funds. With 2 offices, in Milan and Pisa, TAUW Italia is specialised in the design and operation management of remediation projects and site redevelopment, permitting, auditing and compliance management.

## Project Contacts

### TAUW Italia S.r.l

#### Christian Nielsen

Senior Project Manager

Piazza Leonardo da Vinci 7 - 20133 Milano - Italy

[c.nielsen@tauw.com](mailto:c.nielsen@tauw.com)

+39 335 5209504

[www.tauw.it](http://www.tauw.it)

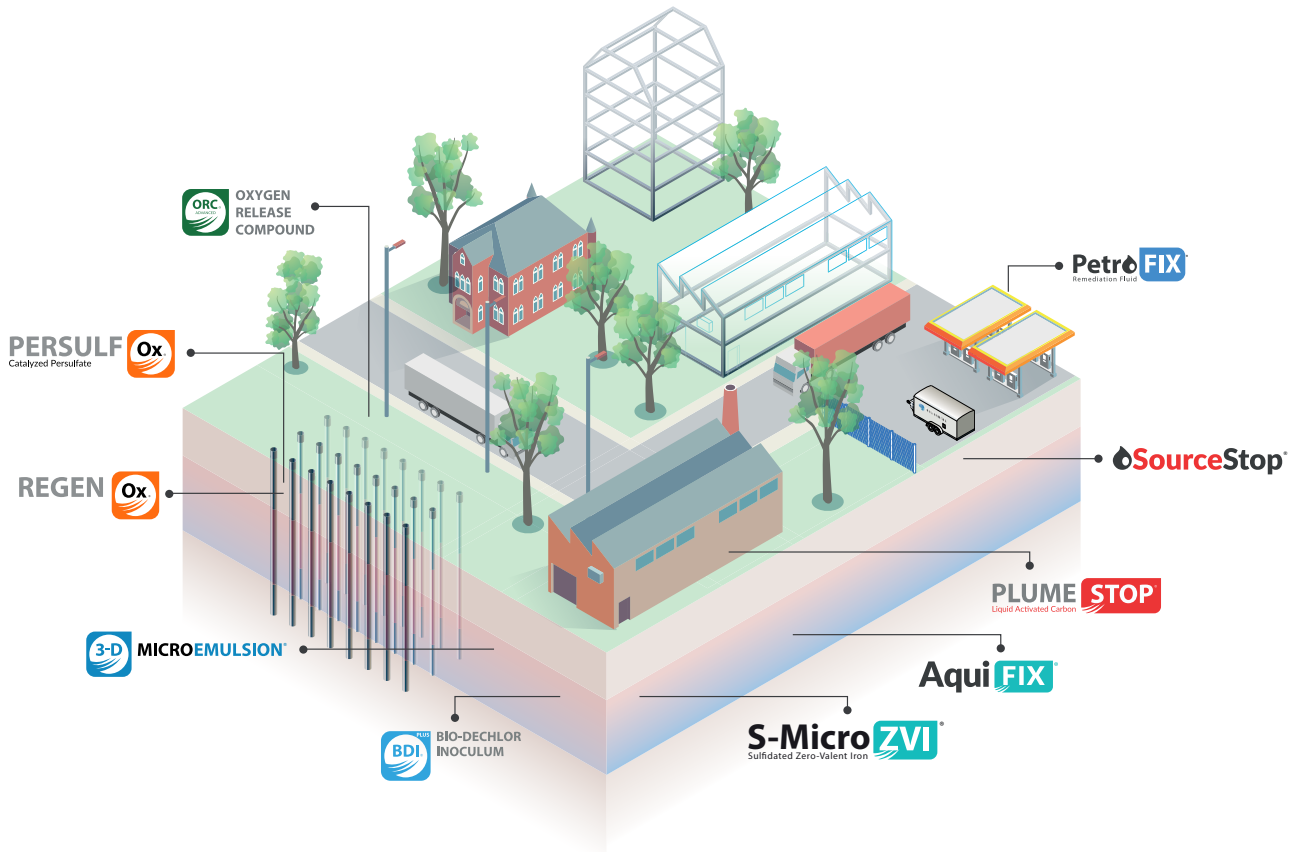
[www.tauw.com](http://www.tauw.com)

### Università La Sapienza di Roma

#### Prof. Marco Petrangeli Papini

Project Coordinator

[marco.petrangelipapini@uniroma1.it](mailto:marco.petrangelipapini@uniroma1.it)



**PlumeStop®** Liquid Activated Carbon™ is composed of very fine (1-2 micron-size) activated particles suspended in water through a unique, organic polymeric dispersion chemistry that resists clumping and allows permeation through aquifer materials. PlumeStop sorbs to the aquifer matrix soon after injection, rapidly removing contaminants from the groundwater to eliminate risk. It can be co-applied with electron donors, electron acceptors, or used as a stand-alone amendment to treat most organic groundwater contaminants.

