# COUPLING IN SITU CHEMICAL OXIDATION/REDUCTION (ISCO/ISCR) WITH BIOREMEDIATION FOR SUSTAINABLE SITE REMEDIATION

Lorenzo Sacchetti

Technical Manager Europe, Middle East and Africa
Carus Europe USA - SPAIN, lorenzo.sacchetti@caruscorporation.com

## ABSTRACT

In the field of remediation it has also become more common to combine two complimentary remediation technologies to present the best technical and economic approach to a given site. This article will examine the use of In Situ Chemical Oxidation (ISCO) utilising RemOx® L ISCO Reagent (sodium permanganate) for source area treatment used in combination with biostimulation for enhanced reductive dechlorination utilizing CAP18 ME® Anaerobic Bioremediation Product for polishing of the source area and treatment of the lower concentration downgradient plume at an industrial dry cleaning facility. The site is a closed industrial dry cleaning facility that is surrounded by both commercial and residential areas. Over the course of the facilities operation, the soil and groundwater at the site became contaminated with tetrachloroethylene (PCE) and trichloroethylene (TCE) which are common chlorinated dry cleaning agents.

**Keywords**: CARUS, RemOx®, ISCO, permanganate, CAP 18, CAPISCO, reductive dechlorination, full scale, bioremediation, anaerobic, sustainable, remediation.

## 1. INTRODUCTION

There are times where the use of two complimentary items produce solutions or situations where the sum of these products is greater than the individual products alone. Wine and cheese, tea and crumpets, Ferrari's and the Autobahn are a few of these combinations that come readily to mind. In the field of remediation it has also become more common to combine two complimentary remediation technologies to present the best technical and economic approach to a given site. This article will examine the use of In Situ Chemical Oxidation (ISCO) utilising RemOx® L ISCO Reagent (sodium permanganate) for source area treatment used in combination with biostimulation for enhanced reductive dechlorination utilizing CAP18 ME® Anaerobic Bioremediation Product for polishing of the source area and treatment of the lower concentration downgradient plume at an industrial dry cleaning facility.

The site is a closed industrial dry cleaning facility that is surrounded by both commercial and residential areas. Over the course of the facilities operation, the soil and groundwater at the site became contaminated with tetrachloroethylene (PCE) and trichloroethylene (TCE) which are common chlorinated dry cleaning agents. A remedial investigation and feasibility study (RIFS) was undertaken at the site and three or four remedial options were

chosen. Two of these options were ISCO with RemOx® L sodium permanganate and bioremediation with a carbon substrate to provide a hydrogen food source for the natural microbes that can degrade the chlorinated compounds to minerals over time. An ISCO pilot test with RemOx® L sodium permanganate was performed and a pilot test with the injection of molasses was also performed and the results were studied.

When reviewing the results of the pilot tests it was determined that the ISCO with RemOx® L would be the best approach to treat the high concentration of contaminants in the source area but that the remainder of the plume should be treated with a biostimulant to provide a better technical approach to the lower concentration downgradient plume. Based on the initial results of a molasses pilot which showed that the injected carbon source disappeared fairly quickly, it was decided to use another product to provide a longer term carbon source. CAP18 ME®, which has demonstrated the ability to provide a long term carbon source for over three years at several sites was chosen as the carbon source for the full scale remediation.

When considering the use of ISCO at a site, there is a very important test that needs to be performed to help the environmental engineer determine the volume of oxidant that is required to be injected. This test is called an oxidant demand test. This test will calculate the volume of natural organics and transition metals that need to be taken into account to accurately calculate the volume of oxidant needed to treat the site with ISCO.

ERT, a Belgian based remediation contractor, planned and performed that pilot tests and implemented the full scale remediation project at this site. Their name for combining ISCO with bioremediation with CAP18 is called the CAPISCO™ process.

