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June 28, 2007

Mr. Jeffrey A. Konsella, P.E.
Environmental Engineer II
Division of Environmental Remediation
New York State Department of Environmental Conservation
270 Michigan Avenue
Buffalo, New York 14203

Reference: Ekonol Polyester Resins Site (#V00653-9).
Treatability Testing Summary and Pilot Test Scope of Work

Dear Mr. Konsella:

Provided herein, on behalf of Atlantic Richfield Company, is an amendment to the Alternative Evaluation Phase 2 data summary report and proposed pilot test scope of work submitted to the New York State Department of Environmental Conservation (NYSDEC) on December 28, 2006. The purpose of this letter is to provide NYSDEC with a summary of the treatability testing results, define the selected treatment technology, and update the scope of work (SOW) for the pilot test.

Together with the December 2006 submittal, this letter will complete the addendum to the Remedial Alternatives Report (February 2006, Revised July 2006). Subsequent to NYSDEC review of this report, concurrence with the selected treatment, and proposed SOW, a pilot test work plan will be issued. A summary of the treatability study, technology selection, and the pilot test SOW are provided below.

TREATABILITY STUDY

The treatability study (see Attachment 1) was a laboratory-scale test in which microcosms of site rock and ground water were amended with various *in situ* technologies. The microcosms were sampled over time and the analytical results were compared to evaluate the effectiveness of the treatments. Using the results of treatability testing with the geologic and hydrogeologic site model, a treatment technology was chosen for a pilot-phase treatment. The treatability studies were designed to determine:

- The presence/absence of native microorganisms that are capable of facilitating biodegradation of site-specific chlorinated compounds of concern (COCs).
- If biodegradation of chlorinated COCs can be enhanced in Site rock and groundwater by the addition of carbon substrates (i.e., biostimulation).
- If the addition of a microbial culture that is known to completely dechlorinate chlorinated COCs with a carbon substrate (i.e., bioaugmentation) can enhance biodegradation beyond what can be achieved by addition of the carbon substrate alone.

- If formulations combining zero valent iron (ZVI) and a carbon source can increase the overall degradation rate of chlorinated COCs relative to the biostimulation and bioaugmentation approaches described above.

Each treatment option was tested during the treatability study and was applied to two groups of microcosms. One set of microcosms contained rock and groundwater from the source area, whereas the second set of microcosms contained rock and groundwater from locations that are downgradient of the source area. Source zone microcosm tests utilized bedrock from MW-7D and groundwater from MW-4D (see Figure 1). Downgradient microcosm tests utilized bedrock from MW-21D and groundwater from MW-20D.

Bedrock and groundwater samples were composited upon receipt at the laboratory, and characterized for volatile organic carbons (VOCs), total organic carbon (TOC), and total iron. Groundwater samples were analyzed for geochemical parameters including nitrate, sulfate, ferrous iron, alkalinity, methane, ethene, and ethane, along with biological indicators of reductive dechlorination activity. The biological indicators that were measured in groundwater samples were concentrations of two microbial populations and the genes for enzymes that are associated with complete reductive dechlorination of TCE. The two microbial populations that were measured were *Dehalococcoides*, which are bacteria known to degrade TCE through DCE and VC to ethene, and *Dehalobacter*, which are bacteria known to degrade TCA. The genes for the enzymes TCE and VC reductase were also measured. The results of the analytical testing are provided in Table 1.

Laboratory-scale treatability testing evaluated the following *in situ* technologies:

- Biostimulation using Slow Release Substrate™ (SRS™), which is an emulsified soybean oil product to enhance biodegradation.
- Bioaugmentation using the SDC-9 microbial culture (contains *Dehalococcoides spp.*) in addition to SRS™.
- Combined abiotic and biostimulation treatment using zero valent iron (ZVI) in combination with either emulsified vegetable oil or a solid-phase plant protein. The three formulations of ZVI mixed with carbon substrate were emulsified vegetable oil with nanoscale ZVI, emulsified vegetable oil with microscale ZVI, and the propriety formulation of ZVI mixed with vegetable protein and nutrients (EHC®).

Each treatment described above was added to triplicate microcosms that were prepared for both source and downgradient microcosm sets. Two laboratory controls were prepared in triplicate to evaluate natural biotic and abiotic pathways as well as unknown loss. The microcosms were sampled at 0, 4, 8, 12, and 16 weeks into the study.

TREATABILITY STUDY RESULTS AND EVALUATION

The results of the treatability test are described in detail in the *In Situ Bioremediation and Zero Valent Iron Treatability Studies* report that is attached to this letter (Attachment 1). The results of the treatability testing indicated the following:

- Groundwater in bedrock contains substantial concentrations of an indigenous microbial population that includes *Dehalococcoides* and *Dehalobacter,* species that are known to completely degrade chlorinated COCs to innocuous end products. The microbial consortium expresses TCE and VC reductase gene activity and may be well adapted to complete reductive dechlorination of TCE. Although these microcultures exist in native groundwater, historical Site data suggests that the time frame involved for breakdown of the COC's can be enhanced to more quickly meet remedial goals as per the Remedial Alternatives Report (February 2006, Revised July 2006).
- Emulsified vegetable oil was able to stimulate the indigenous microbial population, resulting in enhanced degradation of site-specific chlorinated COCs.
- Bioaugmentation with SDC-9 or other bacteria known to degrade chlorinated COCs, when combined with an organic substrate (vegetable oil), may have enhanced degradation of *cis*-1,2-DCE in the source area microcosm set.
- Although emulsified ZVI and EHC are designed to enhance both biotic and abiotic degradation pathways for chlorinated COCs, there was no significant difference between their performance and the performance of the biostimulation and bioaugmenation treatment approaches. In addition, geochemical results including oxidation reduction potential indicated that ZVI based treatments may be consumed at a faster rate than emulsified vegetable oil treatments.
- High concentrations of sulfate may compete with chlorinated COCs as an alternate electron acceptor. The dosage and type of substrate should be designed to account for elevated sulfate concentrations.

The results of laboratory-scale treatability testing were used to support selection of the most appropriate technology to use in a field-scale pilot. The table below, which was developed by considering the results of bench-scale testing and previous experience using the various treatment technologies, lists the advantages and limitations of using a particular technology for *in situ* treatment of chlorinated COCs in bedrock.

Treatment	Advantages	Disadvantages
Biostimulation using SRS™	Longer lasting carbon source extends duration of treatment beyond ZVI-based technologies, potentially resulting in the mass of chlorinated ethenes and ethanes degraded over long term.	May result in a slower degradation rate of chlorinated ethenes and ethanes relative to ZVI-based technologies.
	Anaerobic biodegradation is already occurring at Site, so technology would simply enhance existing processes.	Dose applied must be sufficient to overcome sulfate concentration.

Treatment	Advantages	Disadvantages
	Inexpensive relative to ZVI-based technologies, which allows technology to be applied cost-effectively over a larger treatment zone.	More likely to temporarily produce regulated intermediate degradation products (e.g., *cis*-1,2-DCE, VC) than ZVI or bioaugmentation approaches.
Bioaugmentation using SDC-9 with SRS™	Faster degradation of intermediate degradation products than would be realized with biostimulation alone.	Initial injection cost higher than biostimulation alone with no guarantee of an improvement in long-term performance.
	May aid in competition with sulfate reducing bacteria for added substrate.	Introduction of non-native microorganisms may be of concern to project stakeholders and could delay completion of the injection permit process.
	Less expensive than ZVI-based technologies.	
Nanoscale Emulsified Zero Valent Iron (EZVI)	Potential for rapid reduction in chlorinated ethene and ethane concentrations.	Geochemical changes not sustained because highly-reactive ZVI would be consumed. Rapid reaction rate likely to require frequent re-injection and substantial increase in cost.
	Easier to uniformly distribute in the subsurface relative to EHC.	Cost of nanoscale ZVI is very high relative to emulsified vegetable oil and moderately higher than microscale ZVI.
		Bench-scale study did not demonstrate that nanoscale EZVI significantly outperformed biostimulation-based approaches.
		Need to evaluate the introduction of iron on existing microbial population
Microscale EZVI	Potential for rapid reduction in chlorinated ethene and ethane concentrations.	Geochemical changes not sustained because highly-reactive ZVI would be consumed. Rapid reaction rate likely to require frequent re-injection and substantial increase in cost.
	Bench-scale tests suggest improved removal of 1,1 DCA relative to nanoscale EZVI.	Cost of microscale ZVI is high relative to emulsified vegetable oil, but less than nanoscale ZVI..
		More difficult to distribute evenly in subsurface than nanoscale EZVI and emulsified vegetable oil.
		Need to evaluate the introduction of iron on existing microbial population.

Treatment	Advantages	Disadvantages
EHC	May assist in reducing sulfate concentrations, leading to enhanced degradation of chlorinated COCs.	Less effective removal of chlorinated ethenes and ethanes than EZVI.
	Initial rapid reaction with gas production.	Some chlorinated ethene and ethane removal may be due to gas stripping, which introduces the potential for additional soil gas generation. .
	In treatability study EHC produced relatively higher amounts of innocuous end products.	Much more difficult to distribute evenly in subsurface relative to EZVI and emulsified vegetable oil.
		Introduction of iron may have unintended consequences on existing microbial populations.

TREATMENT TECHNOLOGY SELECTION

The evaluation of the treatability testing results and other site data reveal that bioaugmentation has the best overall potential for remediation of chlorinated COCs in bedrock groundwater in an accelerated time frame compared to natural attenuation. For initial treatments, including pilot testing, the addition of microcultures (i.e. bioaugmentation) will likely have a more pronounced affect on the groundwater concentrations than biostimulation alone. Biostimulation may also be an affective treatment and could be considered in the future, if required.

EZVI treatments performed very well in the laboratory however, Site conditions and implantation factors (e.g. injection and distribution of the EZVI, treatment duration per application) favor bioaugmentation. EHC® was not considered an appropriate treatment technology for the Site due to gas production and the difficulty of distributing this substance in the subsurface.

Therefore, a bioaugmentation injection approach using a carbon-based substrate and commercially available microcultures is proposed for remediation of the chlorinated COCs in bedrock groundwater. This, coupled with the proposed bioreactor in overburden near the former containment tank (Parsons, 2006) are anticipated to provide enough carbon in both the overburden and bedrock groundwater to effectively reduce the chlorinated COCs at the site.

The design specifics of the carbon-based emulsion will be presented in the pilot test work plan.

FINAL PILOT TEST SCOPE OF WORK

The field-scale pilot test is the first phase of remediation of the chlorinated COCs in bedrock groundwater. This section discusses the final scope of work for a pilot test to evaluate bioaugmentation as the remedial treatment technology(s) to effectively decrease Site COCs.

Shallow Groundwater: Based on Site conditions and a review of technologies, a bioreactor will be most effective in addressing the shallow groundwater. Given the limited size of the bioreactor, a pilot field test is not warranted.

Deep Groundwater: Based on the results of the laboratory treatability testing (February 2007), and previous studies, the treatment technology selected for deep groundwater is bioaugmentation with an emulsified carbon substrate and microcultures known to degrade chlorinated COCs. The anticipated SOW for the pilot test using this selected technology is described below. Details regarding the material selected, injection volumes, well spacing, and other design criteria will be defined in the work plan.

The pilot test will be designed with the following primary objectives:

- Determine if the selected technology is capable of reducing Site groundwater COCs in a more timely manner to a level by which remedial goals can be reached by monitored natural attenuation.
- Evaluate design parameters for full-scale implementation, and determine if there are any adverse secondary effects to groundwater.
- Refine injection methodology and estimate a radius of influence;
- Assess impacts to hydrogeology; and
- Assess the potential for increased solubility of inorganics (e.g., arsenic), generation of gases (e.g., methane, hydrogen or hydrogen sulfide), and other undesirable effects.

Scope of Work

The pilot test will be comprised of (1) treatment application and (2) performance monitoring. The treatment application involves all processes and monitoring related to the field application to specific sections of the bedrock groundwater. Performance monitoring includes the methods to assess the remedial technology.

Treatment Application

The pilot test will be performed near the source area between RMW-2D and RMW-4D (see Figure 2). It is anticipated that five injection wells will be used during the test to apply the substrate to the fractured bedrock and eight monitoring wells will be included in the performance monitoring. Details of the treatment application design will be presented in the field-scale pilot test work plan. The treatment application design is anticipated to include:

- Installation of injection wells/points.

- Injection of one or more conservative tracers to estimate the radius of influence and injection hydraulics of the bedrock groundwater system.

- Development of injection dosages based on a combination of field data, laboratory data, and literature design criteria.

- Development of a mitigation plan for health and safety issues including procedures for handling system leaks and injection pressure build up.

- Application of bioaugmentation including injection of a vegetable oil emulsion followed by an injection of microcultures.

Performance Monitoring

Details of the performance monitoring design will be presented in the pilot test work plan. The performance monitoring is anticipated to include:

- Monitoring wells will be located upgradient, within the treatment zone, and downgradient of the treatment zone. The network may include a combination of new wells and the existing monitoring wells (e.g. RMW-1D RMW-2D, RMW-3D RMW-4D, MW-7D and MW-20D).

- A monitoring schedule including a baseline sampling event (prior to injection), and up to four performance monitoring events that will occur approximately 1 week, 6 weeks, 13 weeks, and 26 weeks following injection. Note that site data will be evaluated after each performance monitoring event to determine if the proposed monitoring program should be modified or extended.

- An analytical protocol defined for baseline and performance monitoring events. This analytical protocol will include site-specific COCs and various biogeochemical indicators.

- Hydraulic parameters, (hydraulic gradient and hydraulic conductivity), will be monitored to determine the effect of the substrate on formation permeability.

- Evaluation of the performance data will include changes in COC mass, geochemical parameters, and calculation of degradation rates.

ANTICIPATED SCHEDULE

An estimated schedule of field activities and report submittals is described below. A more detailed schedule will be provided in the pilot test work plan.

Task	Schedule
Remedial Alternatives Addendum Report and Recommended Alternative Pilot Test Scope of Work (this submittal)	June 2007
Pilot Test Work Plan	July 2007
Implement Pilot Test Work Plan	September 2007
Completion of Pilot Program	To be determined based on final design of pilot test.

If you have any comments, questions, or concerns, please feel free to contact William B. Barber of Atlantic Richfield Company at (216) 271-8038.

Sincerely,

Mark S. Raybuck

Mark S. Raybuck
Project Manager

cc: W. Barber, Atlantic Richfield
S. Fiorenza, BP
S. Brauner, Parsons
W. Hughes, Parsons
G. Hermance, Parsons
File: 442257 No. 2

TABLES

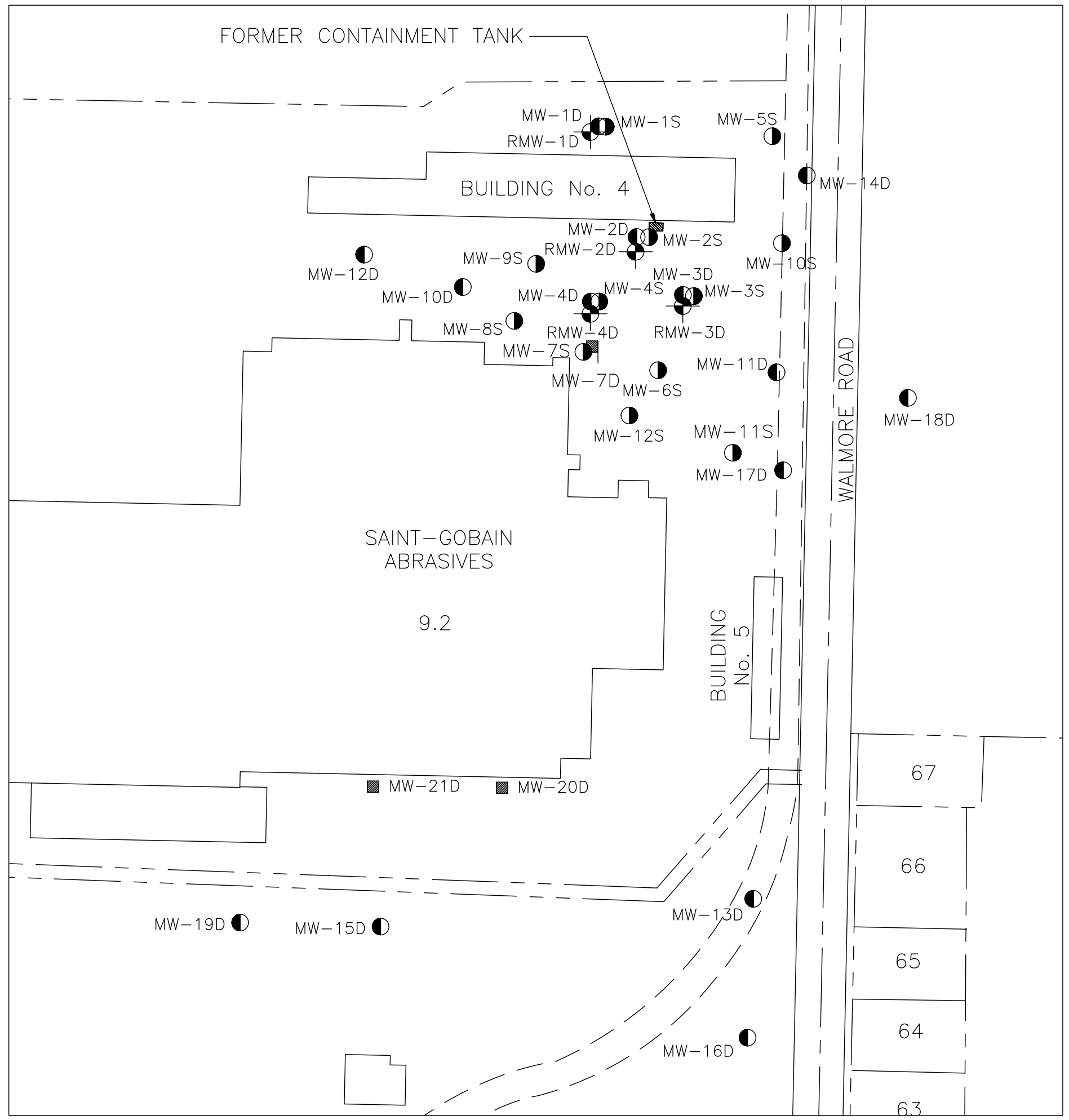
Table 1. Concentrations of CVOCs, Dissolved Hydrocarbon Gases, Electron Acceptors, and Dehalogenating Bacteria in Site Groundwater and Rock

Parameter	Units	RMW-4D (Source) Groundwater	MW-7D (Source) Rock	MW-20D Plume (Groundwater)	MW-21D (Plume) Rock
Alkalinity	mg/L as CaCO3	290		280	
Ferrous Iron	mg/L	<1.0		4	
Nitrate	mg/L	<0.5		0.94	
Sulfate	mg/L	1300		1200	
Total Organic Carbon	mg/L or mg/kg	6.6	540	<5.0	930
Total Iron	mg/L or mg/kg	0.33	2600	0.22	3100
Percent Solids	%		99		96
Vinyl Chloride	µg/L or µg/kg	560	<2.0	590	9.1
Chloroethane	µg/L or µg/kg	<100	<2.0	<100	<2.0
1,1-Dichloroethene	µg/L or µg/kg	<100	<2.0	<100	<2.0
1,1-Dichloroethane	µg/L or µg/kg	150	<2.0	170	3.3
cis-1,2-Dichloroethene	µg/L or µg/kg	6310	21	3050	21
1,1,1-Trichloroethane	µg/L or µg/kg	160	<2.0	420	1
Trichloroethene	µg/L or µg/kg	15600	61	<100	5.8
Tetrachloroethene	µg/L or µg/kg	1040	9.9	<100	7.5
Methane	µg/L or µg/kg	200	42	<67	14
Ethene	µg/L or µg/kg	<120	<2.4	<120	<2.4
Ethane	µg/L or µg/kg	<120	43	<120	<2.4
Dehalococcoides spp.	cells/mL	1.16E+04		4.48E+01	
Dehalobacter spp.	cells/mL	3.62E+03		2.09E+02	
TCE R-Dase	cells/mL	3.13E-01		<4.99E-01	
BAV1 VC R-Dase	cells/mL	1.09E+04		9.63E+01	
VC R-Dase	cells/mL	2.92E+03		4.71E+00	