**SourceStop®** prevents leaching of PFAS from soils and halts further migration in groundwater to eliminate the risk to downgradient receptors. Available in Liquid and Solid formulations, SourceStop's colloidal activated carbon (CAC) technology provides unsurpassed distribution, penetrating and permanently coating impacted soils. Engineered for easy application, rapid results and long-term treatment, SourceStop is an adaptable and affordable solution for PFAS sites.

**PetroFix®** is a colloidal activated carbon technology used to remediate total petroleum hydrocarbons (TPHs) from contaminated environments. Petrofix uses a proprietary formula of activated carbon to adsorb total petroleum hydrocarbons. It then adds electron acceptors to stimulate hydrocarbon biodegradation.

**RegenOx®** is an *in situ* chemical oxidation (ISCO) reagent used to directly oxidize contaminants. Its unique catalytic component generates a range of highly oxidizing free radicals that rapidly and effectively destroy a range of target contaminants including both petroleum hydrocarbons and chlorinated compounds. RegenOx is an injectable, two-part ISCO reagent combining a solid sodium percarbonate based alkaline oxidant (Part A), with a liquid mixture of sodium silicates, silica gel and ferrous sulfate (Part B), resulting in a powerful contaminant destroying technology.

**PersulfOx®** is an advanced *in situ* chemical oxidation (ISCO) reagent that destroys organic contaminants found in groundwater and soil through abiotic chemical oxidation reactions. It is an all-in-one product with a built-in catalyst which activates the sodium persulfate component and generates contaminant-destroying free radicals without the costly and potentially hazardous addition of a separate activator.

**ORC Advanced®** is an engineered, oxygen-release compound developed for enhanced, *in situ* aerobic bioremediation of petroleum hydrocarbon contaminants in groundwater and saturated soils. Containing 17% by weight molecular oxygen, ORC Advanced provides a controlled release of molecular oxygen—an electron acceptor that optimizes microbial utilization in a treatment zone for up to 12 months post-application.

**3-D Microemulsion®** is an easy-to-apply remedial amendment for the *in situ* treatment of chlorinated solvent-contaminated aquifers. The patented technology, applied as a micellar suspension, provides a controlled, self-distributing hydrogen source to facilitate biologically mediated enhanced reductive dechlorination. 3-D Microemulsion's unique chemistry enables its distribution by naturally flowing groundwater while persisting for years after injection, resulting in much greater treatment coverage and faster degradation rates than other electron donor amendments.

**Aquifix™** is a solid, colloidal remediation amendment for the *in situ* treatment of chlorinated solvent-contaminated aquifers, designed for direct mixing and co-application with PlumeStop. The novel formulation, patent-pending, includes a nutrient-enriched, solid-phase, fatty acid source that quickly establishes and sustains enhanced reductive dechlorination over long timeframes (e.g., ten years post-injection). Aquifix's optimized hydrogen release profile significantly improves remediation efficacy and reduces life-cycle costs to treat these contaminants.

**BDI PLUS®** (Bio-Dechlor INOCULUM Plus) is an enriched natural consortium containing *Dehalococcoides sp.* and other dechlorinating microbes for biologically augmenting enhanced reductive dechlorination remedies. Co-applied with electron donor amendments such as 3-D Microemulsion and Aquifix, BDI PLUS has proven to improve chlorinated solvent remediation efficiency.

**S-MicroZVI®** is a colloidal suspension of sulfidated zero-valent iron that promotes the destruction of a wide range of organic pollutants including chlorinated solvents, pesticides, haloalkanes and energetics. S-MicroZVI is engineered to promote rapid contamination degradation through multiple pathways which leads to faster cleanup while minimizing daughter product formation. Compared to larger particle size ZVI products, S-MicroZVI's 2-3 micron-sized particles, suspended in a proprietary polymer, make it easy to handle and simple to inject, leading to significantly better reagent distribution.



## Global Headquarters

Email: [info@REGENESIS.com](mailto:info@REGENESIS.com)

1011 Calle Sombra  
San Clemente, CA 92673 USA

Ph: (949) 366-8000  
Fax: (949) 366-8090

## Europe

Email: [europe@REGENESIS.com](mailto:europe@REGENESIS.com)

Bath, United Kingdom  
Ph: +44 (0) 1225 61 81 61

Dublin, Ireland  
Ph: +353 (0) 1 853 7384

Torino, Italia  
Ph: +39 338 8717925

leper, België  
Ph: +32 (0) 57 35 97 28