Post-Bioremediation Chemical Reduction to Achieve Treatment Standards for Carbon Tetrachloride/Chloroform at an Industrial Site in Brazil

Group 1

anteagroup

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BACKGROUND

COMMON THEMES IN BRAZIL

- Brazil has many large chlorinated solvent sites
- There is extensive experience with in situ chemical oxidation (ISCO), bioremediation, and in situ chemical reduction (ISCR) to remediate sites
- The regulatory agency, CETESB, has favored technologies that protect site occupants and minimize daughter products to the extent practicable
- Remediation projects can target Commercial or Residential Standards
- Transition to monitored natural attenuation (MNA) and long-term monitoring are part of the project process

THE SITE

An adhesive manufacturing facility (abandoned in 2018) in the city of **Sorocaba**, state of São Paulo, Brazil

SITE — Sorocaba

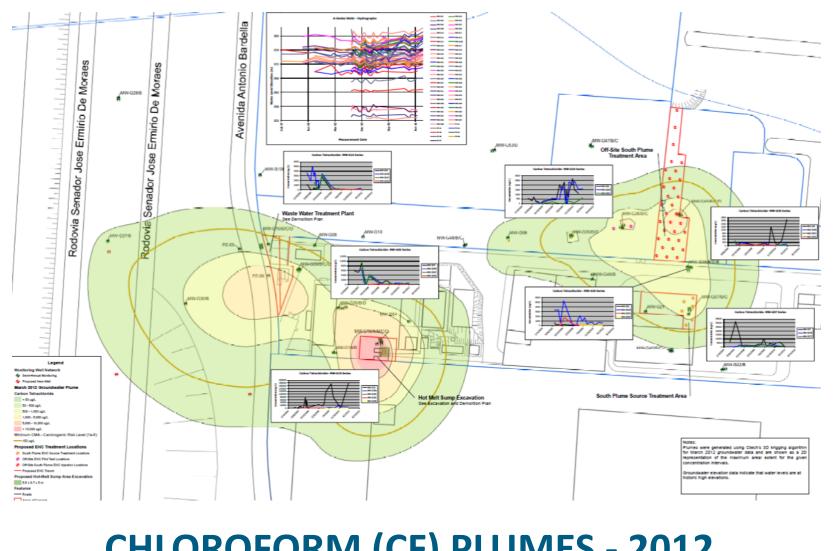Source: Google Earth

A TALE OF TWO PLUMES

- Carbon tetrachloride (CT) and chloroform (CF) impacts in groundwater > 10,000 µg/L in 2012
- Two plumes – North and South with an Upper Zone (surface to 12 m) and a Lower Zone (12 m to 24 m)
- Geology is mix of silts, clays, and fractured rock, making remediation a challenge
- Two off-site properties also impacted and plume migrated under a highway
- Prior cometabolic bioremediation using butane led to a temporary reduction in CT, but left significant CF (daughter product) plume behind
- CT rebounded!

CARBON TETRACHLORIDE (CT) PLUMES - 2012

CHLOROFORM (CF) PLUMES - 2012

REMEDIAL GOALS
Maximum Acceptable Concentrations (called CMAs in Brazil)

	CT	CF
Commercial	439 µg/L	473 µg/L
Residential	37 µg/L	147 µg/L

INOGEN®

APPROACH

UTILIZING MOLECULAR BIOLOGICAL TOOLS AND GEOCHEMISTRY

Microbial Populations – Reductive Dechlorination

APPLICATION TECHNIQUES – (60% SLURRY)

Excavation of point source at wastewater treatment plant with emplacement of EHC® amendment (1,000 kg) in trench

Single row barrier installed through mixing, direct push, and pneumatic fracturing in secondary source area (3,000 kg of EHC® amendment)

Injection array installed through mixing, direct push, and pneumatic fracturing in distal plume. (12,000 kg of EHC® amendment)

Micro-scale ZVI
Bacterial cluster
Controlled-release carbon
Soluble Derivatives
Volatile Fatty Acids
Fe^{2+} OH^- and H_2

AMENDMENT MIXING
AMENDMENT PLACEMENT
REDUCTANT INJECTION
AUGER TECHNIQUE

SOUTH PLUME INJECTIONS

NORTH PLUME INJECTIONS

INJECTION SCENARIOS

Injection Point	Date	Drilling Equipment	Drilling Diameter	Quantity of EHC (kg)	Mixed Interval (m)
A1	22-Jan-13	Geoprobe 7822DT	8 ¼"	325	2.40 - 26.40
A2	25-Jan-13	Mach 7200	8"	325	1.90 - 24.00
A3	31-Jan-13	Geoprobe 7822DT	8 ¼"	300	2.00 - 25.80
A4	25-Jan-13	Geoprobe 7822DT	8 ¼"	325	3.00 - 27.00
B1	30-Jan-13	Mach 7200	8"	250	2.20 - 25.00
B2	30-Jan-13	Mach 7200	8"	300	1.50 - 23.00
B3	29-Jan-13	Geoprobe 7822DT	8 ¼"	300	3.00 - 25.50
C1	01-Feb-13	Mach 7200	8"	250	1.70 - 23.50
C2	17-Jan-13	CME-75	8"	250	1.80 - 24.00
C3	15-Jan-13	CME-75	8 ¼"	325	3.10 - 25.00
C4	11-Jan-13	CME-75	8 ¼"	325	1.30 - 26.00