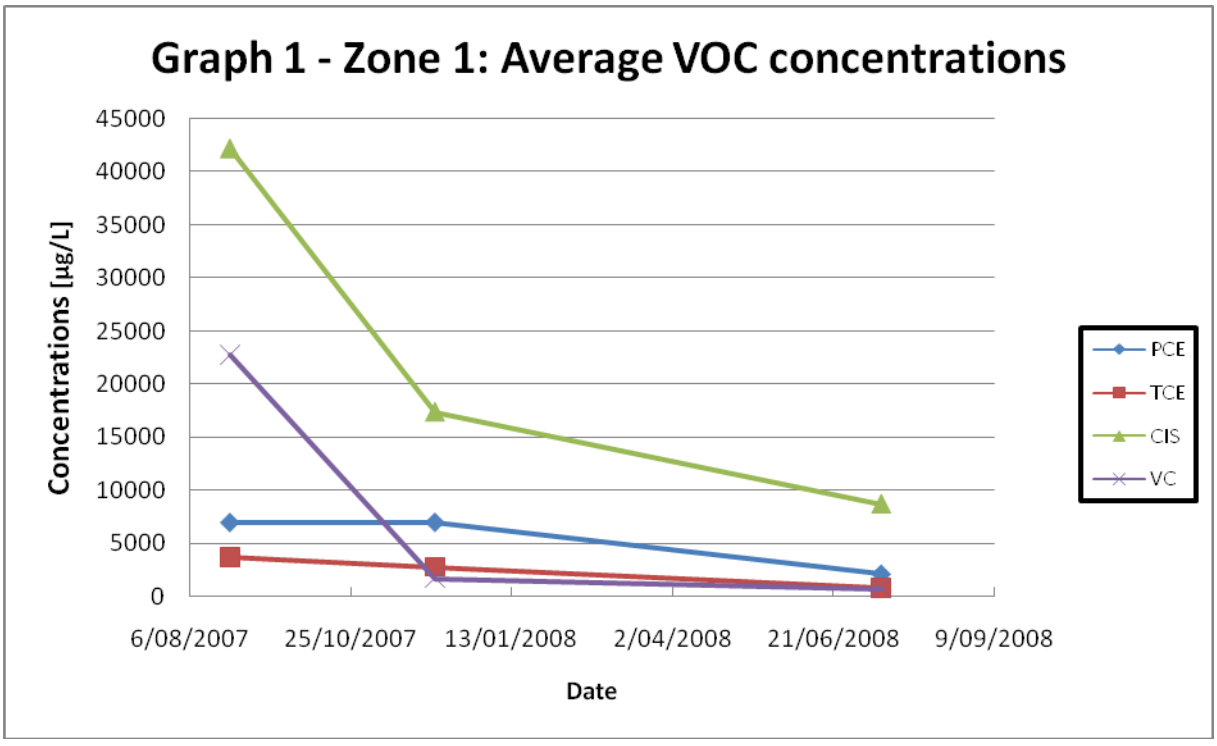
Prior to the full scale implementation of the combined ISCO and bioremediation project, an oxidant demand test was performed by ERT and these results were compared to pilot test results of ISCO with RemOx® L sodium permanganate and CAP18® pilot to create the full scale plan, the site implemented the CAPISCO™ process. This process was developed to remove chlorinated solvents economically and accurately. In this CAPISCO™ project the source (*'Zone 1'*) was initially treated with RemOx® L sodium permanganate and was subsequently treated with CAP18-ME® in order to achieve the required target values. The *'Zones 2&3'*, which contain dissolved volatile organic contaminants (VOC's) that can be treated anaerobic via biological stimulation, and the downstream plume *'Zone 4'* are treated with CAP18® and CAP18 ME® Anaerobic Bioremediation Product. The results of the baseline monitoring and the results after circa one year of treatment are given below. The depth to be treated is between 1 and 3 m bgl; below this level an impermeable clay layer is present.

## 2. Zone 1: NaMnO4 injections

In August 2007 the first series of RemOx® L ISCO Reagent (sodium permanganate) injections by ERT were made in which a total of 6.800 kg of 40% RemOx® L sodium permanganate in a diluted concentration was injected via approximately 50 'direct push' injection points. After the first injection the

PCE and TCE concentrations dropped in some wells but not sufficiently in all of the wells. For this reason a second series of RemOx® L sodium permanganate injections were made in March 2008 in which 5.440 kg of 40% RemOx® L sodium permanganate was again distributed in a diluted concentration into about 100 'direct push' injection points.