µg/L = micrograms per liter (water); µg/kg = micrograms per kilogram (rock), spp. = species, R-Dase = Reductase

mg/L = milligrams per liter (water), mg/kg = milligrams per kilogram (rock)

FIGURES



LEGEND:

MW-1D	BEDROCK MONITORING WELL
MW-1S	OVERBURDEN MONITORING WELL
MW-21D	RECENT BEDROCK MONITORING WELL
RMW-1D	REPLACEMENT BEDROCK MONITORING WELL
	PROPERTY LINE
	RIGHT-OF-WAY

SCALE

200 100 0 200 400

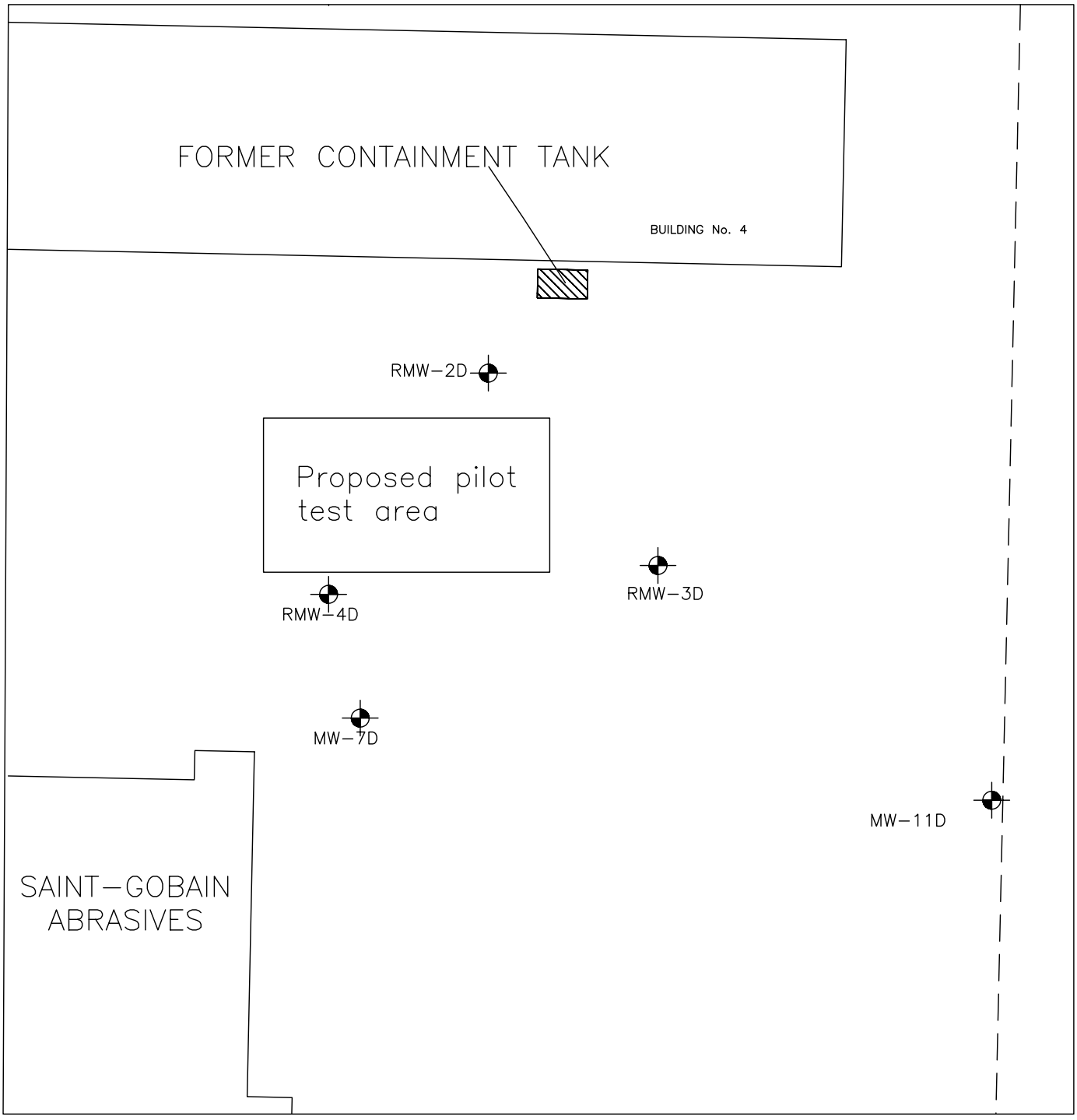
FIGURE 1

EKONOL POLYESTER
RESINS FACILITY
WHEATFIELD, NEW YORK

SITE PLAN AND
2006 WELL INSTALLATIONS

PARSONS
180 LAWRENCE BELL DRIVE, SUITE 104, WILLIAMSVILLE, N.Y. 14221, PHONE: 716-633-7074

P:\441610\cad\RARP2\SK-441610-RAR2-siteplan.dwg, 06/27/06, JWS
No XREFs



SCALE

100 50 0 100 200

LEGEND:

RMW-1D — BEDROCK MONITORING WELL

— — — — — — — RIGHT-OF-WAY

N

FIGURE 2

EKONOL POLYESTER
RESINS FACILITY
WHEATFIELD, NEW YORK

Proposed Pilot Test Area

PARSONS
40 La Riviere Dr. Suite 350 Buffalo, NY 14202

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No XREFs

ATTACHMENT 1

FINAL REPORT

IN SITU BIOREMEDIATION AND ZERO VALENT IRON TREATABILITY STUDIES
EKONOL POLYESTER RESINS FACILITY
WHEATFIELD, NY

PREPARED FOR:

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JUNE 18, 2007

1.0 INTRODUCTION

Terra Systems, Inc. (TSI) has completed a treatability study for Atlantic Richfield Company (ARCO) and Parsons to evaluate enhanced anaerobic bioremediation and three formulations of zero valent iron (ZVI) and carbon sources to remediate chlorinated ethenes and chlorinated ethanes in groundwater underlying the former Ekonol Polyester facility (the Site) in Wheatfield, New York. Tetrachloroethene (PCE), trichloroethene (TCE) and their daughter products cis-1,2-dichloroethene (cDCE), trans-1,2-dichloroethene (tDCE), and vinyl chloride (VC) and 1,1,1-trichloroethane (1TCA) and its daughter products 1,1-dichloroethane (1DCA), and 1,1-dichloroethene (1DCE) have been detected in groundwater at the Site above their respective NYS Groundwater Standards. Two areas of the Site were evaluated: the source area near RMW-4D with rock samples from MW-7D and a plume area near MW-20D with rock samples from MW-21D. The source area contains high levels of PCE, TCE, and cDCE and detectable levels of VC with much lower levels of 1TCA, 1DCE, and 1DCA. The plume area has little of the parent PCE or TCE, high cDCE concentrations, detectable VC, and somewhat higher levels of 1TCA, 1DCE, and 1DCA than in the source area.

Anaerobic biodegradation is a well-established methodology for the treatment of TCE and its daughter products. These chlorinated volatile organic compounds (CVOC) can be degraded to carbon dioxide (CO_2), methane (CH_4) and other innocuous products such as ethene or ethane via reductive dechlorination and other biological processes. Similarly, 1TCA undergoes anaerobic biotransformation to 1DCA and CA. There is also an abiotic, dehydroelimination reaction that can transform 1TCA to 1,1- 1DCE, VC, ethene, and potentially onto acetate. The study evaluated the potential for the addition of a slow-release substrate (emulsified soy bean oil) and a bioaugmented slow-release substrate to stimulate reductive dechlorination of PCE, TCE, cDCE, 1TCA, 1DCA, and 1DCE to ethene/ethane.

Three formulations of ZVI with carbon substrates were also evaluated. Two treatments were prepared with emulsified ZVI (EZVI); a nanoscale formulation with submicron ZVI particles (Toda American RNIP 10-DS with an average particle size of 70 nm) and a microscale formulation with an average particle size of 5 microns in diameter (BASF Carbonyl Iron Powder OM). The RNIP 10-DS ZVI is shipped in water and was not activated by washing with acid. The BASF Carbonyl Iron Powder was first washed with sulfuric acid to remove the iron oxide coating. The EZVI formulations for this study include 10.2% by weight ZVI, 37.4% soybean oil, 50.9% water, and 1.5% emulsifier. The vegetable oil emulsion coating the ZVI causes the chlorinated solvents to partition into the oil where it then reacts with the ZVI forming less chlorinated compounds and ultimately acetylene, ethene, and ethane. The oil coating should also protect the ZVI from oxidation which extends the time that the ZVI remains reactive. The oil and surfactants will be fermented to hydrogen. In addition, corrosion of the

iron with water may lead to hydrogen formation which can then support biological reductive dechlorination of the chlorinated solvents. The third ZVI containing material was Adventus ISCR EHC – a mixture of 45% by weight 5 to 35 micron diameter ZVI particles and 55% of a fibrous carbon matrix and other materials.

The treatability studies were performed to determine:

- If biodegradation of PCE, TCE, 1TCA, and 1DCA can be stimulated in Site rock and groundwater by the addition of carbon substrates;
- If the optimal biological microorganisms are present to facilitate biodegradation;
- If addition of the substrate, nutrients, and a dechlorinating culture can stimulate further biodegradation than the substrate alone; and
- If formulations combining ZVI and a carbon source can speed the dechlorination rates.

2.0 ROCK AND GROUND WATER CHARACTERIZATION

Rock samples were collected from the MW-21D on September 29, 2006 (plume area) and from MW-7D (source area) on October 3, 2006 by Jim Schuetz of Parsons. The samples were collected in steel tubes. The rock samples were shipped on the days they were collected and received at TSI on September 30, 2006 and October 4, 2006. After receipt at the laboratory, the rock samples were transferred from the steel tubes, broken into smaller pieces, and composited under anaerobic conditions.

Groundwater samples were collected and shipped from MW-20D (plume area) on September 28, 2006 and from RMW-4D (source area) on October 2, 2006. The samples were received at TSI on September 29, 2006 and October 3, 2006, respectively.

Portions of the rock and groundwater composites were then submitted for initial characterization. Table 1 summarizes the ground water and rock analytical results at the time of the October 2006 sampling event.

High concentrations (>1,000 µg/L) of PCE, TCE, and cDCE were detected in the groundwater sample from RMW-4D with lower concentrations (<1,000 µg/L) of 1TCA, 1DCA, and VC. Other volatile chlorinated ethenes and ethanes, acetylene, ethene, and ethane were not detected and a minor amount of methane was detected. Acetylene is produced by the abiotic reaction of zero valent iron or ferrous sulfide with PCE, TCE, and cDCE. Ethene and ethane may also be generated by the abiotic reaction with ZVI, but are characteristically produced by the biological reductive dechlorination of PCE and TCE and 1TCA. There was only 6.6 mg/L of total organic carbon (TOC) in the groundwater. Sulfate was the dominant electron acceptor (1,300 mg/L) with no-detectable nitrate or ferrous iron. The groundwater was analyzed by Microbial Insights of Rockford, TN for the numbers of *Dehalococcoides* (the only organism known to metabolize cDCE to VC and ethene) and *Dehalobacter* (known to convert PCE and TCE to cDCE and to be able to metabolize 1TCA to chloroethane) and the number of gene copies of the TCE-reductase (TCE R-Dase), VC R-Dase, and BAV1 VC R-Dase. BAV1 is an isolate from a site in Michigan that has different dehalogenase than the generic VC R-dase. High numbers of *Dehalococcoides* and *Dehalobacter* were found in the groundwater from RWM-4D with good expression of the TCE-, VC-, and BAV1 VC reductase genes. The rock sample from MR-7D contained only low levels of cDCE, TCE, PCE, methane, and ethane. The TOC of the rock was relatively low (540 mg/kg). The rock contained 2,600 mg/kg of total iron.

The plume area groundwater collected from MW-20D contained high levels (>1,000 µg/L) of cDCE with detectable, but lower levels of 1TCA, 1DCA, and VC. Methane, acetylene, ethene, and ethane were not detected. TOC was not detected above the detection limit of 5.0 mg/L; substrate availability probably controls the extent of dechlorination. There were modest levels of nitrate and ferrous iron in the

groundwater. Sulfate concentrations were high (1,200 mg/L) and sulfate is the dominant electron acceptor. Iron reduction may also be an important electron acceptor, but was not measured in these studies. The counts of *Dehalococcoides* and *Dehalobacter* were much lower in MW-20D. Detection of both the VC reductase genes suggests that the microbial population is capable of complete transformation of cDCE once substrate is available and more favorable conditions for dechlorination have been achieved.

The results of the initial rock/ground water analyses indicate that:

- The analytical data for CVOCs and natural attenuation parameters provide evidence of naturally occurring reductive dechlorination; and
- The high levels of sulfate and potentially iron may control the extent of dechlorination.

Section 3 presents the test conditions for the anaerobic bioremediation and ZVI studies. The results for the studies are presented in Section 4. Conclusions are presented in Section 5.

Table 1. Concentrations of CVOCs, Dissolved Hydrocarbon Gases, Electron Acceptors, and Dehalogenating Bacteria in Site Groundwater and Rock

Parameter	Units	RMW-4D (Source) Groundwater	MW-7D (Source) Rock	MW-20D Plume (Groundwater)	MW-21D (Plume) Rock
Alkalinity	mg/L as CaCO3	290		280	
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Nitrate	mg/L	<0.5		0.94	
Sulfate	mg/L	1300		1200	
Total Organic Carbon	mg/L or mg/kg	6.6	540	<5.0	930
Total Iron	mg/L or mg/kg	0.33	2600	0.22	3100
Percent Solids	%		99		96
Vinyl Chloride	µg/L or µg/kg	560	<2.0	590	9.1
Chloroethane	µg/L or µg/kg	<100	<2.0	<100	<2.0
1,1-Dichloroethene	µg/L or µg/kg	<100	<2.0	<100	<2.0
1,1-Dichloroethane	µg/L or µg/kg	150	<2.0	170	3.3
cis-1,2-Dichloroethene	µg/L or µg/kg	6310	21	3050	21
1,1,1-Trichloroethane	µg/L or µg/kg	160	<2.0	420	1.0
Trichloroethene	µg/L or µg/kg	15600	61	<100	5.8
Tetrachloroethene	µg/L or µg/kg	1040	9.9	<100	7.5
Methane	µg/L or µg/kg	200	42	<67	14
Ethene	µg/L or µg/kg	<120	<2.4	<120	<2.4
Ethane	µg/L or µg/kg	<120	43	<120	<2.4
Dehalococcoides spp.	cells/mL	1.16E+04		4.48E+01	
Dehalobacter spp.	cells/mL	3.62E+03		2.09E+02	
TCE R-Dase	cells/mL	3.13E-01		<4.99E-01	
BAV1 VC R-Dase	cells/mL	1.09E+04		9.63E+01	
VC R-Dase	cells/mL	2.92E+03		4.71E+00	

µg/L = micrograms per liter; µg/kg = micrograms per kilogram (rock); spp. = species; R-Dase = Reductase; mg/L = milligrams per liter; mg/kg = milligrams per kilogram (rock)

3.0 ANAEROBIC MICROCOSM STUDY

TSI completed the laboratory portion of the Anaerobic Microcosm Study at its Wilmington, Delaware facility between October 24, 2006 and February 14, 2007. The study evaluated the potential for the addition of a slow-release substrate (SRS™, TSI's emulsified soy bean oil) to stimulate reductive dechlorination of PCE, TCE, cDCE, 1TCA, 1DCA, and 1DCE to ethene/ethane. The SRS™ was added at 2,000 mg/L (0.8 mL SRS™ per 400 mL groundwater) which would provide about 1,010 mg/L of carbon. The SRS™ contains sodium lactate (4% by volume) as a fast-acting substrate to rapidly generate anaerobic conditions and well as yeast extract, nitrogen, and phosphorus. Other treatments evaluated the potential for SRS™ in combination with bioaugmentation to achieve complete dechlorination and three formulations of ZVI and carbon – nano EZVI, micro EZVI, and EHC. These treatments were compared to a poisoned control prepared with autoclaved rock and groundwater and amended with mercuric chloride and an unamended control. Triplicate microcosms were prepared for the source and plume areas for each treatment. Adventus recommended a loading rate of between 0.5 and 1% EHC. The 1% EHC loading rate (4 g EHC per 400 mL groundwater) was chosen which would provide about 1.8 g ZVI per bottle based upon a ZVI content of 45% for EHC. Similar loading rates of 1.8 g ZVI or 17.6 g EZVI were used for the nano and micro EZVI treatments. The EZVI formulation for these studies contained 10.2% by weight ZVI. The standard loading of EZVI was 44 g/L. Additional treatments were prepared with the nano EZVI and micro EZVI at lower (4.5 and 22 g/L) and higher (88 g/L) quantities of EZVI to determine the effect of different loading rates of EZVI on the rates and extent of degradation of the chlorinated solvents. The study procedures and results are presented in this section of the report.

3.1 MICROCOSM PREPARATION

Table 2 summarizes the individual microcosms that were prepared for this study and the quantities of groundwater, rock and amendments added to each microcosm. The killed controls demonstrate losses due to volatilization, sorption, or abiotic reactions as biological reactions are expected to be inhibited. However, the autoclaving process (steam at 121 ^{o}C and 15 pounds per square inch pressure) may change the properties of the soil or bedrock and potentially increase adsorption or release organics that can support microbial growth if any microorganisms survive the autoclaving process or addition of mercuric chloride. The unamended controls evaluate if the native microbial could biodegrade the CVOCs under existing conditions. Two sets of treatments were prepared with SRS™; one set was bioaugmented after two weeks with the Shaw SDC-9 culture. Additional treatments evaluated nano and micro-scale EZVI and EHC. The treatments were prepared using 500-milliliter (mL) amber bottles and were incubated for up to 16 weeks. Each treatment was prepared in triplicate. The microcosms were prepared with 160 g rock and 400 mL of groundwater and amendments. The

microcosms were prepared and sampled in an anaerobic chamber containing 3% hydrogen, 5% carbon dioxide and 92% nitrogen to ensure anaerobic conditions were maintained. The microcosms were incubated at 21°C in the dark throughout the study.

Because EHC generates a relatively large volume of gas, the septum of each lid was pierced with a needle and a 50 mL syringe used to collect the gases. To ensure equivalent losses in all treatments, syringes and needles were used for all bottles.

The sterile poisoned controls were prepared using autoclaved groundwater and composited rock to account for potential abiotic losses of 1TCA and TCE from the microcosm. The sterile control rock was autoclaved for 30 minutes at 120 ^{o}C and 15 pounds per square inch of steam on two successive days. These control microcosms were also amended with 1,000 mg/L of mercuric chloride to further reduce the potential for microorganism survival. A second aliquot of mercuric chloride was added to these bottles on Week 8. The sterile control treatments were amended with TCE and 1TCA in methanol. Approximately 12.5 mg/L of TOC was added with the methanol spike.

A solution of 1 mg/L resazurin was added to each microcosm as a visual indicator of oxidation-reduction potential (ORP). The microcosms remained clear when conditions are anaerobic and reducing, which are necessary for reductive dechlorination to occur. A pink color was observed when the microcosm is under aerobic, oxidizing conditions. Resazurin does not affect the biodegradation process and would not be added as part of a full-scale implementation. All of the microcosms became clear soon after they were set up indicating that there was sufficient organic matter in the rock and groundwater to support anaerobic conditions.

Additional aliquots of 2,000 mg/L SRS™ was added at Week 12 to treatments 3, 4, 10, and 11. The approximately 2,020 mg/L of carbon added to these microcosms should be sufficient to consume the 1,200 to 1,300 mg/L of sulfate in the source and plume area microcosms. Another 4 mL of SDC-9 bioaugmentation culture as added at Week 12 to treatments 4 and 11.