RESULTS

SIX YEAR POST-INJECTION RESULTS (2013 – 2019)

- 54 wells monitored/ 50 have shown reduction to reach Commercial Standards/two are showing an increase. Majority of wells close to Residential Standards
- Amendment signature changing (strongly negative/ORP -250 mv avg., dissolved iron, low TOC). Microbial densities waning, especially at four impacted wells
- Vapor intrusion studies show no impact to indoor air and sub-slab

PERCENT DECREASE

	CT South Plume	CT North Plume	CF South Plume	CF North Plume
Mass	91%	100%	79%	99%
Max. Concentration	89%	96%	87%	97%
Avg. Concentration	51%	85%	54%	94%

CT VERTICAL VIEW

CF VERTICAL VIEW

ISCR PERFORMANCE
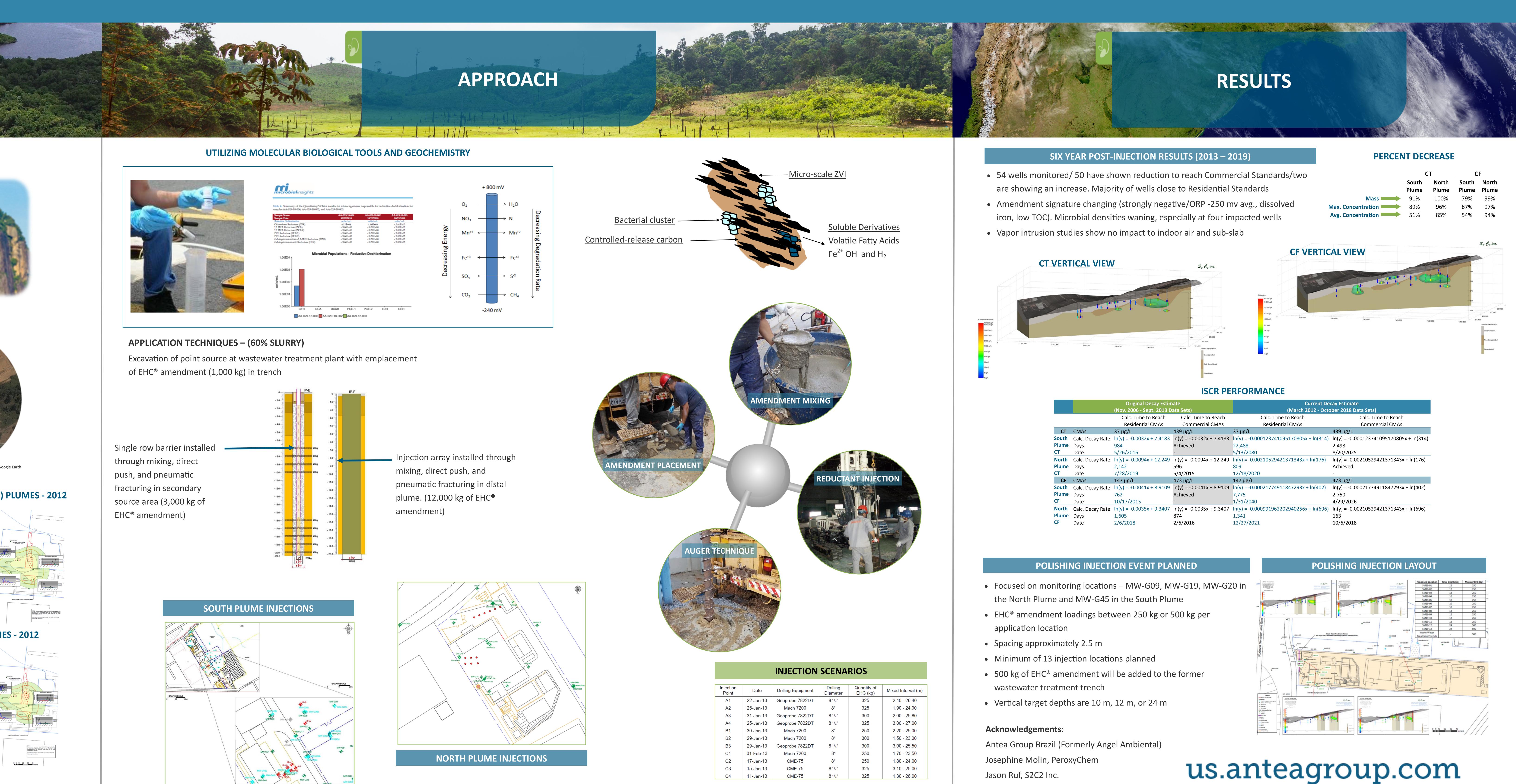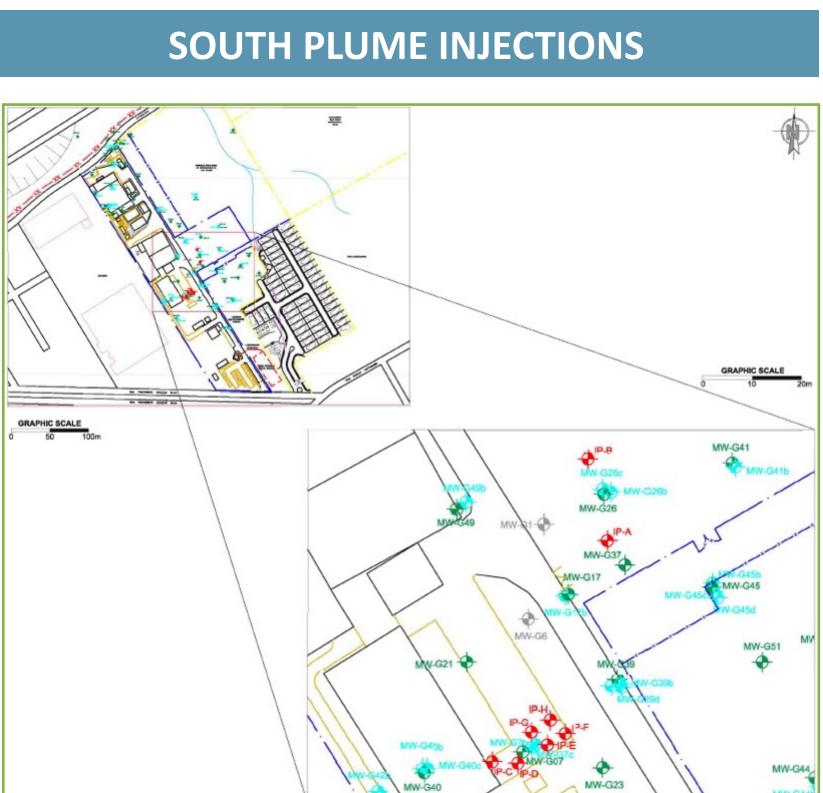
		Original Decay Estimate (Nov. 2006 - Sept. 2013 Data Sets)		Current Decay Estimate (March 2012 - October 2018 Data Sets)	
		Calc. Time to Reach Residential CMAs	Calc. Time to Reach Commercial CMAs	Calc. Time to Reach Residential CMAs	Calc. Time to Reach Commercial CMAs
CT South Plume CT	CMAs	37 µg/L	439 µg/L	37 µg/L	439 µg/L
	Calc. Decay Rate	ln(y) = -0.0032x + 7.4183	ln(y) = -0.0032x + 7.4183	ln(y) = -0.0001237410951708055x + ln(314)	ln(y) = -0.0001237410951708055x + ln(314)
	Days	984	Achieved	22,488	2,498