After the first series of injections (*Graph 1*) a clear decrease in Dichloethylene (DCE) and vinyl chloride (VC) concentrations was observed but some of the TCE and PCE concentrations appeared unchanged. After the second round of permanganate injections there was again an obvious decrease of CIS and VC but also a clear drop of PCE and TCE concentrations. These new lower levels were acceptably low enough to commencement of an after-treatment with CAP18-ME® in the source area to polish the source area with bioremediation. These CAP18-ME® injections were made in October 2008. In total 2.720 kg of CAP18-ME® (=3 IBCs) were injected into approximatly 75 direct push injection points.

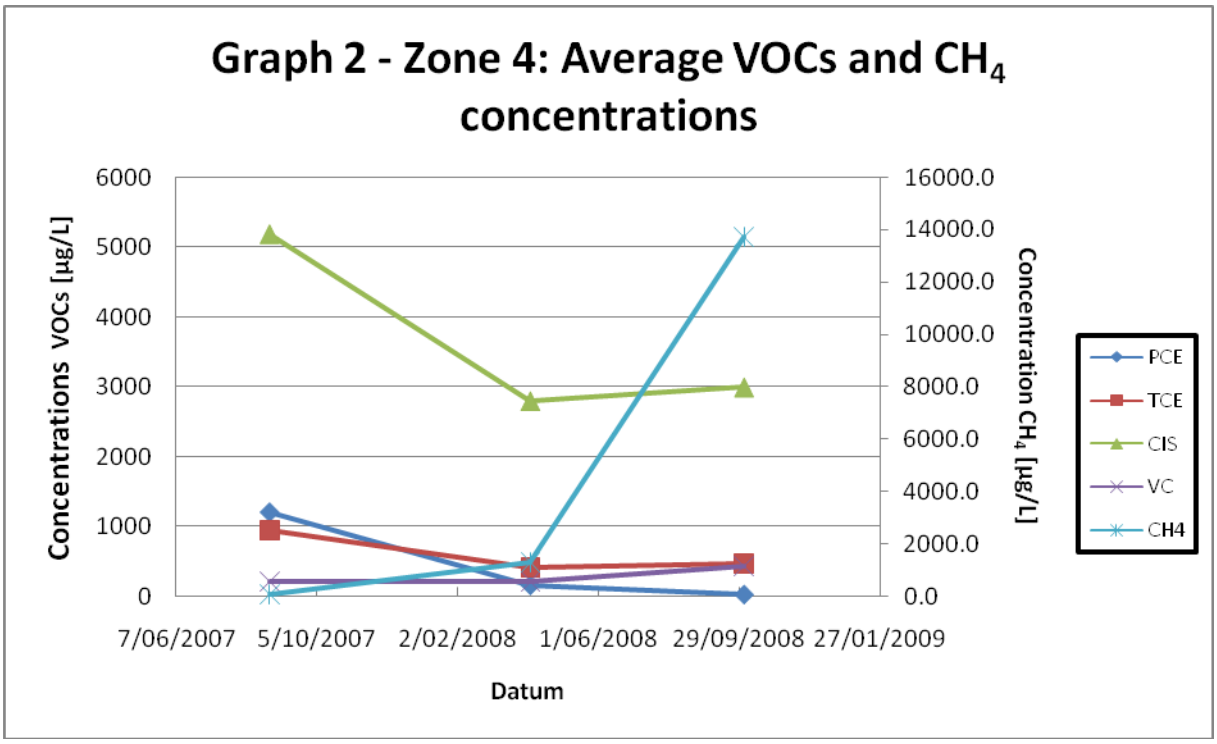


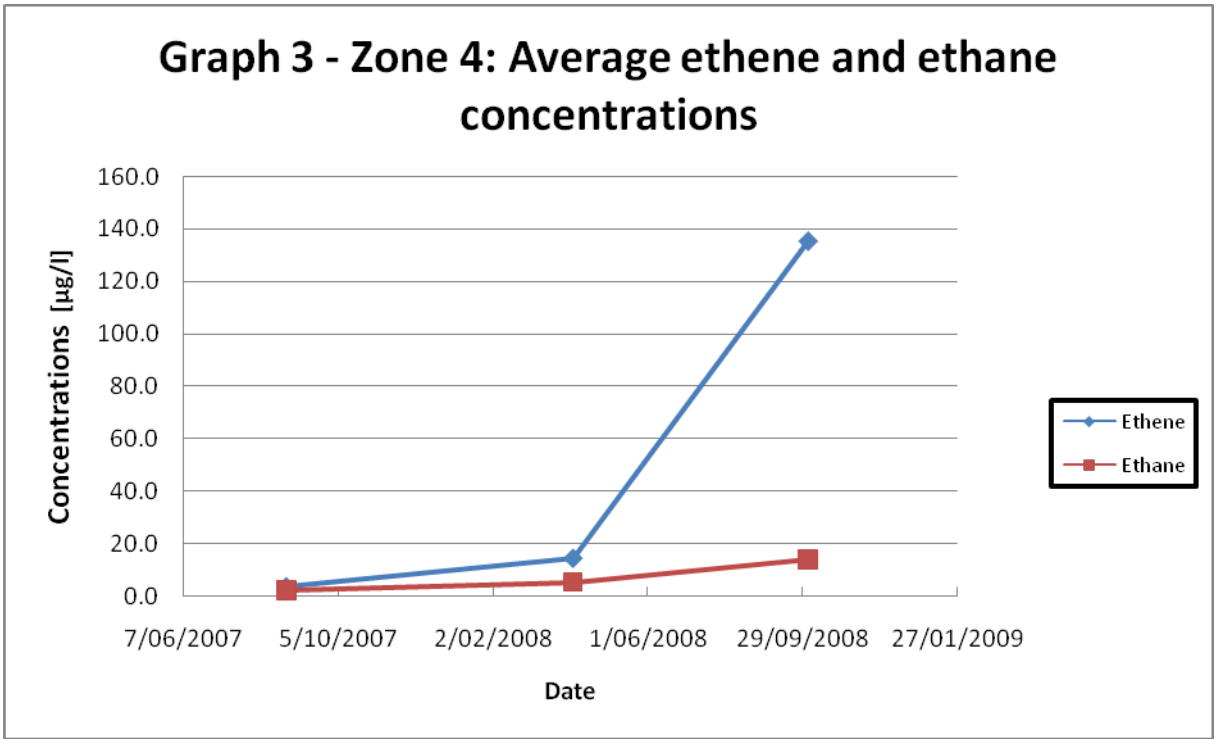

## 3. Zone 4: CAP18® injections

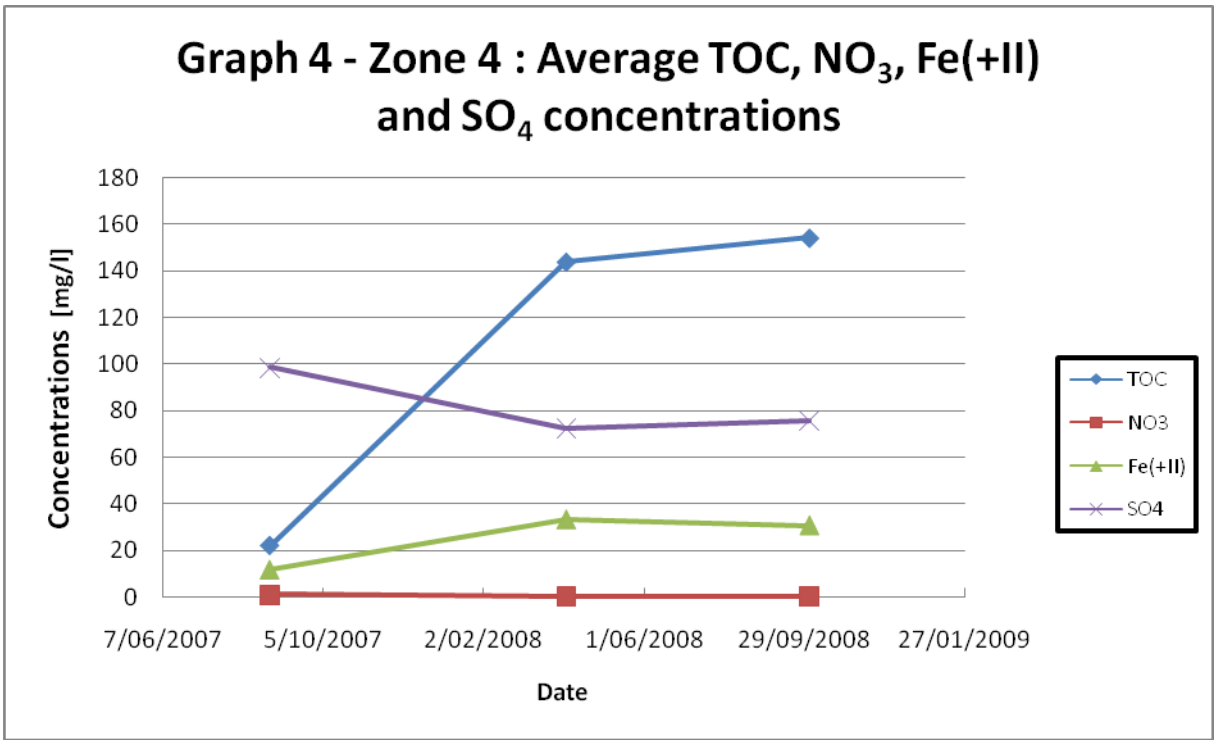
Six IBCs (5.520 kg) of CAP18® (*Figure 1*) were injected in September 2007, into approximatly 150 direct push injection points. The *Graphs 2*, *3* and *4* show us the average results of six monitoring wells from the baseline monitoring from 7 and 13 months after injection; the wells are located in *'Zone 4'*.