Table 1. Microcosm Amendments

No.	Treatment	Rock (g)	Liquid (mL)	Amendments
1A, 1B, 1C	Poisoned Control	160 g MW-7D	400 RMW-4D sterile groundwater	1,000 mg/L mercuric chloride, 1.0 mg/L resazurin, 10 mg/L TCE and 10 mg/L 1TCA spike
2A, 2B, 2C	Unamended	160 g MW-7D	400 RMW-4D groundwater	1.0 mg/L resazurin
3A, 3B, 3C	SRS™	160 g MW-7D	400 RMW-4D groundwater	2,000 mg/L SRS™, 1.0 mg/L resazurin
4A, 4B, 4C	SRS™ with Bioaugmentation	160 g MW-7D	400 RMW-4D groundwater	2,000 mg/L SRS™, 1.0 mg/L resazurin
5A, 5B, 5C	Nanoscale EZVI	160 g MW-7D	400 RMW-4D groundwater	44 g/L Nanoscale EZVI, 1.0 mg/L resazurin
6A, 6B, 6C	Microscale EZVI	160 g MW-7D	400 RMW-4D groundwater	44 g/L Microscale EZVI, 1.0 mg/L resazurin
7A, 7B, 7C	EHC	160 g MW-7D	400 RMW-4D groundwater	10 g/L EHC, 1.0 mg/L resazurin
15A, 15B, 15C	Nanoscale EZVI	160 g MW-7D	400 RMW-4D groundwater	A 4.5 g/L Nanoscale EZVI, 1.0 mg/L resazurin B 22 g/L Nanoscale EZVI, 1.0 mg/L resazurin C 88 g/L Nanoscale EZVI, 1.0 mg/L resazurin
Totals		4,320 g MW-7D	10,800 RMW-4D groundwater	
8A, 8B, 8C	Poisoned Control	160 g MW-21D	400 MW-20Dsterile groundwater	1,000 mg/L mercuric chloride, 1.0 mg/L resazurin, 10 mg/L TCE and 10 mg/L 1TCA spike
9A, 9B, 9C	Unamended	160 g MW-21D	400 MW-20D groundwater	1.0 mg/L resazurin
10A, 10B, 10C	SRS™	160 g MW-21D	400 MW-20D groundwater	2,000 mg/L SRS™, 1.0 mg/L resazurin
11A, 11B, 11C	SRS™ with Bioaugmentation	160 g MW-21D	400 MW-20D groundwater	2,000 mg/L SRS™, 1.0 mg/L resazurin
12A, 12B, 12C	Nanoscale EZVI	160 g MW-21D	400 MW-20D groundwater	44 g/L Nanoscale EZVI, 1.0 mg/L resazurin
13A, 13B, 13C	Microscale EZVI	160 g MW-21D	400 MW-20D groundwater	44 g/L Microscale EZVI, 1.0 mg/L resazurin
14A, 14B, 14C	EHC	160 g MW-21D	400 MW-20D groundwater	10 g/L EHC, 1.0 mg/L resazurin
16A, 16B, 16C	Microscale EZVI	160 g MW-21D	400 MW-20D groundwater	A 4.5 g/L Microscale EZVI, 1.0 mg/L resazurin B 22 g/L Microscale EZVI, 1.0 mg/L resazurin C 88 g/L Microscale EZVI, 1.0 mg/L resazurin
Totals		3,360 g MW-21D	8,400 MW-20D groundwater	

3.2 ANAEROBIC MICROCOSM SAMPLING AND ANALYSIS

Samples were collected from each microcosm for analysis after 0, 4, 8, 12, and 16 weeks of incubation. In addition, aqueous samples were collected on Week 2 from treatments 4A, 4B, 4C (source SRS™ + bioaugmentation); 7A (source EHC); 11A, 11B, 11C (plume SRS™ + bioaugmentation); 14A (plume EHC); 15A, 15B, 15C (source nano EZVI); and 16A, 16B, and 16C (plume micro EZVI) . Additional samples were collected from treatments 15A, 15B, 15C, 16A, 16B, and 16C after 6 weeks. Samples were collected from the microcosms within an anaerobic glove box to maintain anaerobic conditions. Samples were collected for CVOC and light hydrocarbon analyses. Aliquots (0.05 to 9 mL) of the samples to be analyzed by TSI for CVOCs in general accordance with SW-846 Method 8021B and for light hydrocarbons (acetylene, ethene, ethane, and methane) in general accordance with a modified SW 846 Method 8015 were transferred directly into a 20-mL headspace vial containing 1 mL of a 25% sodium chloride solution adjusted to pH 2.0 with phosphoric acid and enough distilled water to bring the entire volume of sample and sodium chloride solution to 10 mL. In addition, a 10 mL sample was collected at each time point to be analyzed for pH, redox potential (ORP), and alkalinity. At the end of the study (Week 16), sulfate samples were collected from the main study (treatments 1 to 14). After sampling, the withdrawn liquid was replaced with sterile glass beads. The volume of liquid in each microcosm decreased with each sampling point. However, this was thought to have little effect on the microcosms as the concentrations of chlorinated compounds within the aqueous phase remained the same and the glass beads are inert and not expected to change the reactivity of the bedrock or amendments.

4.0 RESULTS AND DISCUSSION

4.1 METABOLIC ACTIVITY IN ANAEROBIC MICROCOSMS

Metabolic activity refers to the level of anaerobic biological degradation that is occurring and has been evaluated in this study by measuring dissolved methane concentrations. The reduction in the sulfate concentrations and the presence of methane in a microcosm are indications that anaerobic microorganisms are present and actively biodegrading the organic substrate. Iron reduction may also have occurred, but was not measured in these studies. Much of the ferrous iron produced from iron reduction would likely react with sulfide generated by sulfate reduction. Abiotic reactions of the chlorinated solvents with ferrous sulfide may have occurred. Acetylene is sometimes produced from the reaction of TCE with ferrous sulfide and ZVI. Increases in methane concentrations following addition of an organic substrate to a microcosm indicate that the growth of methanogenic microorganisms can be stimulated. Methane was produced when other electron acceptors (e.g., oxygen, nitrate, sulfate, iron) have been depleted, and reductive dechlorination occurs most readily under these methanogenic conditions.

4.1.1 Source Area Microcosms. Sulfate concentrations were measured only in the initial characterization and at the last time point at Week 16. For the source area treatments, little change in the sulfate concentrations were seen with sterile control, unamended control, nano EZVI, or micro EZVI treatments. About 71% of the sulfate was removed in the SRS™-amended treatment 3 and over 99% with the SRS™ + bioaugmentation (treatment 4) and EHC (treatment 7).

Figure 1 presents the average dissolved methane concentrations for each source area microcosm set constructed with RMW-4D groundwater and MW-7D rock. Appendix I contains the data for all three replicates of each treatment and the data for the three source area treatments with varying loadings rates of nano EZVI and the three plume area treatments with the varying loading rates of micro EZVI. Average methane concentrations in the microcosms at the beginning of the study for the plume treatments ranged from 200 to 220 µg/L. Methane concentrations declined initially in all treatments. In the SRS™ + bioaugmentation microcosms, the maximum methane levels reached 5,200 µg/L. None of the other source area treatments produced appreciable methane.

4.1.2 Plume Area Microcosms. Partial sulfate depletion (26 to 60%) was seen in SRS™-amended treatment 10, SRS™ + bioaugmentation treatment 11, nano-EZVI, and EHC treatment 14. Sulfate remained the predominant electron acceptor. Iron reduction may also be important, but was not evaluated in these studies. Average methane concentrations in the plume area treatments ranged initially from 103 to 110 µg/L.

Methane levels fell to non-detect by week 8 (Figure 2). Low concentrations of methane were detected in the micro EZVI, SRS™, and nano EZVI treatments at weeks 12 and 16.

4.1.3 Microcosm Study Summary. The results of the microcosm study indicate:

- As expected, the sterile microcosms did not reduce the sulfate concentrations or produce appreciable methane;
- Growth of indigenous microorganisms can be stimulated through the addition of an organic substrate. This conclusion is based on decreases in sulfate concentrations observed in substrate-amended microcosms relative to the control microcosms; and
- Sulfate and potentially iron were the dominant electron acceptors in both areas of the site.

4.2 pH , ORP, AND ALKALINITY IN ANAEROBIC MICROCOSMS

Samples were collected from the all sixteen sets microcosms throughout the study to be analyzed for pH, oxidation-reduction potential (ORP), and alkalinity. ORP and pH were measured using 10 mL aliquots of the samples with pH and ORP probes and meters. Alkalinity was measured by titration with 0.02 N sulfuric acid to pH 3.8.

4.2.1 Source Area Treatments. Figures 3, 4, and 5 show the average pH, ORP, and alkalinity for each source area treatment excluding treatment 15 with the varying nano EZVI loadings. Appendix I provides the results of all of the pH, ORP, and alkalinity analyses.

The average initial pH in the source area treatments ranged between 6.4 and 6.8. During the study, the average pH dropped to 5.6 in the EHC treatment 7. The average pH remained relatively neutral (6.6 to 7.3) for the remaining treatments.

Oxidizing conditions (158 to 260 millivolts or mV) were found initially in source control treatment 1, source unamended control treatment 2, and the SRS™ amended treatment 3. The two control treatments remained oxidizing. Negative ORPs were found at Week 2 and thereafter in the other treatments with the lowest ORPs of -400 mV seen in the SRS™ + bioaugmentation treatment 4. The average ORP increased to -100 mV in weeks 12 and 16 for the micro EZVI and EHC treatments.

The initial average alkalinity levels were 200 mg/L $CaCO_3$ for the source sterile control treatment 1 and between 285 and 328 mg/L $CaCO_3$ for the remaining source area treatments. Alkalinity increased slightly with the unamended treatment 2 and micro EZVI with much larger increases with the SRS™, SRS™ + bioaugmentation, and EHC as sulfate was reduced and the fatty acids converted to bicarbonate.

4.2.2 Plume Area Treatments. Figures 6, 7, and 8 show the average pH, ORP, and alkalinity for each plume area treatment excluding treatment 17 with the varying micro EZVI loadings.

The source area treatments pH ranged between 6.4 and 6.8 . A drop to 5.8 was seen in the EHC treatment 14 at week 2. The average pH remained relatively neutral (6.4 to 7.3) thereafter.

Oxidizing conditions (167 to 269 mV) were found initially in source control treatment 8, source unamended control treatment 9, SRS™ amended treatment 10, and SRS™ + bioaugmentation treatment 11. The two control treatments remained oxidizing throughout the study. Negative ORPs were found at Week 2 and thereafter in the other treatments with the lowest ORPs of -370 mV seen in the SRS™ + bioaugmentation treatment 4. The average ORP increased to -157 to -12 mV in week 16 for the nano, micro EZVI, and EHC treatments.

The initial average alkalinity levels were 123 mg/L $CaCO_3$ for the plume sterile control treatment 8 and between 272 and 312 mg/L $CaCO_3$ for the remaining plume area treatments. Alkalinity decreased slightly with the unamended treatment 2 and changed little with micro EZVI and nano EZVI. Larger increases were observed with the SRS™, SRS™ + bioaugmentation, and EHC.

4.3 GAS COLLECTION IN ANAEROBIC MICROCOSMS

Adventus reported that EHC would generate a large volume of gas (carbon dioxide, methane, and hydrogen) that could potentially break the microcosm bottles if they were not vented. Syringes with needles were inserted into all of the microcosm bottles to collect the gas. Table 2 presents the volume of gas collected in each treatment over the first 15 days; no gas was produced after 15 days. There were low volumes of gas (<5.0 mL) produced with the sterile control, unamended, SRS™, SRS™ + bioaugmentation, nano EZVI, and micro EZVI. With EHC, the volume of gas ranged from 0 (microcosm 7C) to 53.5 mL (microcosm 7B) with greater than 10 mL in microcosms 7A and 14A. A sample of the gas was collected from treatment 7A on 10/30/06 (Day 5) and analyzed for VOC and dissolved hydrocarbon gases. Table 3 presents the results of this analysis. The air sample contained high levels of TCE (1,280 µg/L) and cDCE (5,660 µg/L), and lower levels of PCE, 1TCA, 1DCA, VC, and methane. The gas production from the EHC was stripping the contaminants from the groundwater.

Table 2. Gas Volume (mL) Collected in Microcosms

Bottle	Date	10/27/2006	10/28/2006	10/29/2006	10/30/2006	10/31/2006	11/1/2006	11/2/2006	11/3/2006	11/6/2006	11/9/2006	Cumulative
	Day	2	3	4	5	6	7	8	9	12	15	
1A	Source Sterile Control	0	0	0	0	0	0	0	0	0	0	0.0
1B	Source Sterile Control	0	0	0	0	0	0	0	0	0	0	0.0
1C	Source Sterile Control	0	0	0	0	0	0	0	0	0	0	0.0
2A	Source Unamended Control	0	0	0	0	0	0	0	0	0	0	0.0
2B	Source Unamended Control	0	0	0	0	0	0	0	0	0	0	0.0
2C	Source Unamended Control	0	0	0	0	0	0	0	0	0	0	0.0
3A	Source SRS™	0	0	0	0	0	0	0	0	0	0	0.0
3B	Source SRS™	0	0	0	0	0	0	0	0	0	0	0.0
3C	Source SRS™	0.5	0	0	0	0	0	0	0	0	0	0.5
4A	Source SRS™ + Bioaugmentation	0	0	0	0	0	0	0	0	0	0	0.0
4B	Source SRS™ + Bioaugmentation	0	0	0	0	0	0	0	0	0	0	0.0
4C	Source SRS™ + Bioaugmentation	0	0	0	0	0	0	0	0	0	0	0.0
5A	Source Nano EZVI	1	0	0	0	0	1	0	0	0	0	2.0
5B	Source Nano EZVI	0.5	0	0	0	0	0.5	0	0	0	0	1.0
5C	Source Nano EZVI	0	leak	0	0	0	1	0	0	0	0	1.0
6A	Source Micro EZVI	0.5	0	0	0	0	1	0	0	0	0	1.5
6B	Source Micro EZVI	0.5	0	0	0	0	0	0	0	0	0	0.5
6C	Source Micro EZVI	0	0	0	0	0	0	0	0	0	0	0.0
7A	Source EHC	7	27	0	1	3	0	0	0	0	0	38.0
7B	Source EHC	6.5	13	0	5	24	5	0	0	0	0	53.5
7C	Source EHC	0	0	0	0	0	0	0	0	0	0	0.0
8A	Plume Sterile Control	0	0	0	0	0	0	0	0	0	0	0.0
8B	Plume Sterile Control	0	0	0	0	0	0.5	0	0	0	0	0.5
8C	Plume Sterile Control	1	0	0	0	0	0	0	0	0	0	1.0
9A	Plume Unamended Control	0	0	0	0	0	0	0	0	0	0	0.0
9B	Plume Unamended Control	0.5	0	0	0	0	0	0	0	0	0	0.5
9C	Plume Unamended Control	0	0	0	0	0	0	0	0	0	0	0.0
10A	Plume SRS™	0	0	0	0	0	0	0	0	0	0	0.0
10B	Plume SRS™	0	0	0	0	0	0	0	0	0	0	0.0
10C	Plume SRS™	0	0	0	0	0	0	0	0	0	0	0.0
11A	Plume SRS™ + Bioaugmentation	0	0	0	0	0	0	0	0	0	0	0.0
11B	Plume SRS™ + Bioaugmentation	0	0	0	0	0	0	0	0	0	0	0.0
11C	Plume SRS™ + Bioaugmentation	0	0	0	0	0	0	0	0	0	0	0.0
12A	Plume Nano EZVI	0	0	0	0	0	0	0	0	0	1.5	1.5
12B	Plume Nano EZVI	0	0	0	0	1	0	0	0	0	1	2.0
12C	Plume Nano EZVI	0	0	0	2	0	0.5	0.5	0	1	0	4.0
13A	Plume Micro EZVI	1	0	0	0	0	0	0	0	0	0	1.0
13B	Plume Micro EZVI	0	0	0	0	0.5	0	0	0	0	1	1.5
13C	Plume Micro EZVI	0	0	0	1	0	0	0	0	0	0	1.0
14A	Plume EHC	13	33	0	0	0	0	0	0	0	0	46.0
14B	Plume EHC	6	0	0	2	0	0	0	0	0	0	8.0
14C	Plume EHC	0.5	0	0	0	0.5	4	0	0	0	0	5.0

Table 3. VOC and Dissolved Hydrocarbon Gases from Microcosm 7A on 10/30/06

Compound	Unit	Conc.
PCE	µg/L air	84
TCE	µg/L air	1280
cDCE	µg/L air	5663
tDCE	µg/L air	<12
1TCA	µg/L air	62
1DCE	µg/L air	<12
1DCA	µg/L air	69
CA	µg/L air	<12
VC	µg/L air	110
Methane	µg/L air	210
Acetylene	µg/L air	<12
Ethene	µg/L air	<14
Ethane	µg/L air	<14

4.4 CVOC BIODEGRADATION IN ANAEROBIC MICROCOSMS

Appendix I presents the analytical results for the source area anaerobic microcosms containing the RMW-4D groundwater and MW-7D rock and for the plume area microcosm containing the MW-20D groundwater and MW-21D rock. Figures presenting the average chlorinated ethene results for the various microcosms are summarized as follows:

Figure	Microcosm	Amendments
9	1	Source Sterile Control CE Average +/- Standard Deviation
10	2	Source Unamended Control CE Average +/- Standard Deviation
11	3	Source SRS™ CE Average +/- Standard Deviation
12	4	Source SRS™ + Bioaugmentation CE Average +/- Standard Deviation
13	5	Source Nano EZVI CE Average +/- Standard Deviation
14	6	Source Micro EZVI CE Average +/- Standard Deviation
15	7	Source EHC CE Average +/- Standard Deviation
16	15A	Source 4.5 g/L Nano EZVI CE
17	15B	Source 22 g/L Nano EZVI CE
18	15C	Source 88g/L Nano EZVI CE
19	8	Plume Sterile Control CE Average +/- Standard Deviation
20	9	Plume Unamended Control CE Average +/- Standard Deviation
21	10	Plume SRS™ CE Average +/- Standard Deviation
22	11	Plume SRS™ + Bioaugmentation CE Average +/- Standard Deviation
23	12	Plume Nano EZVI CE Average +/- Standard Deviation
24	13	Plume Micro EZVI CE Average +/- Standard Deviation
25	14	Plume EHC CE Average +/- Standard Deviation

26	16A	Plume 4.5 g/L Micro EZVI CE
27	16B	Plume 22 g/L Micro EZVI CE
28	16C	Plume 88g/L Micro EZVI CE

Figures presenting the average chlorinated ethane results for the various microcosms are summarized as follows:

Figure	Microcosm	Amendments
29	1	Source Sterile Control CA Average +/- Standard Deviation
30	2	Source Unamended Control CA Average +/- Standard Deviation
31	3	Source SRS™ CA Average +/- Standard Deviation
32	4	Source SRS™ + Bioaugmentation CA Average +/- Standard Deviation
33	5	Source Nano EZVI CA Average +/- Standard Deviation
34	6	Source Micro EZVI CA Average +/- Standard Deviation
35	7	Source EHC CA Average +/- Standard Deviation
36	15A	Source 4.5 g/L Nano EZVI CA
37	15B	Source 22 g/L Nano EZVI CA
38	15C	Source 88g/L Nano EZVI CA
39	8	Plume Sterile Control CA Average +/- Standard Deviation
40	9	Plume Unamended Control CA Average +/- Standard Deviation
41	10	Plume SRS™ CA Average +/- Standard Deviation
42	11	Plume SRS™ + Bioaugmentation CA Average +/- Standard Deviation
43	12	Plume Nano EZVI CA Average +/- Standard Deviation
44	13	Plume Micro EZVI CA Average +/- Standard Deviation
45	14	Plume EHC CA Average +/- Standard Deviation
46	16A	Plume 4.5 g/L Micro EZVI CA
47	16B	Plume 22 g/L Micro EZVI CA
48	16C	Plume 88 g/L Micro EZVI CA

CVOC concentrations presented on the figures are expressed in total micromoles (µMoles) units. Molar units were used so that each CVOC is expressed on an equivalent mass basis for comparison purposes. The micromolar concentrations are calculated by dividing the concentration in µg/L by the molecular weight of the CVOC (PCE = 165.8 grams per mole [g/mol], TCE = 131.4 g/mol; cis-DCE = 96.9 g/mol ; trans-DCE = 96.9 g/mol; VC = 62.5 g/mol; 1TCA = 133.4; 1,1-DCE = 96.9 g/mol; 1DCA = 99 g/mol; CA = 64.5 g/mol; VC = 62.5 g/mol; acetylene = 26 g/mol; ethene = 28 g/mol; and ethane = 30 g/mol). Table 4 presents the percent removal for the chlorinated ethenes, chlorinated ethanes, electron acceptors, and dissolved hydrocarbon gases for plume area treatments.