	Date	5/26/2016		5/13/2080	8/20/2025
North Plume CT	CMAs	ln(y) = -0.0094x + 12.249	ln(y) = -0.0094x + 12.249	ln(y) = -0.0021052942137134x + ln(176)	ln(y) = -0.0021052942137134x + ln(176)
	Days	2,142	596	809	Achieved
	Date	7/28/2019	5/4/2015	12/18/2020	
CF South Plume CF	CMAs	147 µg/L	473 µg/L	147 µg/L	473 µg/L
	Calc. Decay Rate	ln(y) = -0.0041x + 8.9109	ln(y) = -0.0041x + 8.9109	ln(y) = -0.00021774911847293x + ln(402)	ln(y) = -0.00021774911847293x + ln(402)
	Days	762	Achieved	7,775	2,750
	Date	10/17/2015		1/31/2040	4/29/2026
North Plume CF	Calc. Decay Rate	ln(y) = -0.0035x + 9.3407	ln(y) = -0.0035x + 9.3407	ln(y) = -0.00009196220294025x + ln(696)	ln(y) = -0.0021052942137134x + ln(696)
	Days	1,605	874	1,341	163
	Date	2/6/2018	2/6/2016	12/27/2021	10/6/2018

POLISHING INJECTION EVENT PLANNED

- Focused on monitoring locations – MW-G09, MW-G19, MW-G20 in the North Plume and MW-G45 in the South Plume
- EHC® amendment loadings between 250 kg or 500 kg per application location
- Spacing approximately 2.5 m
- Minimum of 13 injection locations planned
- 500 kg of EHC® amendment will be added to the former wastewater treatment trench
- Vertical target depths are 10 m, 12 m, or 24 m

POLISHING INJECTION LAYOUT

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