The decrease of PCE is obvious after 7 and 13 months; TCE and CIS initially decreased and then stayed stable for over one year. Additionally the gradual increase in VC and the high production of products ethene and ethane demonstrate that the site is achieving significant reductive dechlorination conditions. The anaerobic degradation is also shown through the changes in the

groundwater redox parameters; nitrates have not been present since the beginning, but the reduction of sulphates and the production of ferrous iron and methane is clearly perceptible. Additionally, the high TOC content indicates the presence of well distributed CAP18®.

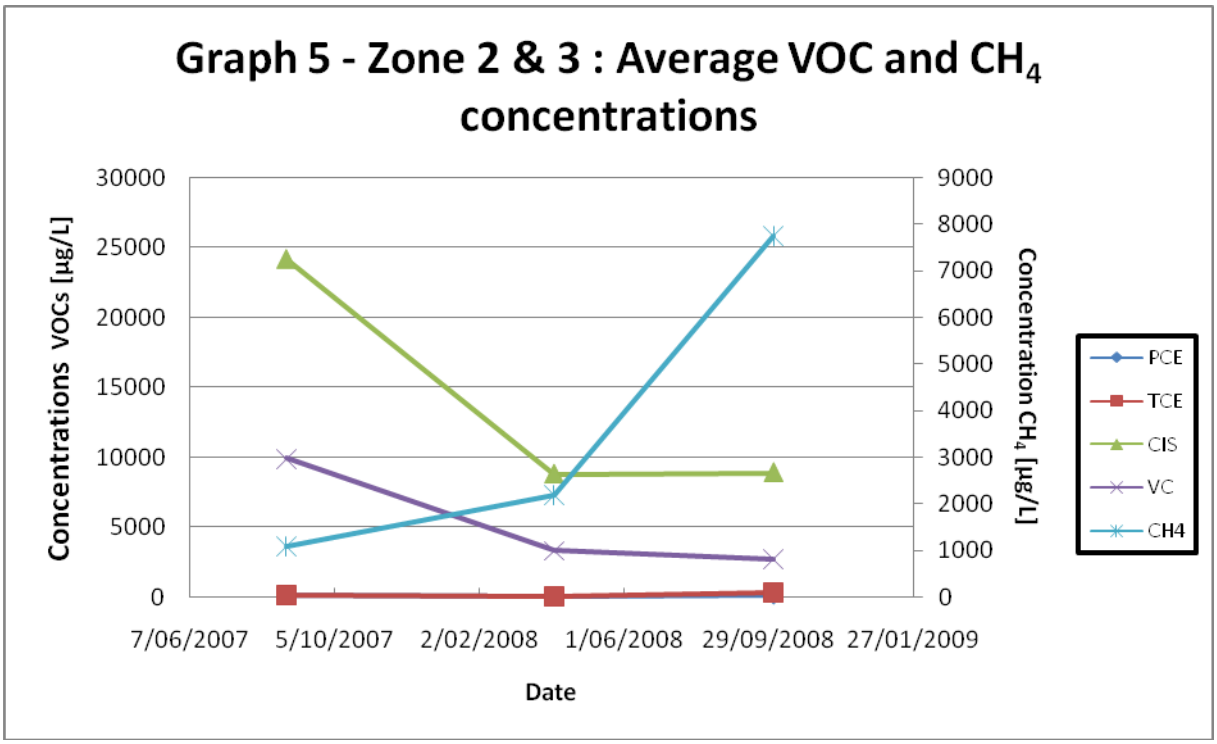


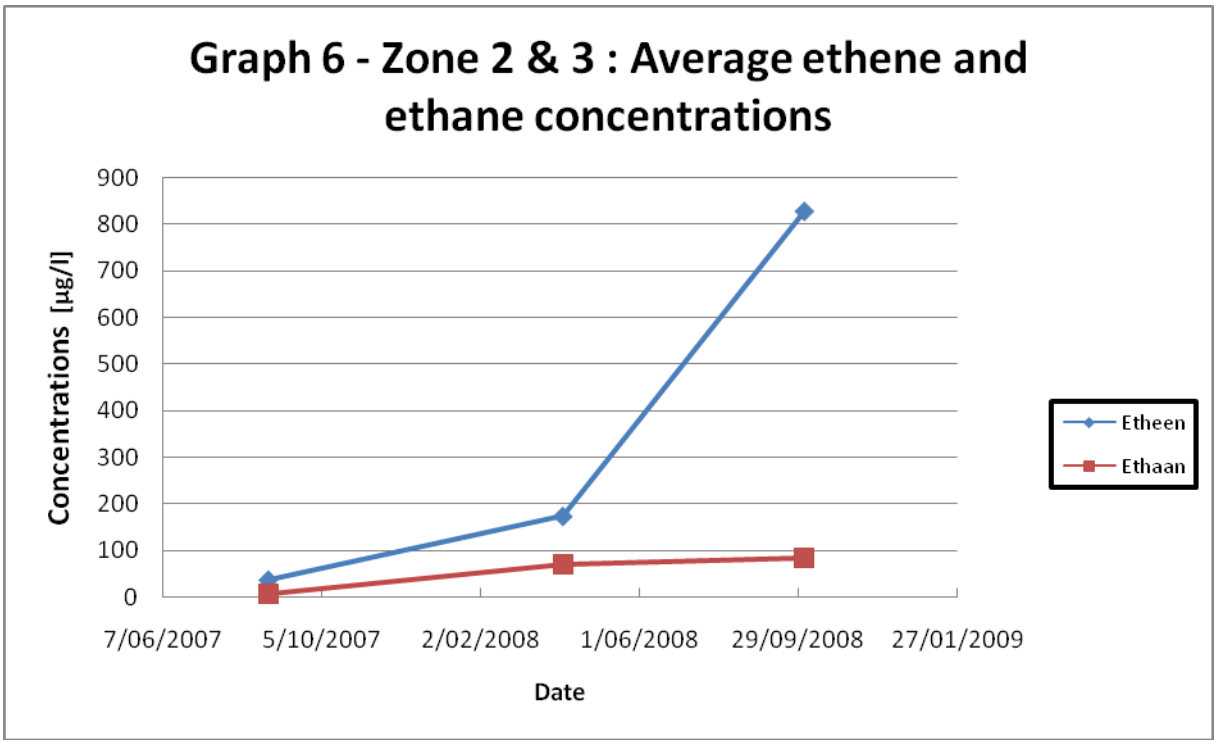






## 4. Zone 2 & 3: CAP18-ME® injections

In mid January 2008, 8 IBCs (about 7.360 kg) of CAP18-ME® were injected into approximately 170 direct push injection points into *Zone 2 and 3*. *Graphs 5, 6* and 7 show us the average results of 8 monitoring wells from the pre-injection monitoring, from 3 and 9 months after injection. The decrease of the VOC's after 3 months clearly indicates that the injected CAP18-ME®, oils do not miss the target. The PCE concentration is fairly low, but the increase of TCE after 9 months shows that the dechlorination is occurring. The decrease of CIS and VC and the clear increase of ethene and ethane products again indicate that the reductive dechlorination vigorous. The groundwater redox parameters confirm this anaerobic change; nitrates and sulphates reduce further; the production of ferrous iron progresses and the production of methane is considerable. After nine months, although the TOC is reduced when compared to the value after 3 months, the average concentration for the nine months remains high. This indicates a good spread and presence of CAP18-ME®.