Non-detects were reported for many of the constituents at Week 4 due to the high dilutions used to bring the cDCE into the calibration range. The syringe and needle in all of the bottles contributed to the losses of the volatile constituents.

4.4.1 Source Area Treatments CVOC Results. The following summarizes the results for source area anaerobic microcosm treatments 1 to 7 containing Ekonol RMW-4D groundwater and MW-7D rock:

- Initial average PCE concentrations in these microcosms ranged from 897 µg/L (1 Sterile Control) to 3,387 µg/L (5 Nano EZVI). Average TCE concentrations ranged from 9,277 to 57,733 µg/L, cDCE from 1,453 to 58,367 µg/L, tDCE <100 to 867 µg/L, VC <100 to 1,297 µg/L, 1TCA 800 to 7,873 µg/L, 1DCE <100 to 1,447 µg/L, 1DCA <100 to 770 µg/L, and ethene <120 to 677 µg/L. CA, acetylene, and ethane were not detected in the initial samples. The sterile control treatment was spiked with TCE and 1TCA. Two of the three replicates in treatment 5 with the nano EZVI contained very high levels of PCE and TCE.
- Over the 16 week incubation period for the sterile control microcosms, there appeared to be losses of PCE, TCE, cDCE, 1TCA, and 1DCA, but no evidence for microbial activity based upon the removal of sulfate, accumulation of methane, or production of daughter products were observed. However, average losses of 100% of PCE, 88% TCE, 80% cDCE, 67% 1TCA, and 99% 1DCE were observed which might be attributed to partitioning into the headspace in the microcosm or adsorption onto the glass bottle, rock, or glass beads. The average total chlorinated ethenes excluding the dissolved gases dropped by 87% and the average chlorinated ethanes excluding the dissolved gases fell by 74%. At week 16, relatively low levels of PCE, TCE, cDCE, 1TCA, and ethane were found in the rock phase of microcosm 1A indicating some potential adsorption onto the rock organic fraction. Some of the groundwater containing these organics may have been collected with the rock fragments.
- There appeared to be limited losses of PCE, TCE, cDCE, 1TCA, 1DCA, and VC in the unamended control, but no further biodegradation to acetylene, ethene, or ethane. There was little evidence of microbial activity based upon the removal of sulfate, production of methane, or conversion of the parent compounds to daughter products. Average losses of 61% of the chlorinated ethenes excluding the gases and 98% of the chlorinated ethanes excluding the gases were observed. PCE, TCE, cDCE, 1TCA, and methane were found in the rock sample at Week 16.

Table 4. Percent Removals of Average Concentrations for Source Area Treatments Over 16 Week Incubation

Source	1	2	3	4	5	6	7	15-A	15-B	15-C
Treatment	Sterile	Unamended	SRS™	SRS™+Bioaug	44 g/L Nano EZVI	Micro EZVI	EHC	4.5 g/L Nano EZVI	22 g/L Nano EZVI	88 g/L Nano EZVI
Methane	100.0	100.0	100.0	-1638.5	100.0	97.8	100.0	>39.1	>70.0	86.4
PCE	100.0	94.1	99.1	100.0	99.6	99.4	100.0	>91.1	>94.6	>99.4
TCE	88.2	66.8	99.8	100.0	99.8	99.6	100.0	>99.4	>99.6	99.9
cDCE	79.8	51.4	8.7	29.3	88.9	78.4	70.2	30.1	21.3	76.2
tDCE					100.0		100.0	>78.7	>89.1	>98.9
1TCA	67.5	98.8	95.9	100.0	100.0	100.0	100.0	>87.2	>48.7	>98.6
1DCE	99.0		100.0	100.0	100.0	100.0	100.0	>79.2	>89.1	>98.9
1DCA		98.1	98.0	100.0	98.9	97.4		>73.7	>86.5	>98.6
CA										
VC		100.0	98.1	-702.6	98.8	98.0	100.0	>85.7	53.0	74.5
Acetylene										
Ethene					40.4	33.2	-113.5	54.2	14.7	-81.5
Ethane									>-350.0	>-450.0
Sum CE-Gases	87.5	60.9	52.3	29.8	93.8	88.7	84.2	63.1	56.1	86.2
Sum CA-Gases	73.9	98.5	98.3	100.0	99.7	99.1	100.0	100.0	100.0	100.0
Sulfate	15.4	23.3	71.3	99.6	37.4	-69.7	99.8			

Blank cells designate that the constituents were not detected or measured at the beginning or end of the study.

- Negative signs indicate an increase in concentrations.

> Signs indicate that the constituent was reduced to below the detection limit for that constituent, the percent removal was reported as greater than initial concentration minus the final detection limit divided by the initial concentration times 100.

< Signs indicate that the constituent was initially below the detection limit for that constituent, the percent removal was reported as less than the initial detection limit minus the final concentration divided by the initial detection limit times 100.

- The microcosms amended initially with SRS™ showed almost complete conversion of the PCE and TCE to cDCE by Week 4, but little further conversion to VC was observed with no acetylene or ethene production. Slow losses of 1TCA, 1DCA, and 1DCE were also observed with no conversion of 1TCA to daughter products. Total chlorinated ethenes without the gases declined by 52% and chlorinated ethanes without the gases by 98%. About 71% of the sulfate was depleted, but no methane was produced. Some PCE, TCE, and cDCE were found in the rock fraction at week 16 indicating adsorption to the rock organic fraction or potentially that low concentrations of these compounds persisted; a lower dilution was run for the rock samples than the groundwater samples.
- The microcosms amended with SRS™ and bioaugmented on Week 2 achieved complete reduction of PCE and TCE to cDCE within 4 weeks with further transformation to VC in two replicates between Weeks 12 and 16. Acetylene, ethene, or ethane had not yet been produced in these replicates by Week 16. Chlorinated ethanes were gradually reduced over the study. 1DCE and 1DCA were not detected at Week 4 (Figure 32), possibly due to the high dilution needed for the chlorinated ethenes. Sulfate was depleted in all three replicates and methane was produced in all 3 replicates. Average total chlorinated ethenes without the gases declined by 30% and total chlorinated ethanes without the gases were not detected at Week 16. Again, PCE, TCE, cDCE, and methane were detected at relatively low levels in the rock phase due to adsorption to the rock organics or the lowered detection limits.
- There were gradual losses of PCE, TCE, cDCE, and VC in the treatment with the 44 g/L nano EZVI without production of cDCE at the intervals that were sampled. The total chlorinated ethenes without the gases declined by 94%. Acetylene, ethene, and ethane were detected in these treatments. 1TCA was consumed within four weeks. Slow losses of 1DCE and 1DCA were observed with only a low level of 1DCA being detected at week 16; total chlorinated ethanes without the gases were reduced by 99.7%. Most of the removal of the chlorinated ethenes and ethanes appeared to be a result of reaction with the ZVI as there was only limited removal of the sulfate and no methane production which would be expected if biological activity was responsible for the decreases.
- In the treatments with the source area rock and groundwater with the different loadings of nano EZVI (4.5, 22, and 88 g/L), there were relatively slow removals of TCE, with the production of cDCE (in contrast to the treatments with 44 g/L nano EZVI). As the concentration of nano EZVI increased, so did the production of acetylene, ethene, and ethane. Overall removals of chlorinated ethenes were 63% for the 4.5 g/L loading, 56% for the 22 g/L loading, and 86% for the 88 g/L loading. Chlorinated ethanes were eliminated in all loading experiment treatments and 2 of the 3 replicates with 44 g/L nano EZVI. Low levels of PCE, TCE, cDCE, VC, and 1DCA were found in the rock phase of bottle 15C (88g/L).

- The micro EZVI performed similarly to the nano EZVI with the gradual removal of PCE, TCE, cDCE, VC, 1TCA, 1DCE, and 1DCA. The average percent removal of chlorinated ethenes without gases in these treatments were 89% and 99% for the chlorinated ethanes without gases. Sulfate was not utilized and only a little methane was produced. Low levels of PCE, TCE, cDCE, and methane were found in the rock phase.
- EHC appeared to provide a slower, less efficient removals of the PCE, TCE, cDCE, and VC than the nano EZVI or micro EZVI. EHC was effective against the chlorinated ethanes, resulting in the reduction to below the detection limits. Acetylene, ethene, and ethane were produced. Overall removal efficiencies for the chlorinated ethenes and chlorinated ethanes (excluding gases) were 84 and 100%, respectively. Sulfate was consumed, but no methane was produced. The rock phase at week 16 contained low levels of PCE, TCE, cDCE, methane, acetylene, ethene, and ethane.

4.4.2 Plume Area Treatments CVOC Results. The following summarizes the results for source area anaerobic microcosm treatments 1 to 7 containing Ekonol MW-20D groundwater and MW-21D rock:

- The plume area wells did not contain detectable levels of TCE and PCE, except for the spiked sterile control where there was an average of 4,113 µg/L. Average cDCE concentrations ranged from 638 to 23,568 µg/L, tDCE <100 to 303 µg/L, VC <100 to 1,297 µg/L, 1TCA 850 to 3,753 µg/L, 1DCE 463 to 637 µg/L, 1DCA <100 to 483 µg/L, and ethene <120 to 553 µg/L. CA, acetylene, and ethane were not detected in the initial samples.
- Over the 16 week incubation period for the sterile control microcosms, there were losses of TCE, cDCE, 1TCA, and 1DCE, but no evidence for microbial activity based upon the removal of sulfate, accumulation of methane, or production of daughter products were observed. The average total chlorinated ethenes excluding the dissolved gases dropped by 80% and the average chlorinated ethanes excluding the dissolved gases fell by 55%. At week 16, relatively low levels of PCE, TCE, cDCE, 1TCA, and 1DCA were found in the rock phase of microcosm 8A indicating some potential adsorption onto the rock organic fraction. Some of the groundwater containing these organics may have been collected with the rock fragments.
- There appeared to be limited losses of cDCE, tDCE, 1TCA, 1DCE, 1DCA, and VC in the unamended control. There was little evidence of microbial activity based upon the removal of sulfate, production of methane, or conversion of the parent compounds to daughter products. Low levels of ethene and ethane were detected at Week 16 in all three replicates. Average losses of 61% of the chlorinated ethenes excluding the gases and 80% of the chlorinated ethanes

Table 5. Percent Removals of Average Concentrations for Plume Area Treatments Over 16 Week Incubation

Plume	8	9	10	11	12	13	14	16-A	16-B	16-C
Treatment	Sterile	Unamended	SRS™	SRS™+Bioaug	Nano EZVI	44 g/L Micro EZVI	EHC	4.5 g/L Micro EZVI	22 g/L Micro EZVI	88 g/L g Micro EZVI
Methane	100.0	100.0	77.3	100.0	84.2	71.6	100.0	>96.9	>96.9	95.8
PCE										
TCE	79.2									
cDCE	81.4	56.2	74.6	68.4	69.5	81.1	33.9	94.5	88.8	96.1
tDCE		100.0						>98.9	>98.9	
1TCA	47.7	66.1	45.9	78.6	100.0	95.5	100.0	>99.6	>99.4	>99.8
1DCE	95.1	100.0	100.0	100.0	100.0	100.0	100.0	>99.3	>98.9	
1DCA		81.2	69.7	76.3	78.9	82.1	54.0	85.3	87.4	97.1
CA										
VC		100.0	88.2	85.1	53.4	86.5	73.5	97.5	94.0	98.4
Acetylene										
Ethene					85.6	58.6	-9.8	89.8	79.3	95.3
Ethane									<37.5	<80.3
Sum CE-Gases	79.6	61.3	75.6	70.2	67.6	81.8	38.2	94.8	89.8	96.4
Sum CA-Gases	54.6	80.1	68.4	85.2	94.3	93.2	86.9	96.6	96.5	98.6
Sulfate	-25.0	-27.8	33.6	25.8	26.1	-13.9	59.7			

Blank cells designate that the constituents were not detected or measured at the beginning or end of the study.
- Negative signs indicate an increase in concentrations.
> Signs indicate that the constituent was reduced to below the detection limit for that constituent, the percent removal was reported as greater than initial concentration minus the final detection limit divided by the initial concentration times 100.
< Signs indicate that the constituent was initially below the detection limit for that constituent, the percent removal was reported as less than the initial detection limit minus the final concentration divided by the initial detection limit times 100.

excluding the gases were observed. PCE, TCE, cDCE, 1TCA, 1DCA, ethene, and ethane were found in the rock sample at Week 16.

- The plume microcosms amended initially with SRS™ showed slow reductions in cDCE and VC concentrations. Relatively low levels of ethene were detected at Week 16 in all three replicates. Slow losses of 1TCA, 1DCA, and 1DCE were also observed with no apparent conversion of 1TCA to daughter products. Total chlorinated ethenes without the gases declined by 74% and chlorinated ethanes without the gases by 61%. About 34% of the sulfate was depleted. Methane concentrations dropped to non-detect in all 3 replicates, but was found at 75 µg/L at Week 16 in treatment 10A. cDCE, 1TCA, 1DCA, methane, and ethane were found in the rock fraction at week 16 indicating adsorption to the rock organic fraction or potentially that low concentrations of these compounds persisted; a lower dilution was run for the rock samples than the groundwater samples.
- The microcosms amended with SRS™ and bioaugmented on Week 2 showed gradual losses of cDCE and VC. Ethene and/or ethane were detected at Week 16 in all 3 replicates. Sulfate concentrations at week 16 ranged from 430 to 1,400 mg/L; sulfate was partially depleted in only one of the three replicates and methane was not produced. Average total chlorinated ethenes without the gases declined by 70% and total chlorinated ethanes without the gases declined by 85%. PCE, TCE, cDCE, 1TCA, 1DCA, VC, and ethane were detected at relatively low levels in the rock phase due to adsorption to the rock organics or the lowered detection limits.
- There were gradual losses of cDCE and VC in the treatment with the 44 g/L nano EZVI. The total chlorinated ethenes without the gases declined by 68%. Ethene was detected at Week 0 in all three replicates, but fell to non-detect at Week 4. Both ethene and ethane were produced in these treatments. 1TCA was consumed within four weeks with slower losses of 1DCE and 1DCA. Only a low level of 1DCA was detected at week 16; total chlorinated ethanes without the gases were reduced by 94%. Most of the removal of the chlorinated ethenes and ethanes seemed to be a result of reaction with the ZVI as there was only limited removal of the sulfate and little methane production which would be expected if biological activity was responsible for the decreases.
- The micro EZVI performed similarly to the nano EZVI with the gradual removal of cDCE, VC, 1TCA, 1DCE, and 1DCA. The average percent removal of chlorinated ethenes without gases in these treatments were 82% and 93% for the chlorinated ethanes without gases. Sulfate was not utilized and only a little methane was produced. Low levels of PCE, TCE, cDCE, and methane were found in the rock phase at Week 16.

- In the treatments with the plume area rock and groundwater with the different loadings of micro EZVI (4.5, 22, and 88 g/L), there were relatively slow removals of cDCE and VC. Ethene was detected in most of the treatments at Week 0, but fell to non-detect levels by Week 2 or 4. Ethene and ethane were produced from Weeks 6 to 16, but only a trace of acetylene. Overall removals of chlorinated ethenes were 95% for the 4.5 g/L loading, 90% for the 22 g/L loading, and 96% for the 88 g/L loading. Chlorinated ethanes were reduced by 97, 96, and 99%, respectively at the three loadings. Low levels of PCE, TCE, cDCE, methane, acetylene, ethene, and ethane were found in the rock phase of bottle 16C.
- EHC provided similar removal rates of the cDCE and VC as the nano EZVI or micro EZVI. EHC was effective against the chlorinated ethanes, resulting in the reduction to below the detection limits. Ethene and ethane were produced. Overall removal efficiencies for the chlorinated ethenes and chlorinated ethanes (excluding gases) were 38 and 87%, respectively. However, it appeared that at least a portion of the removal observed for EHC was due to stripping with the gas formed from EHC. Sulfate concentrations were reduced by 60%, but no methane was produced. The rock phase at week 16 contained low levels of cDCE, 1DCA, methane, ethene, and ethane.

5.0 CONCLUSIONS

Conclusions of the bioremediation evaluation based on the results presented in this report are as follows:

- The growth of indigenous microorganisms at the Ekonol site can be stimulated through the addition of an organic substrate such as SRS™. This conclusion is supported by the observed increases in metabolic activity including sulfate and iron reduction through the addition of SRS™ or EHC. Bioaugmentation with a dechlorinating enrichment promoted sulfate and potentially iron reduction and methane production in the source area microcosms, but not the plume area microcosms (at least by Week 16).
- The high levels of sulfate and potentially iron controlled the rate and extent of dechlorination of the PCE, TCE, and cDCE in both the source and plume areas. Only in two replicates of the SRS™ bioaugmentation treatment were substantial methane and VC produced. Further transformation to ethene may occur in subsequent weeks once the sulfate and iron are depleted. Although sulfate concentrations were reduced by between 26 to 60% in the plume area treatments, sulfate levels remained above 330 mg/L; a level where sulfate-reduction would complete with cDCE dechlorination to VC for electron donors.
- Based upon the increases in VC concentrations in at Week 16 in two of three replicates (Figure 12), a slow release substrate and bioaugmentation may be a potential treatment to be considered for full-scale implementation in the source area. A slow release substrate would require much less frequent injection than a soluble substrate such as sodium lactate and will not require groundwater recirculation, but would likely require delivery through multiple injection points.
- The micro and nano EZVI both performed well with removals of 68 to 94% of the chlorinated ethenes and 93 to 99.7% of the chlorinated ethanes. In the source area with higher concentrations of chlorinated ethenes, the nano EZVI outperformed the micro EZVI. The intermediate loading (44 g EZVI/L) of the nano EZVI gave more complete removals of the chlorinated ethenes and ethanes than the lower and higher loadings (4.5, 22, and 88 g EZVI/L). In the plume area with only cDCE and higher levels of 1TCA, the micro EZVI performed better than nano EZVI and the highest loading of 9.0 g ZVI /L of the micro EZVI gave the highest removal efficiency of 96% of the chlorinated ethenes and 99% of the chlorinated ethanes.
- EHC resulted in the removal of almost all of the sulfate in the source area treatments and a substantial reduction in the plume area. However, chlorinated solvent removal efficiencies for the EHC were not as high as the nano and micro EZVI. Chlorinated ethene removal efficiencies ranged from 38 to 84% and 87 to

100% for the chlorinated ethanes. A portion of the removal was due to stripping from the gas formed by EHC.

The results of this study indicate that enhanced natural attenuation may be a viable remedial alternative for the Ekonol Facility to address the chlorinated VOC plumes. More complete transformation of the VOCs was obtained during the 16 week long study with the micro and nano EZVI than EHC or SRS™ with and without bioaugmentation. The micro EZVI will be significantly cheaper than the nano EZVI because of the price differential between micro ZVI ($2-5 per pound) versus nano ZVI (greater than $20 per pound). The micro EZVI outperformed the nano-EZVI in the plume studies and gave relatively similar results in the source area. Based upon the lower costs and similar removal efficiencies, the micro EZVI is recommended for a field-scale pilot test to evaluate remedial performance. If micro EZVI is selected for a pilot scale study, it is recommended that the injection of the micro EZVI be monitored for at least six months to determine if the material can be effectively distributed.

FIGURES

Figure 1. Methane Concentrations Source Average +/- Standard Deviation

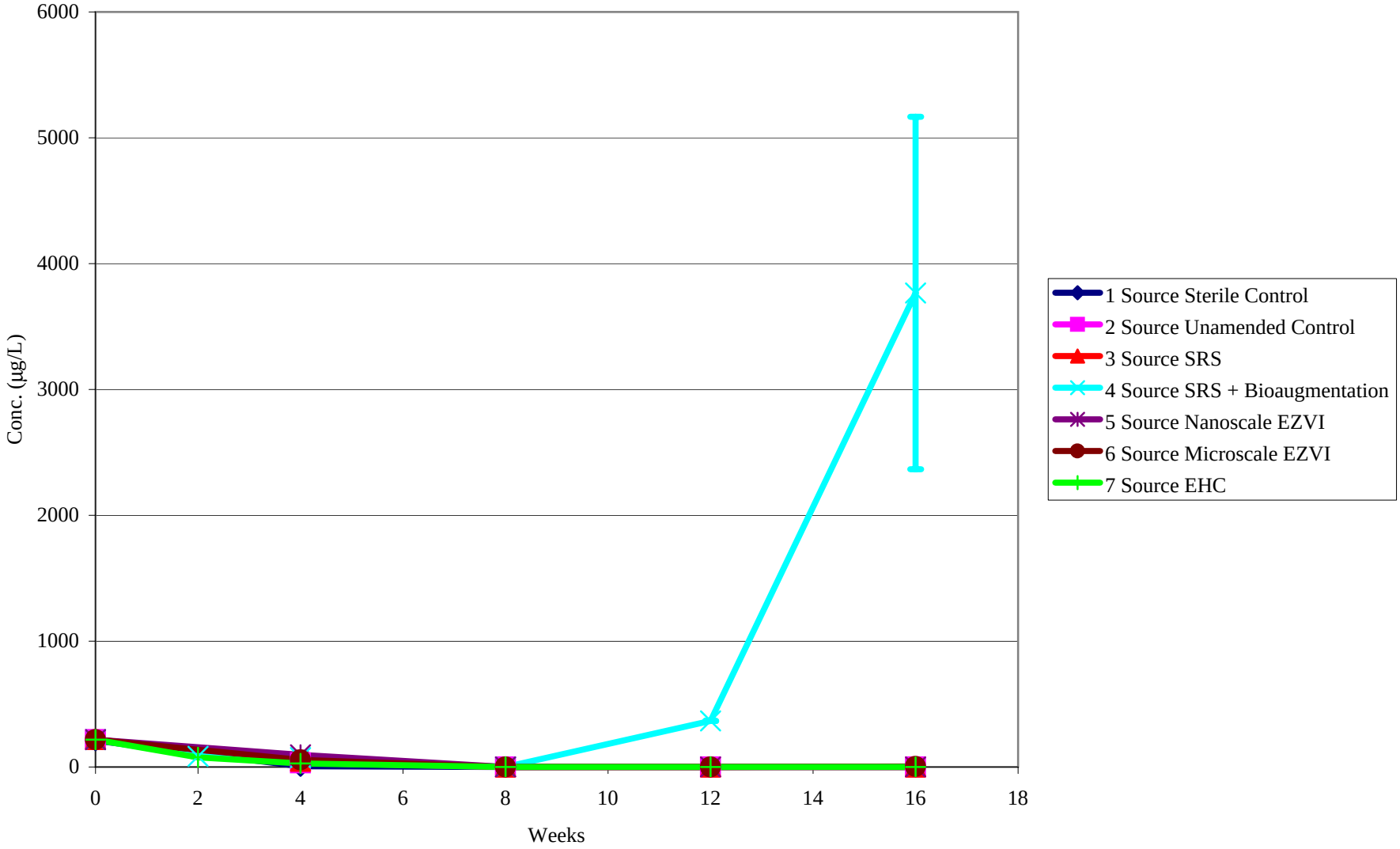


Figure 2. Methane Concentrations Plume Average +/- Standard Deviation

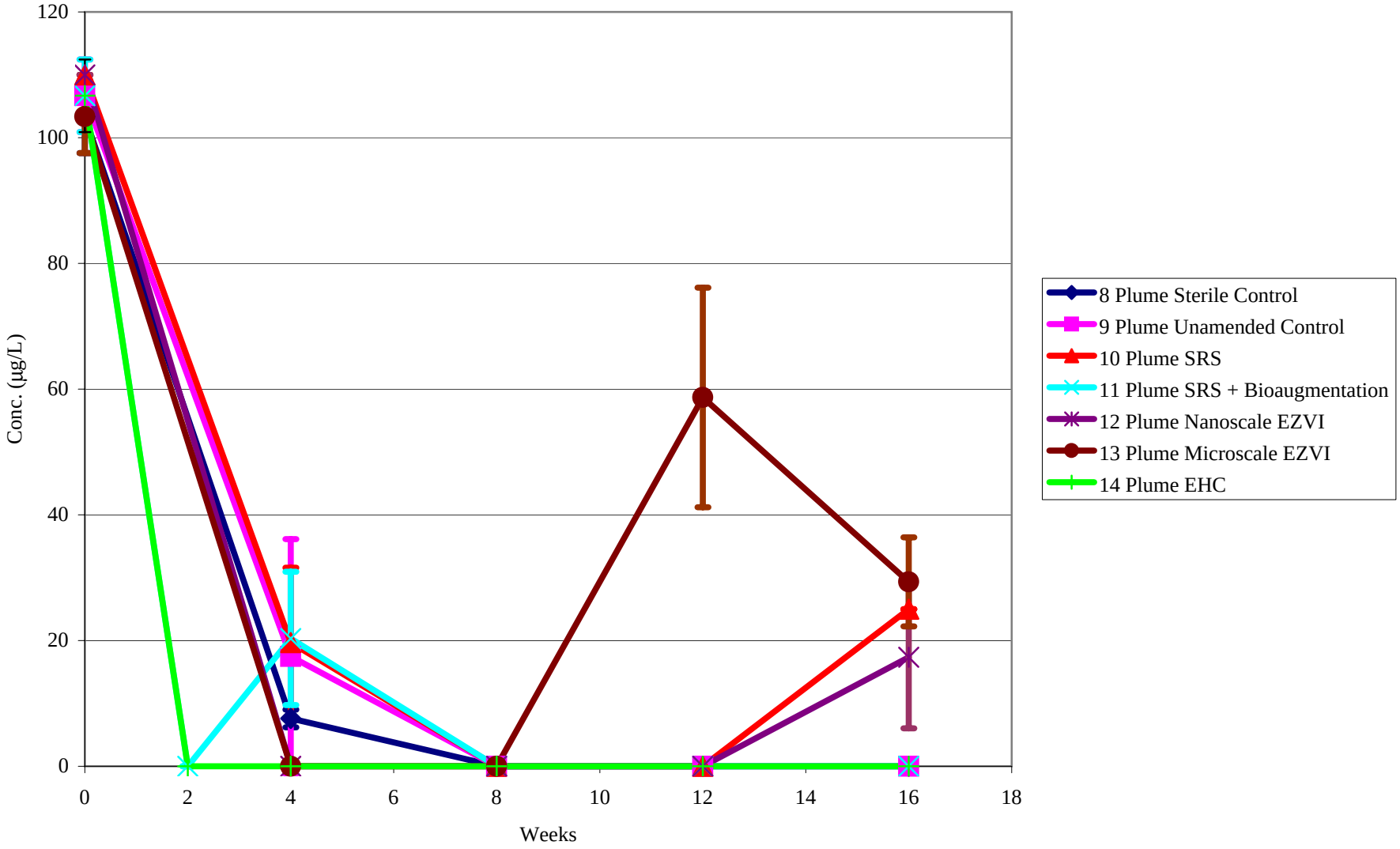


Figure 3. pH Source Treatments Average +/- Standard Deviation

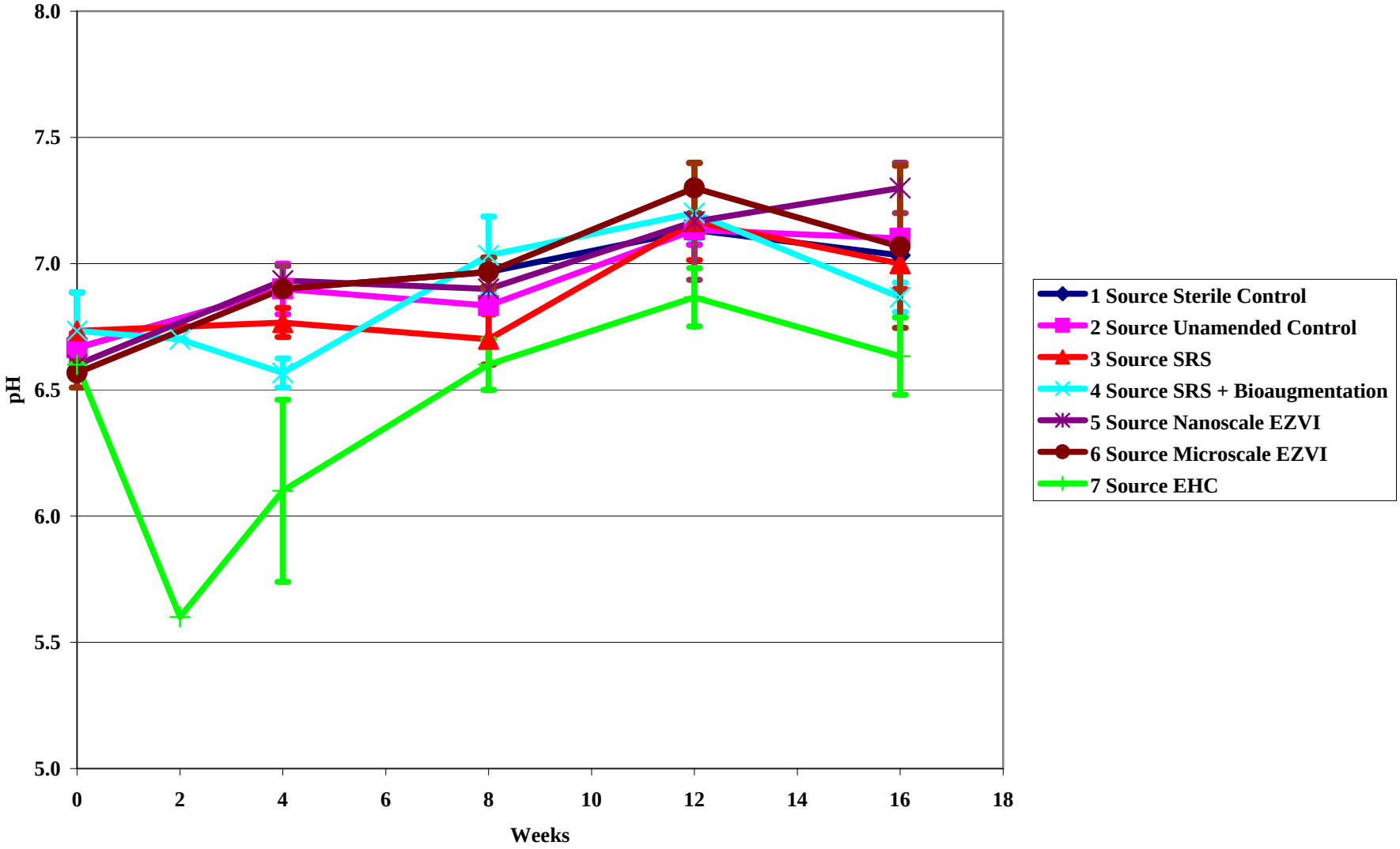


Figure 4. ORP Source Treatments Source Treatments Average +/- Standard Deviation

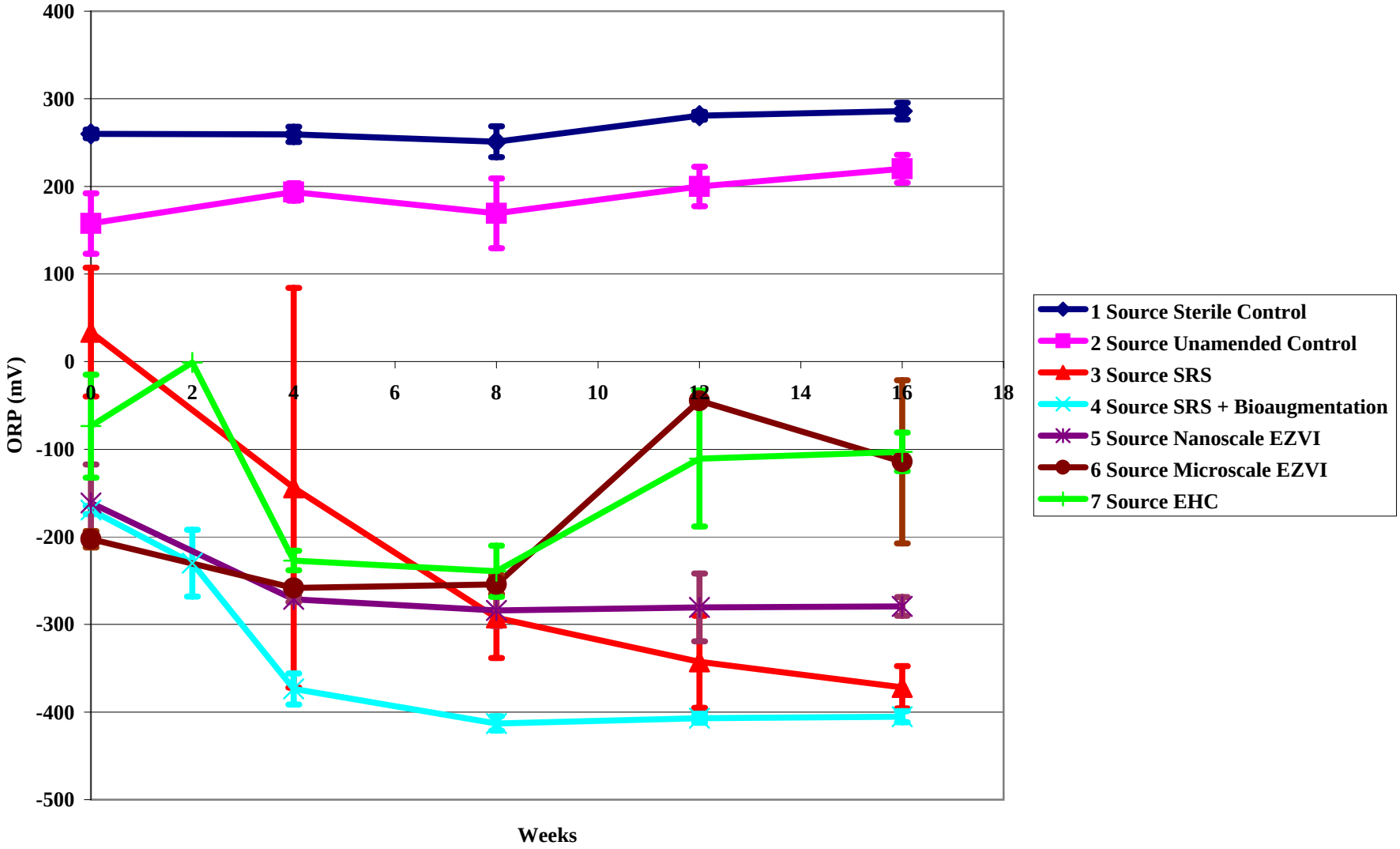


Figure 5. Alkalinity Source Treatments Average +/- Standard Deviation

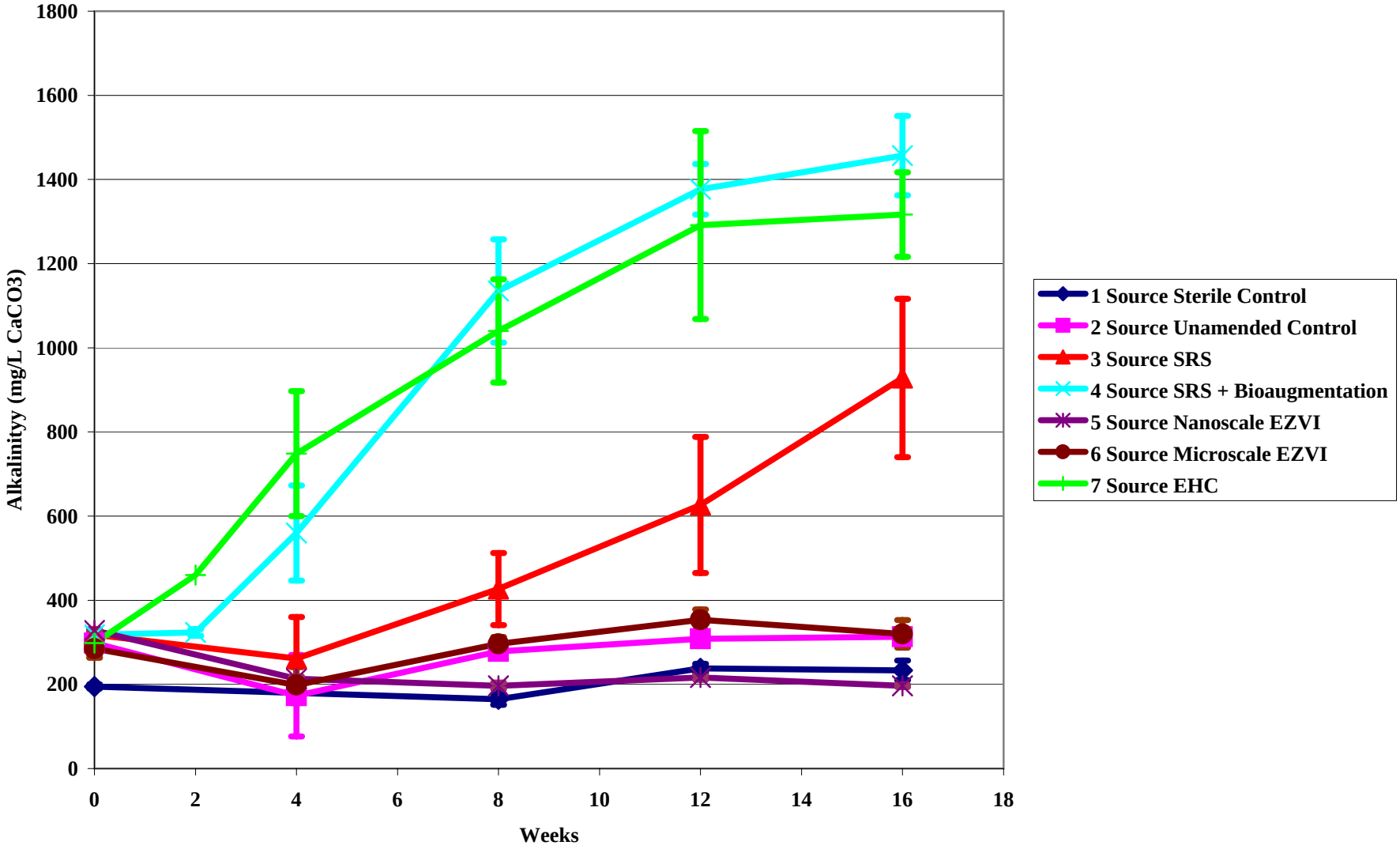