Graph 5 - Zone 2 & 3 : Average VOC and CH4 concentrations
Concentrations VOCs [µg/L]
30000
25000
20000
15000
10000
5000
0
Concentration CH4 [µg/L]
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
7/06/2007
5/10/2007
2/02/2008
1/06/2008
29/09/2008
27/01/2009
Date
PCE
TCE
CIS
VC
CH4


Graph 6 - Zone 2 & 3 : Average ethene and ethane concentrations
Concentrations [µg/l]
900
800
700
600
500
400
300
200
100
0
7/06/2007
5/10/2007
2/02/2008
1/06/2008
29/09/2008
27/01/2009
Date
Etheen
Ethaan

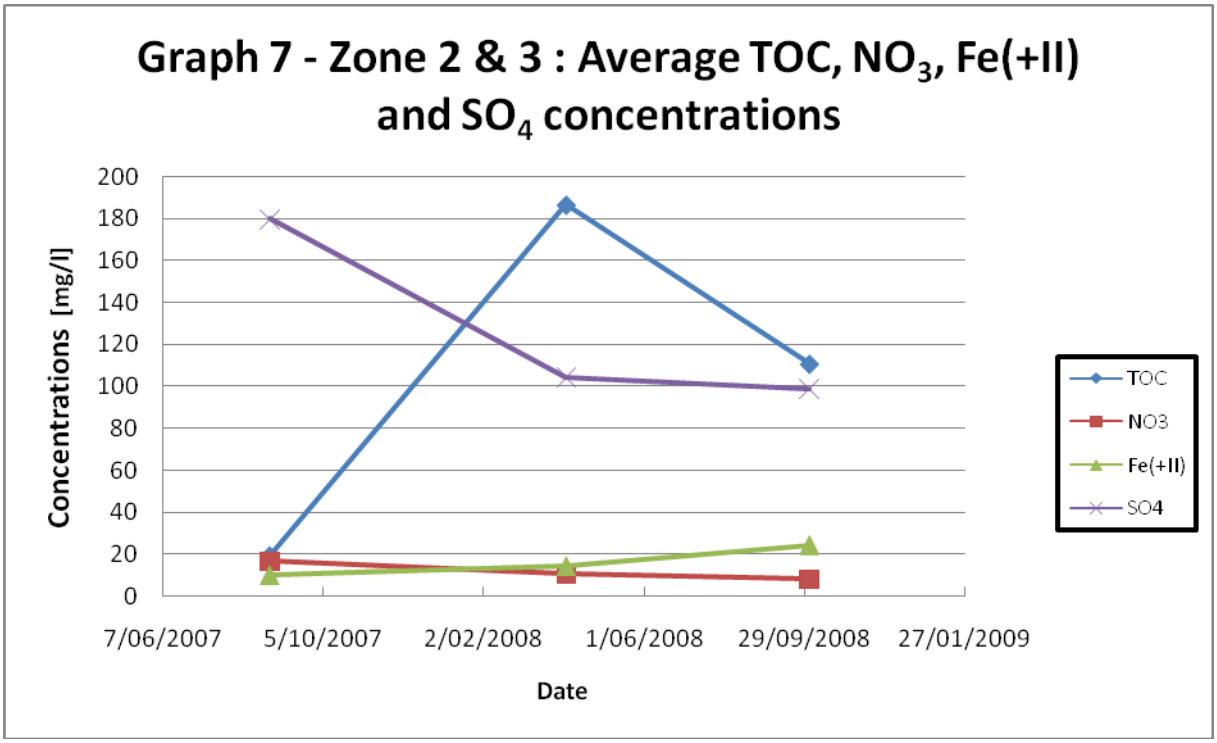



**Figure 1-** CAP18® and CAP18ME® injection equipment

## 5. CONCLUSIONS

The application of a treatment train with In Situ Chemical Oxidation with RemOx® L ISCO Reagent (sodium permanganate) and anaerobic bioremediation via CAP18® and CAP18 ME® Anaerobic Bioremediation Products resulted in a vigorous reduction of Chloroethenes concentrations in groundwater.

The use of these two synergic technologies can be seen as a very sustainable solution in which costs, energy consumption and carbon footprint are optimized to achieve the remediation targets.

## REFERENCES

1. Siegrist L., Urynowicz M. A. et al. (2001) 'In Situ Chemical Oxidation Uning Permanganate', *Battelle Press*.