Figure 6. pH Plume Treatments Average +/- Standard Deviation

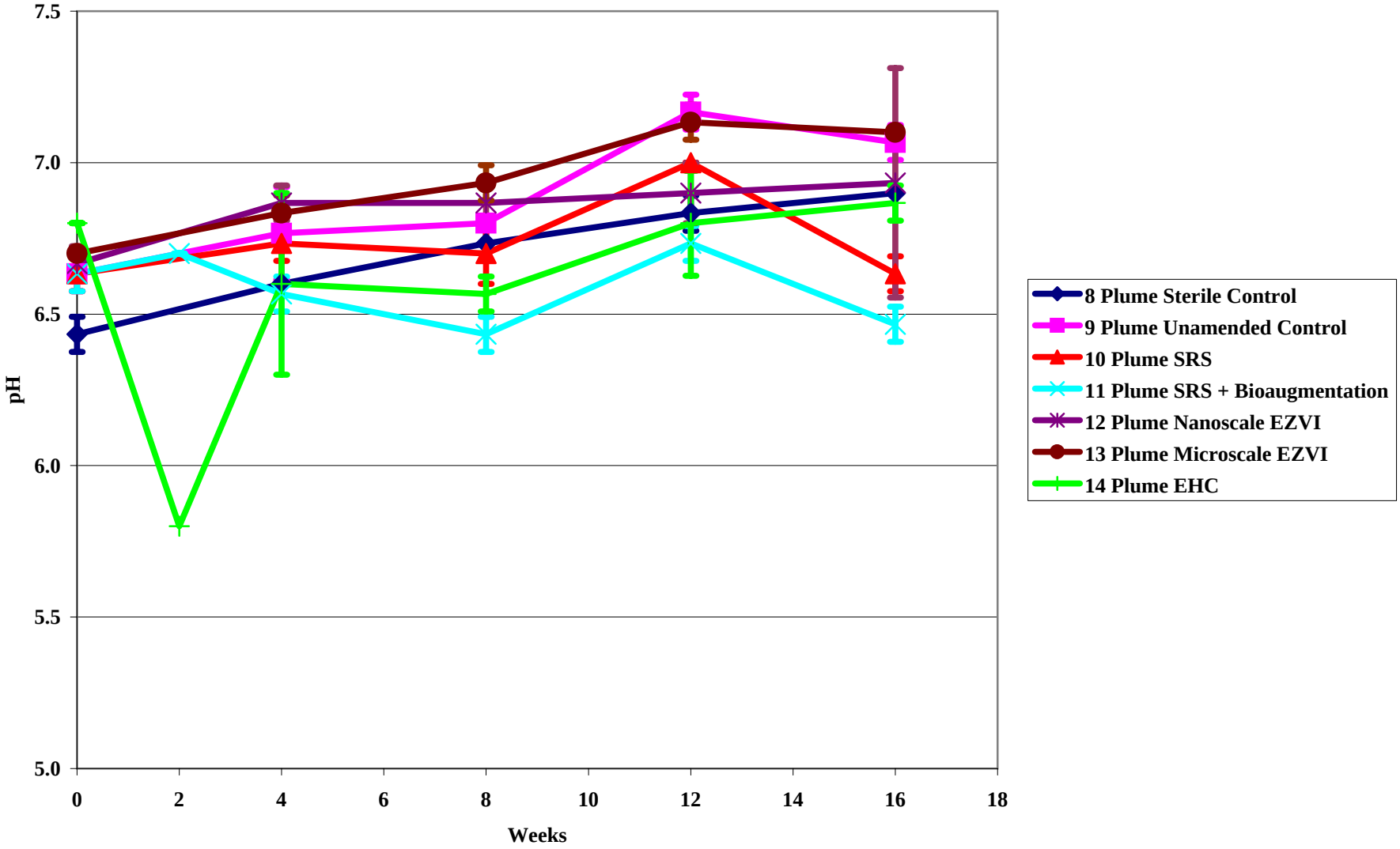


Figure 7. ORP Plume Treatments Average +/- Standard Deviation

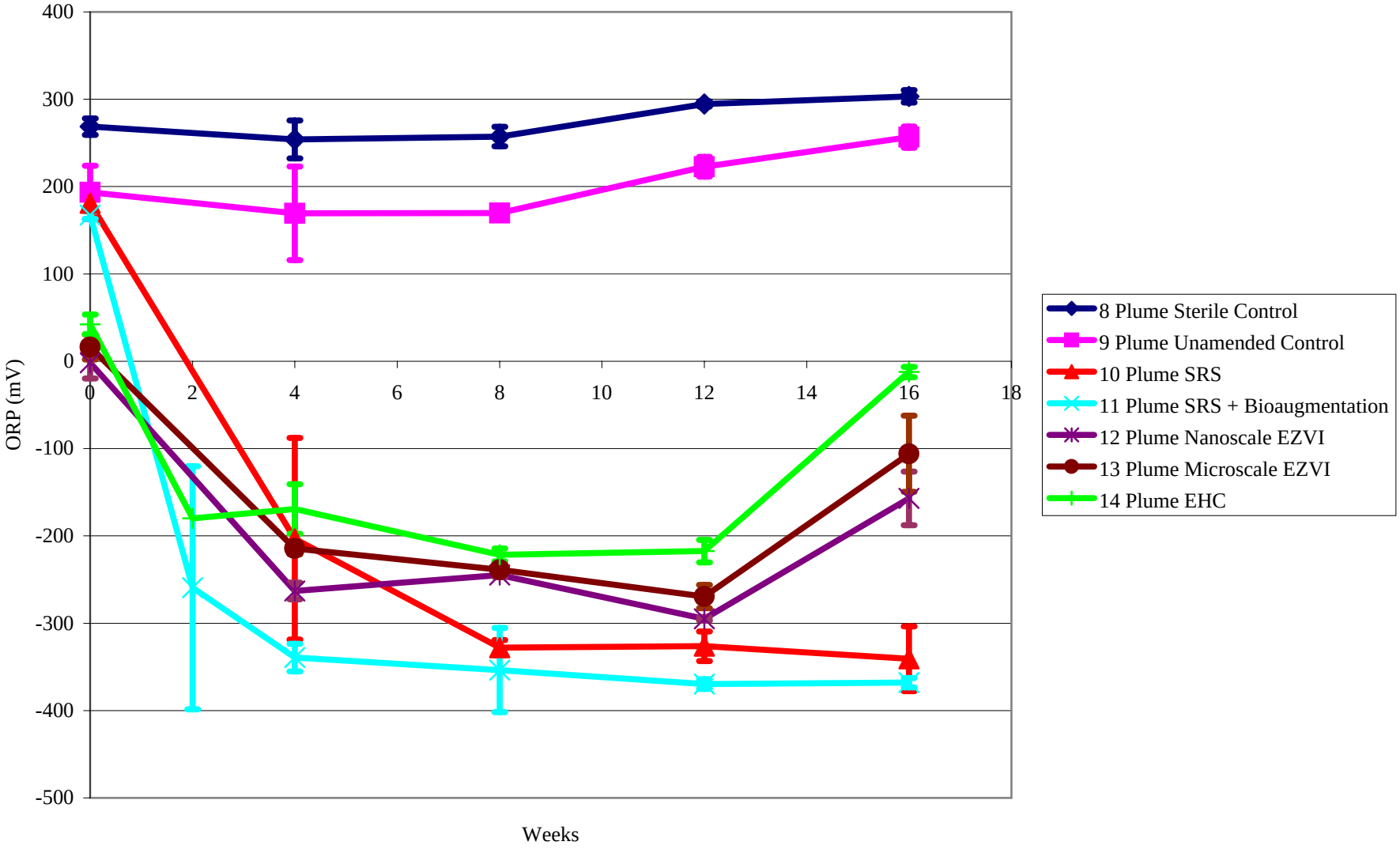


Figure 8. Alkalinity Plume TreatmentsAverage +/- Standard Deviation

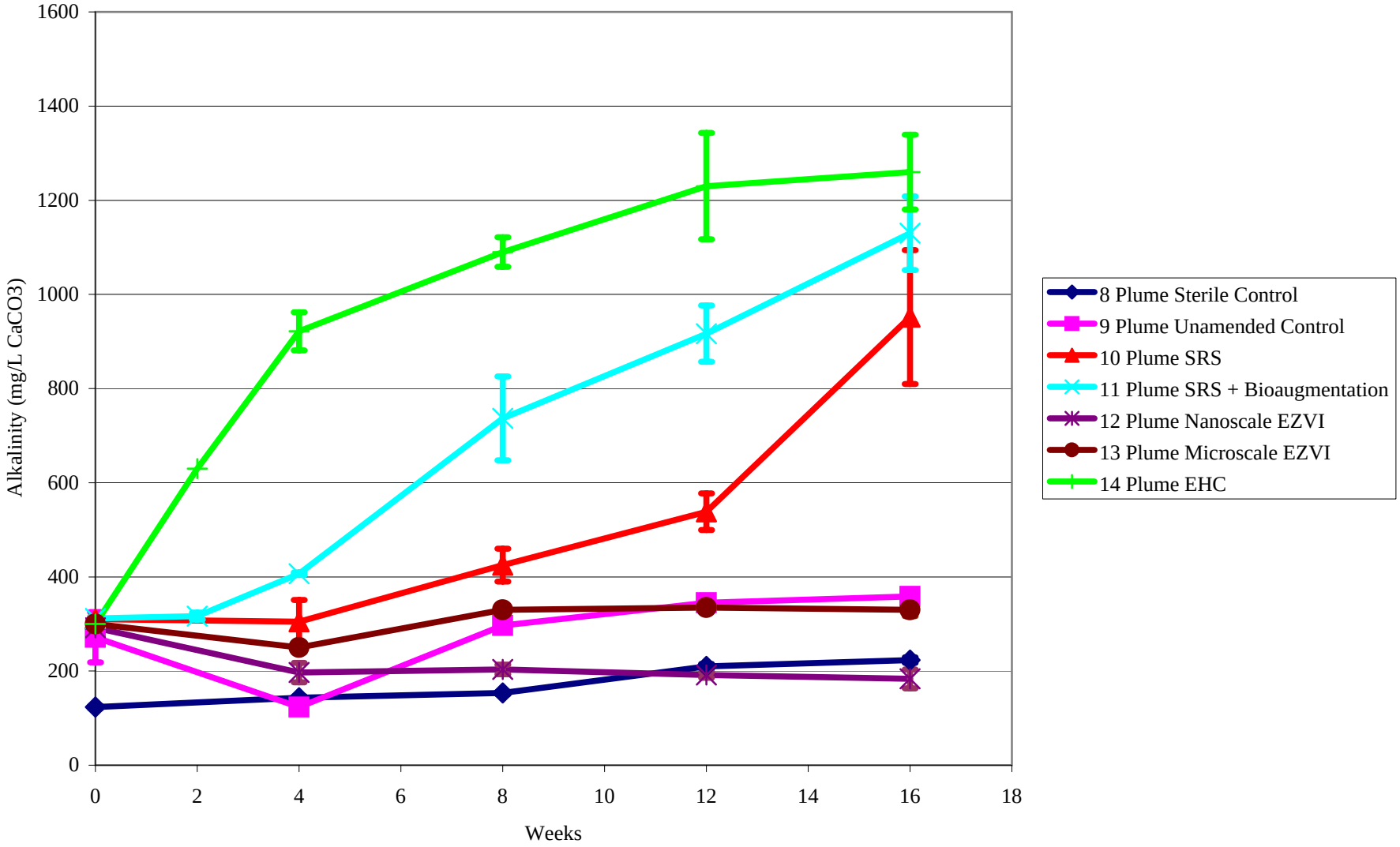


Figure 9 Source Sterile Control CE Average +/- Standard Deviation

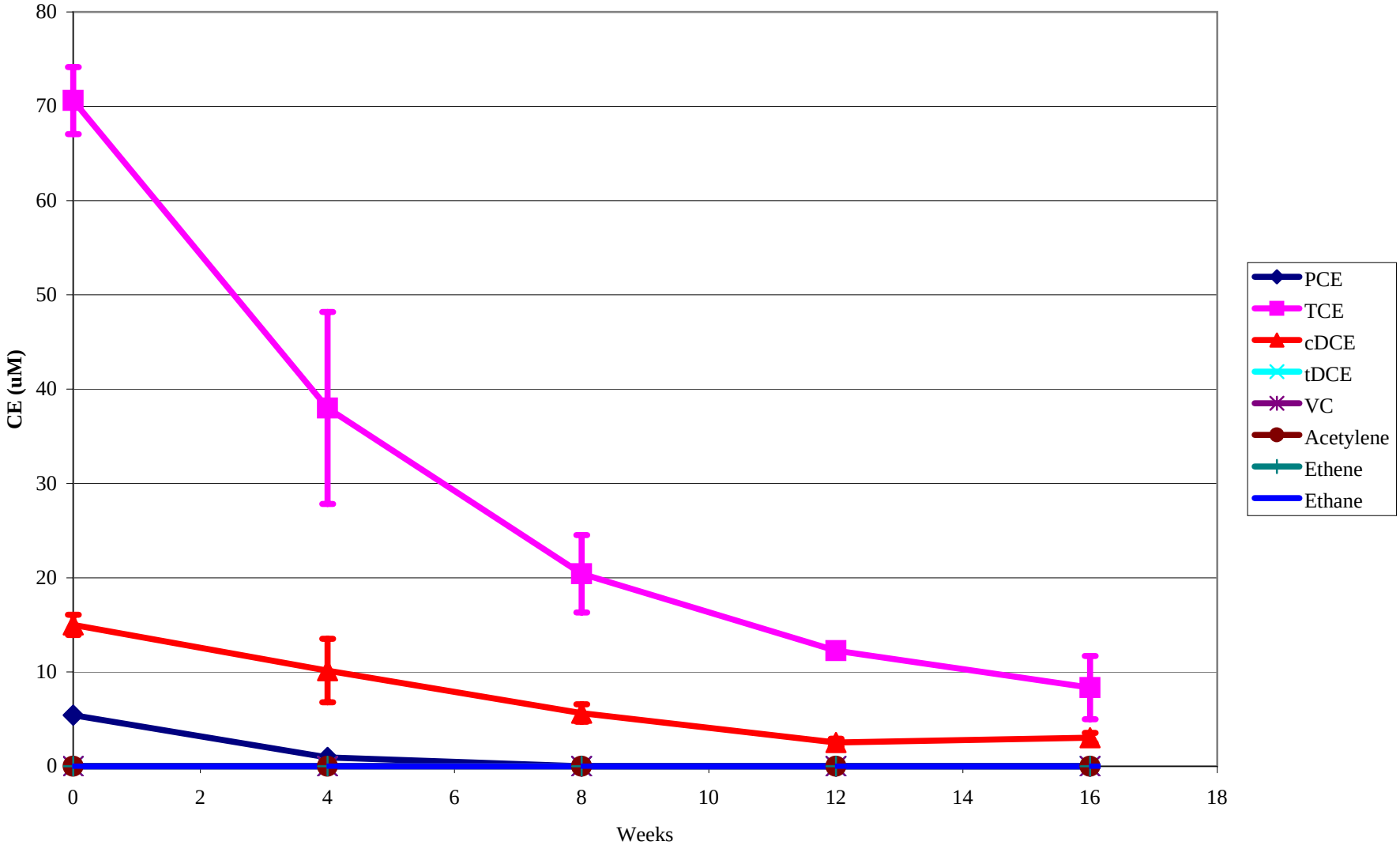


Figure 10 Source Unamended Control CEAverage +/- Standard Deviation

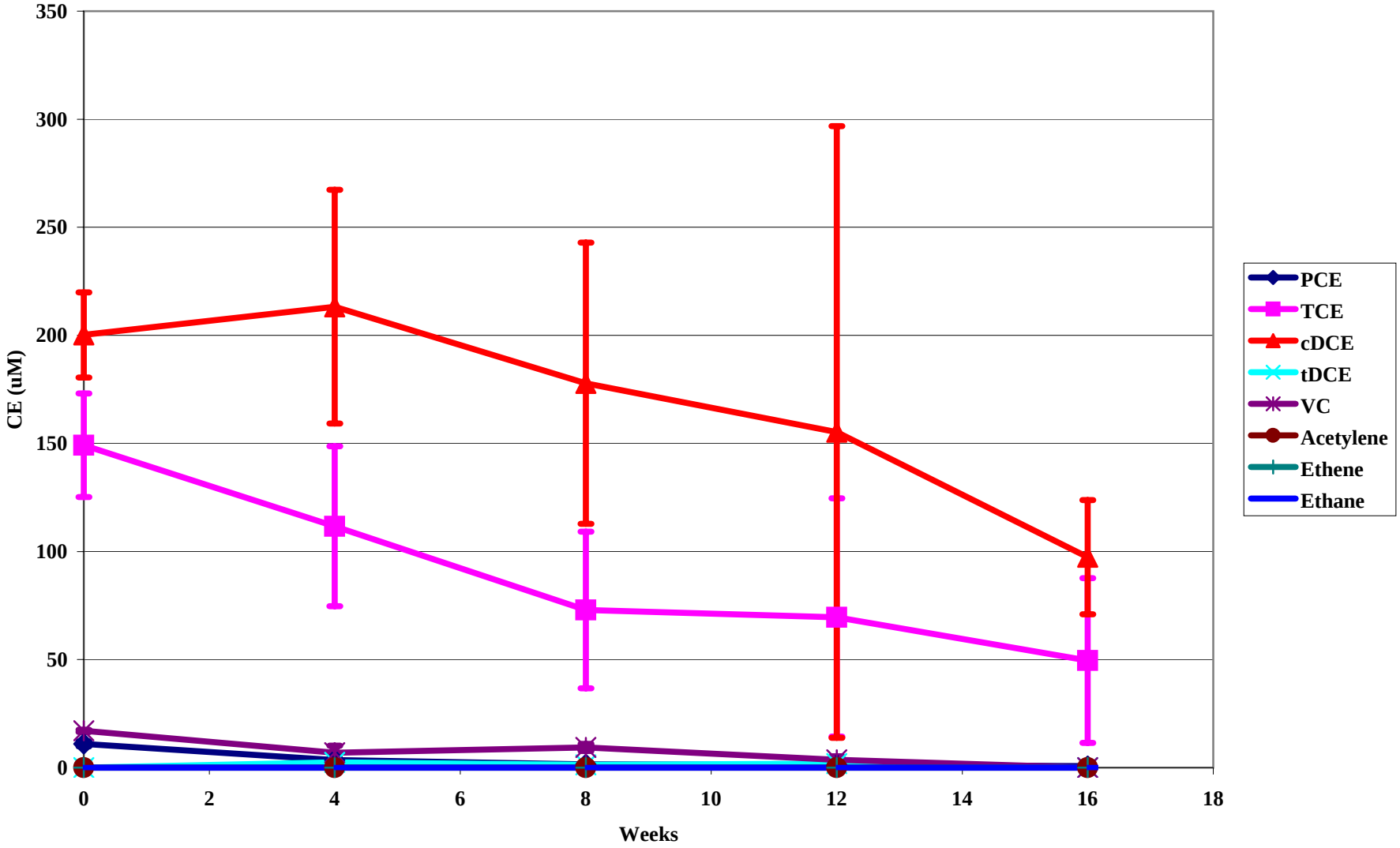


Figure 11 Source SRS CEAverage +/- Standard Deviation

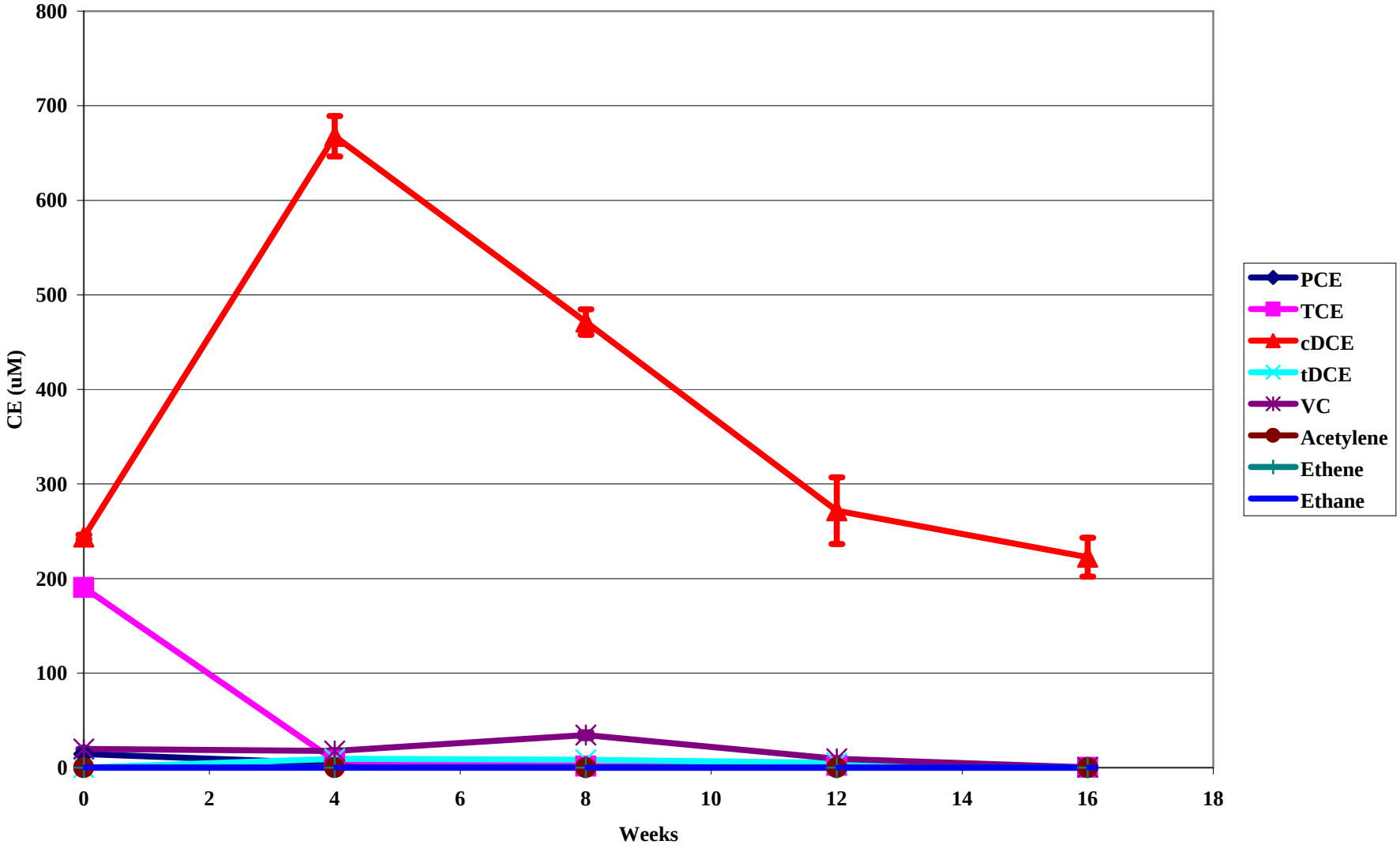


Figure 12 Source SRS + Bioaugmentation CE Average +/- Standard Deviation

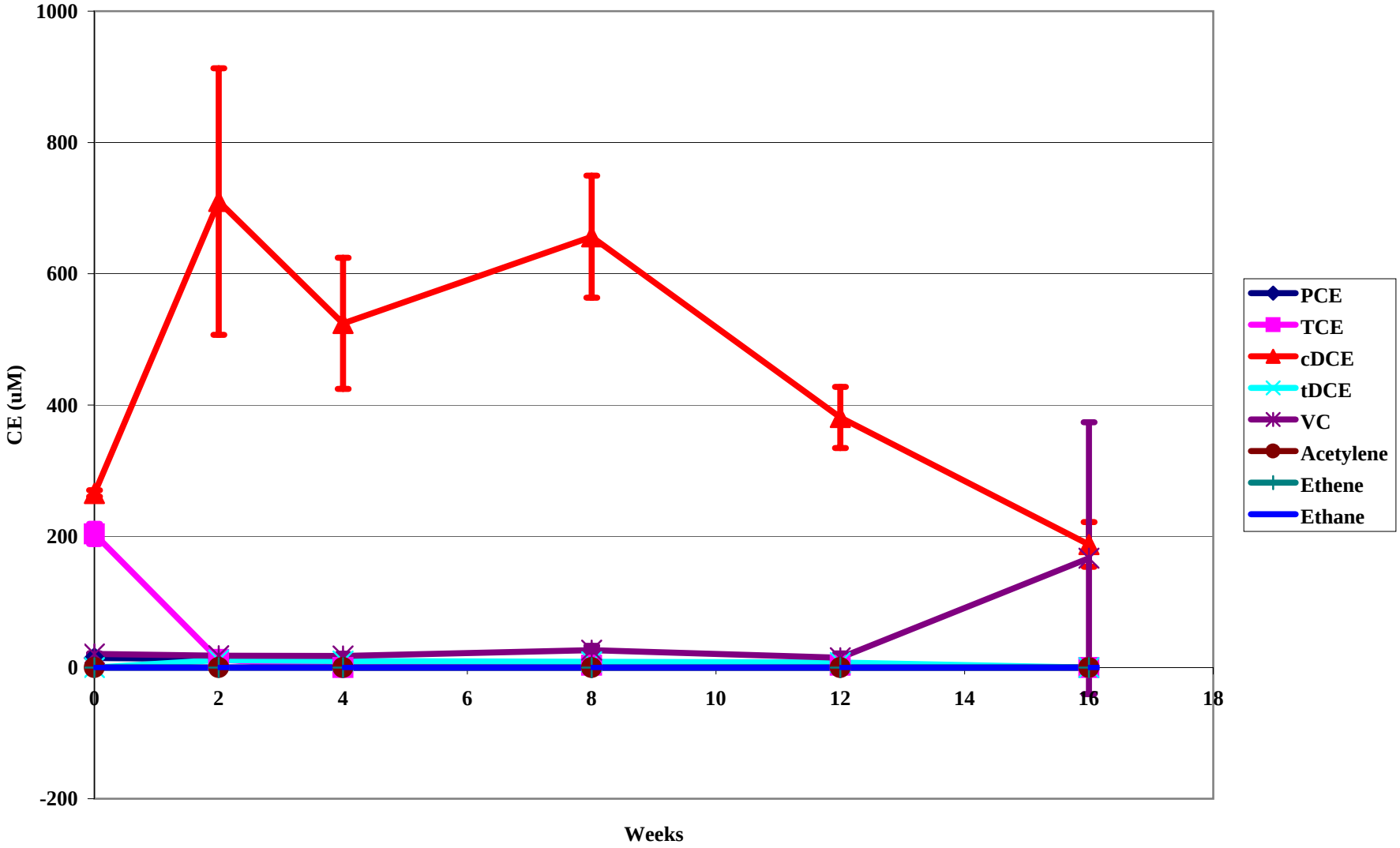


Figure 13 Source Nano EZVI CE Average +/- Standard Deviation

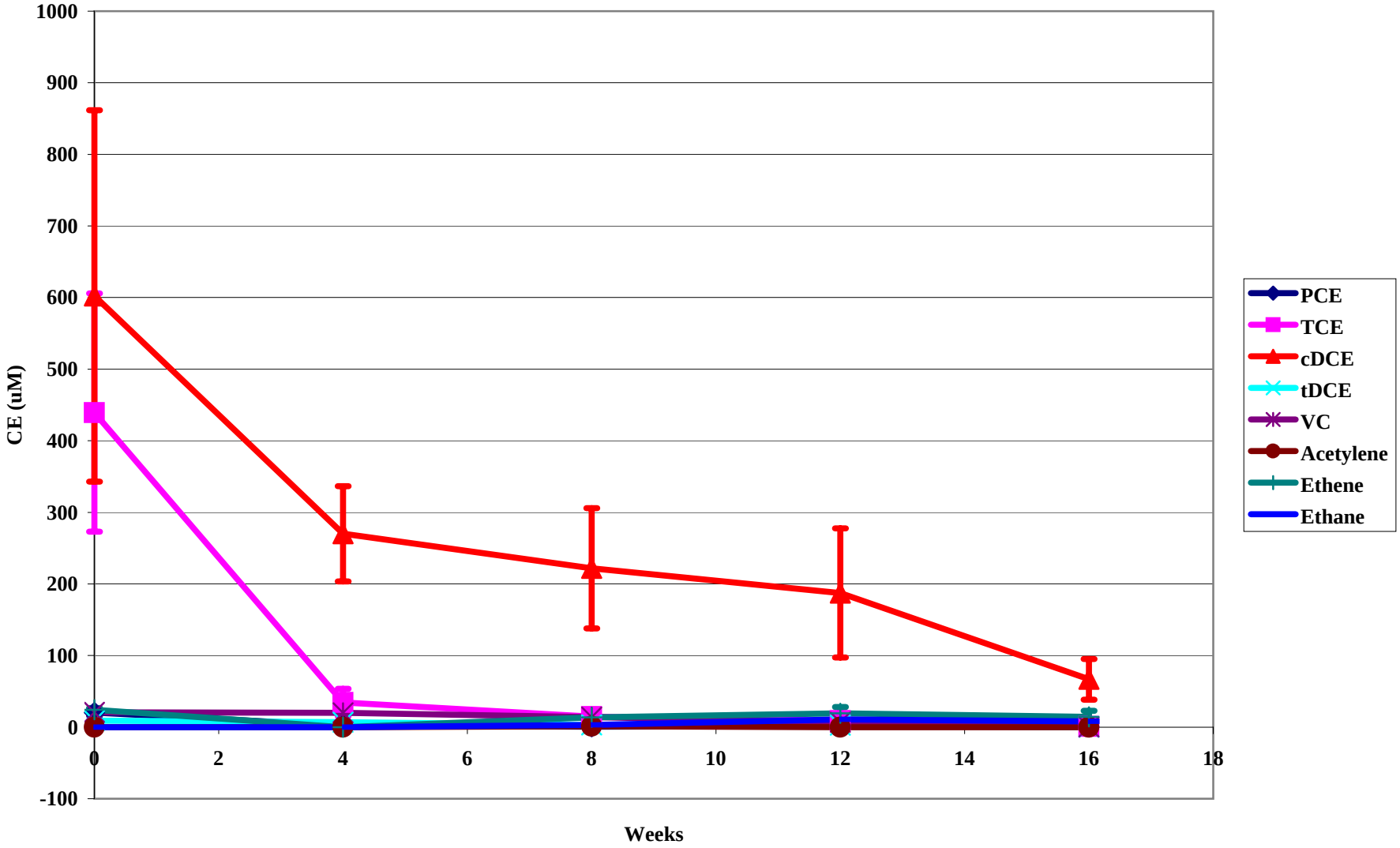


Figure 14 Source Micro EZVI CEAverage +/- Standard Deviation

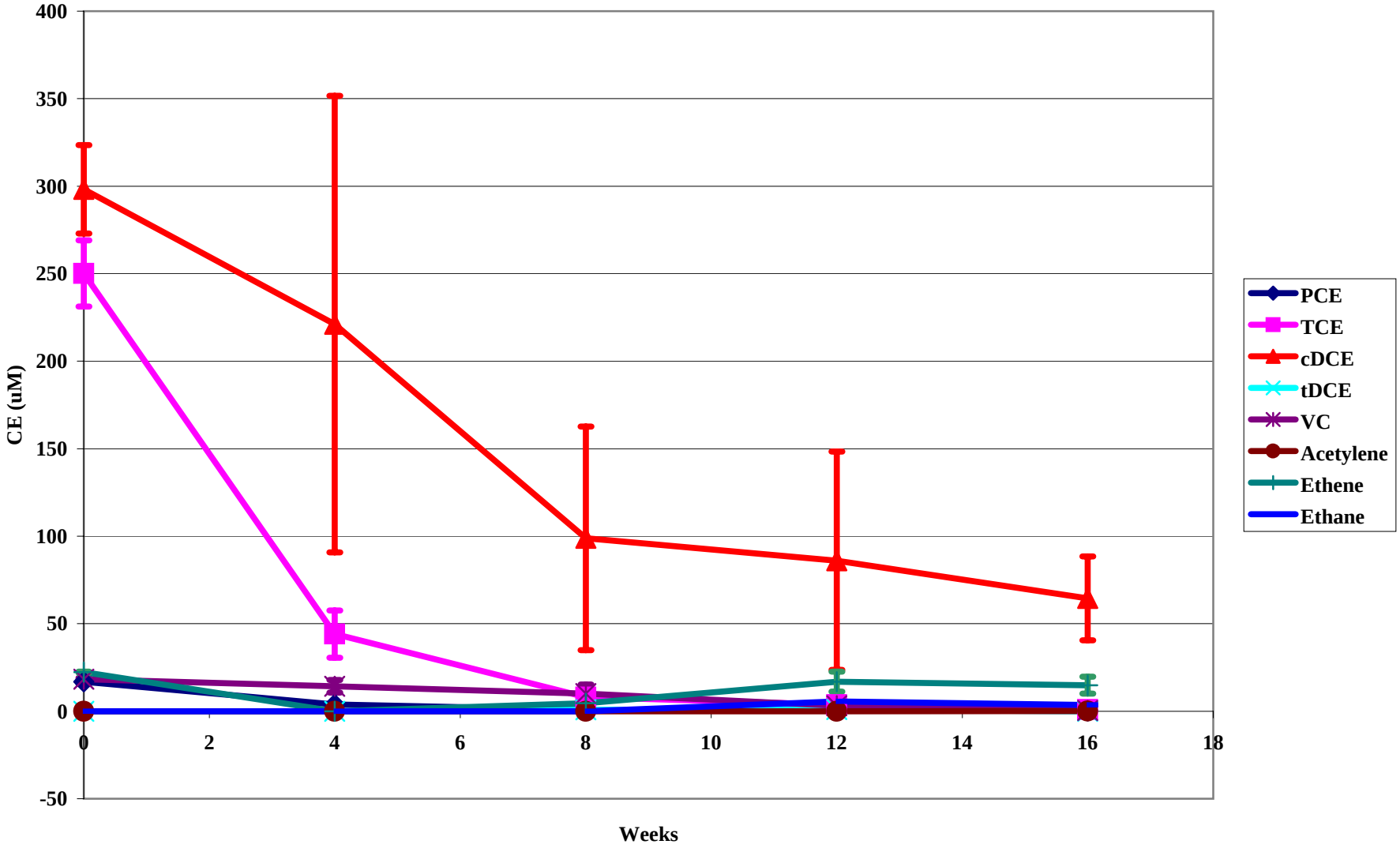


Figure 15 Source EHC CE Average +/- Standard Deviation

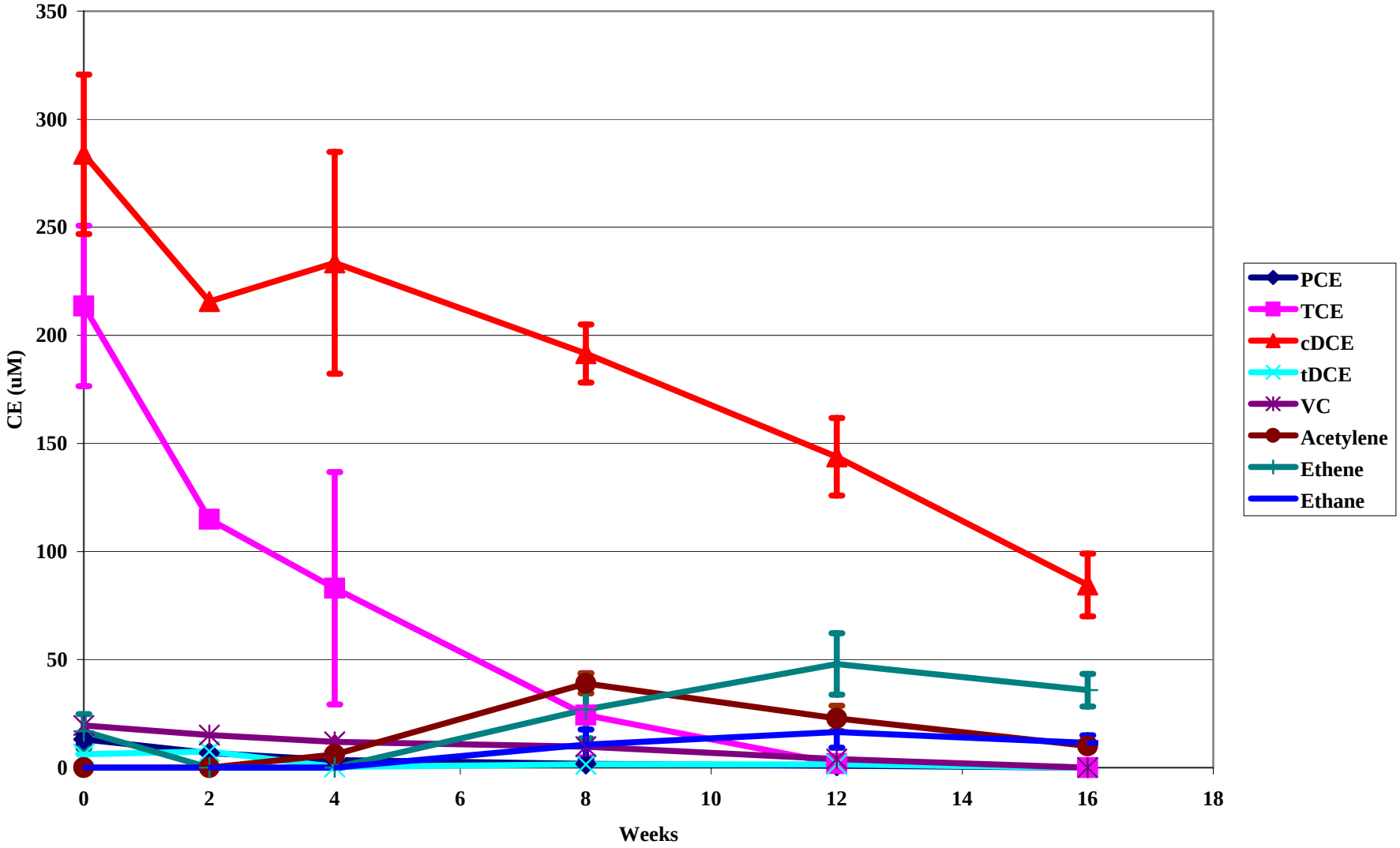


Figure 16 Source 4.5 g/L Nano EZVI CE

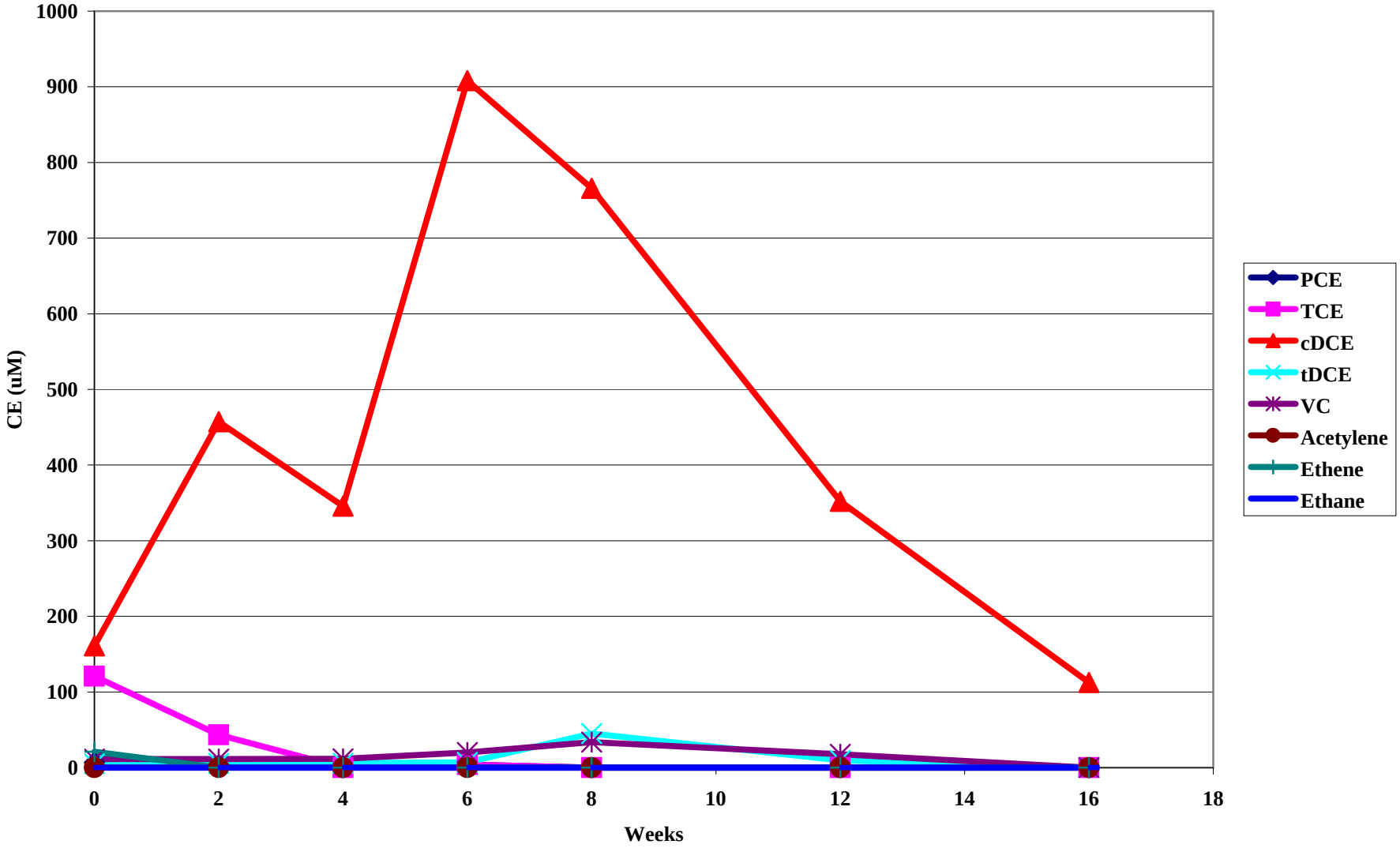


Figure 17 Source 22 g/L Nano EZVI CE

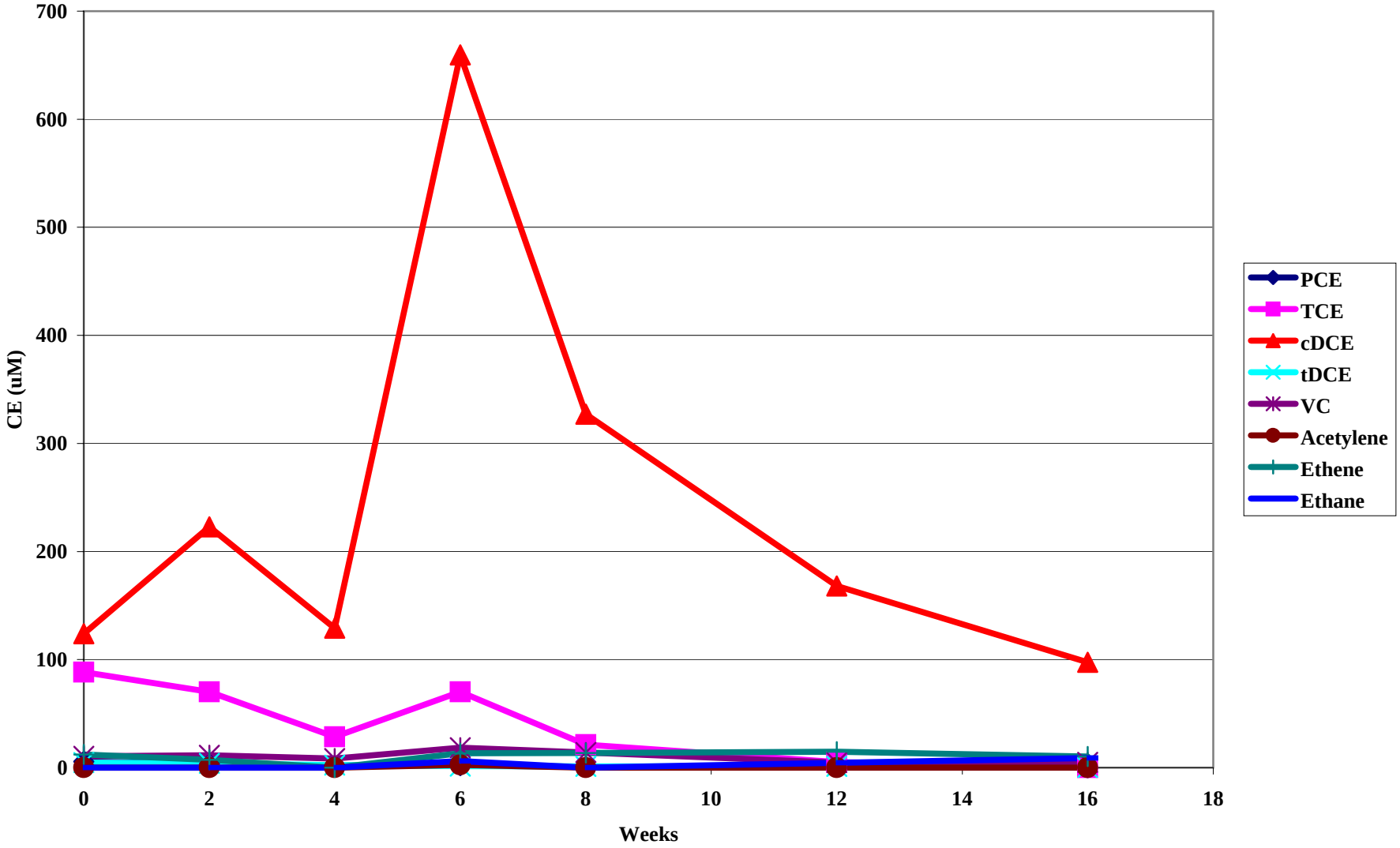


Figure 18 Source 88 g/L Nano EZVI CE

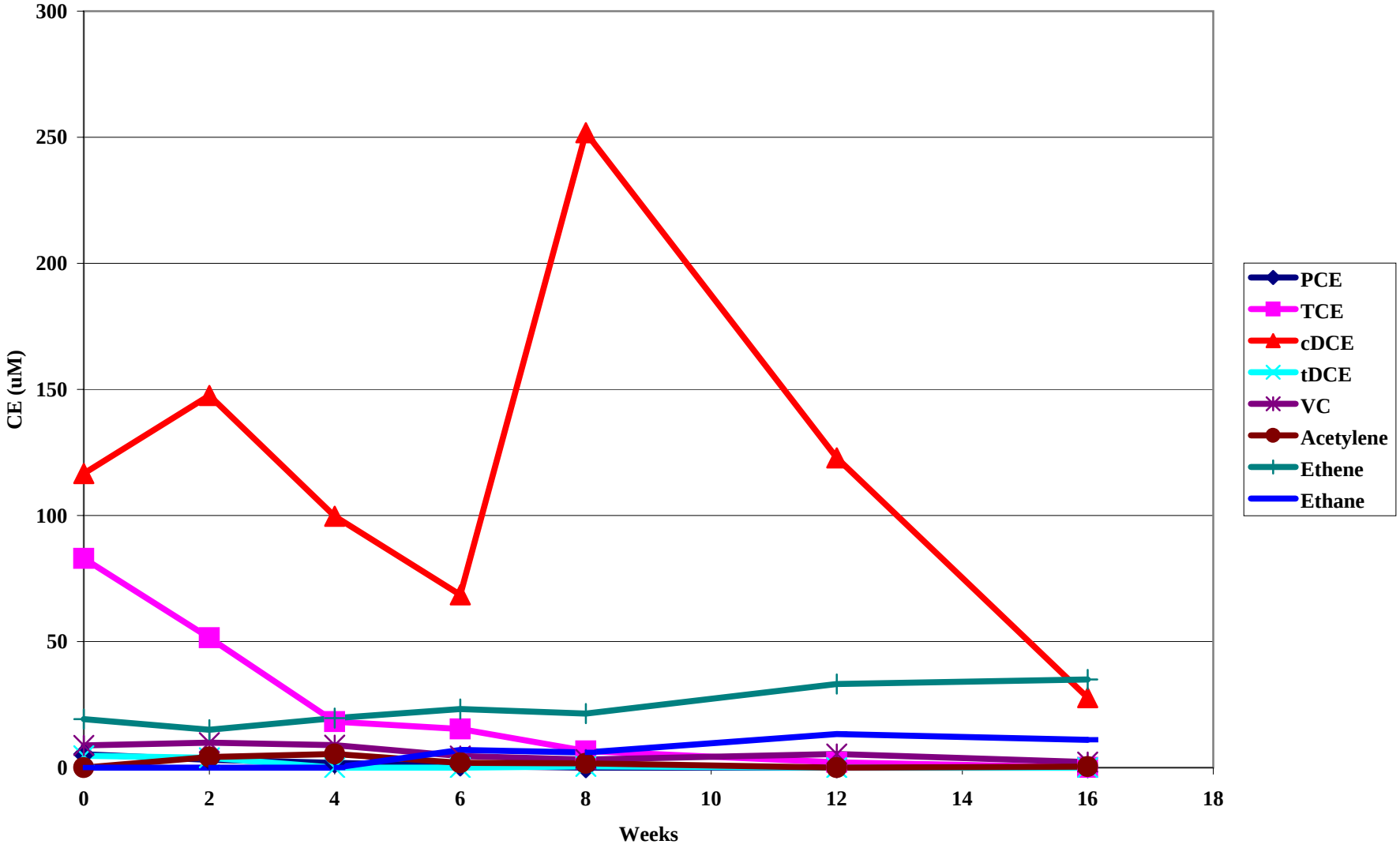


Figure 19 Plume Sterile Control CE Average +/- Standard Deviation

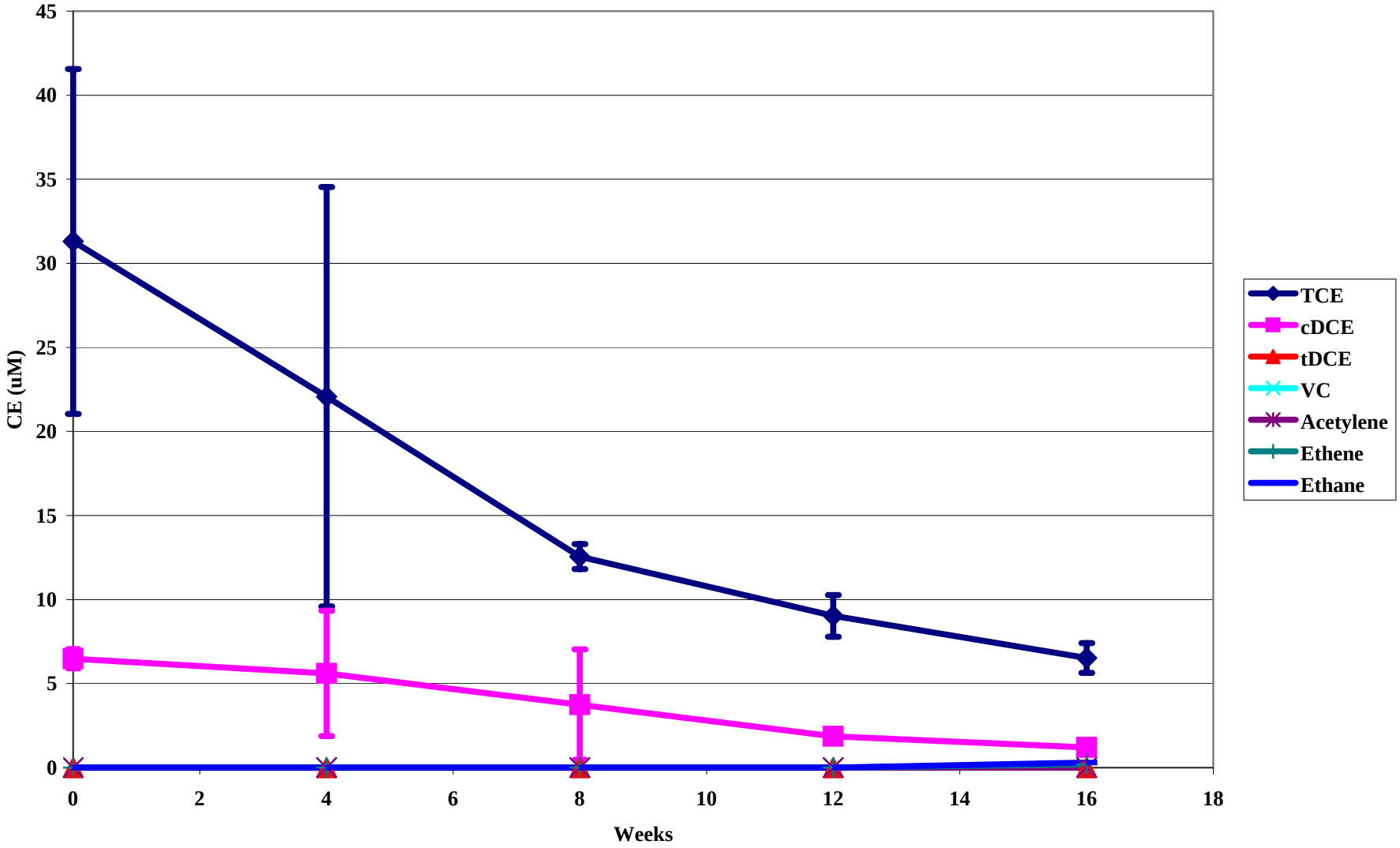


Figure 20 Plume Unamended Control CE Average +/- Standard Deviation

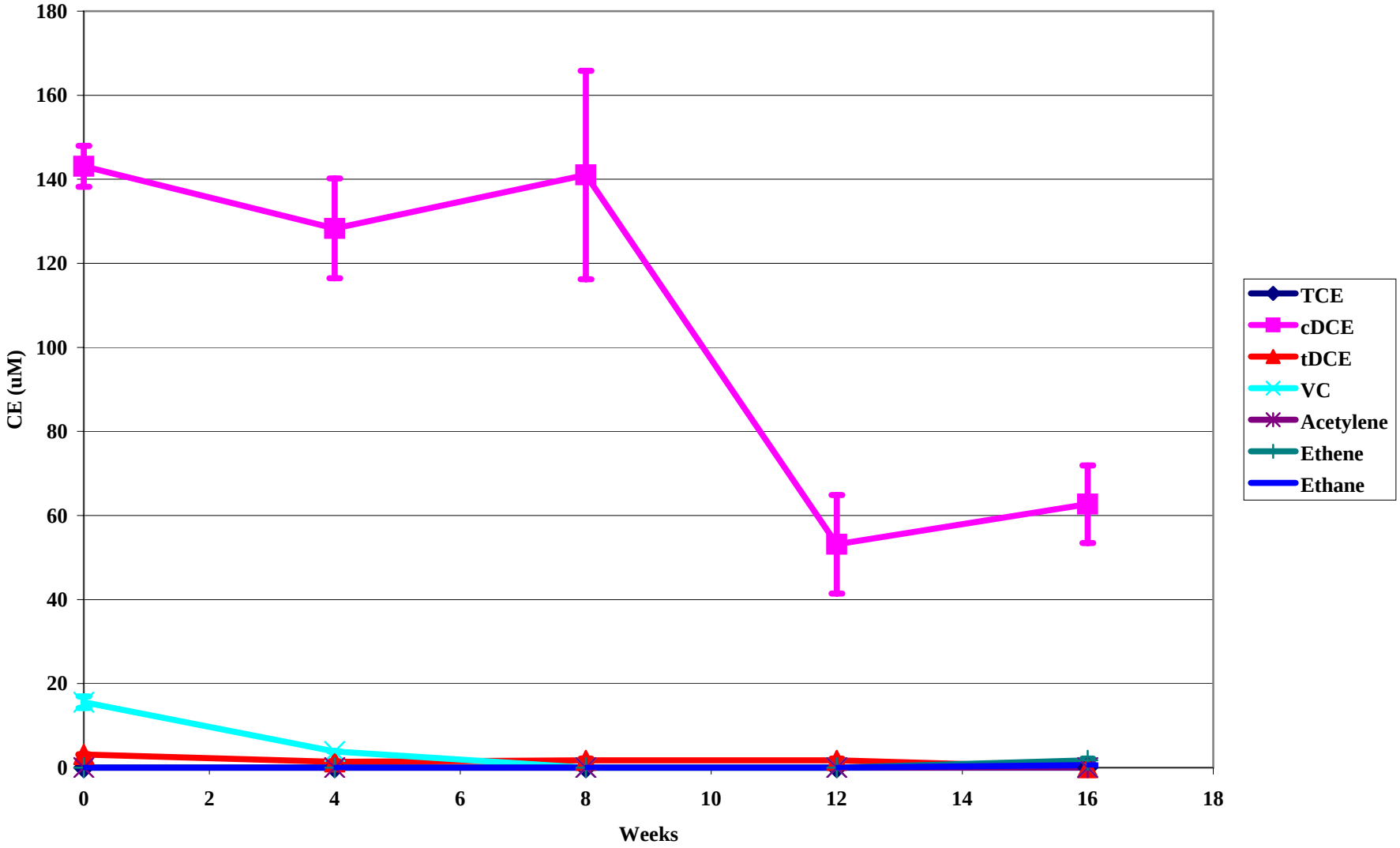


Figure 21 Plume SRS CE Average +/- Standard Deviation

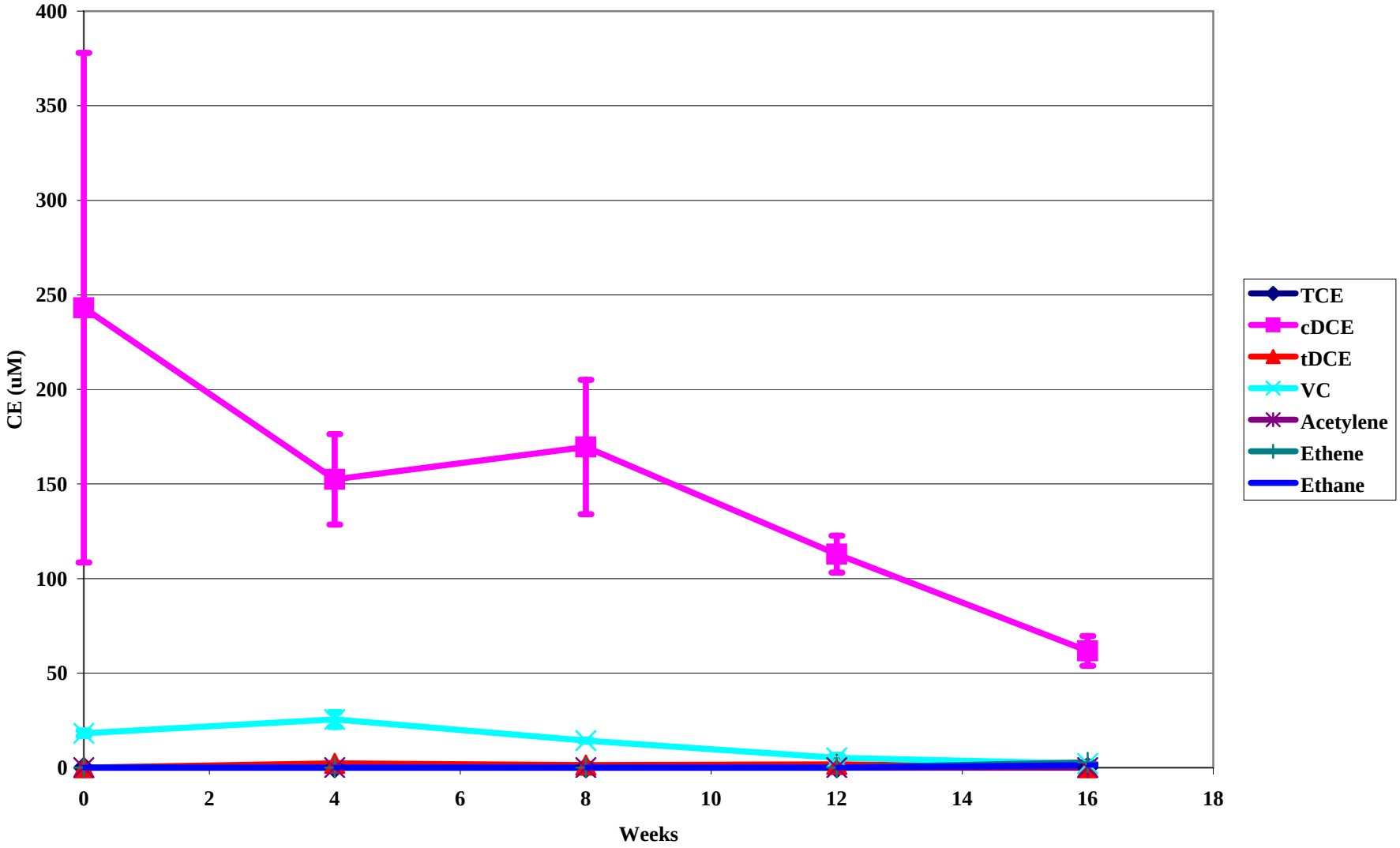


Figure 22 Plume SRS + Bioaugmentation CE Average +/- Standard Deviation

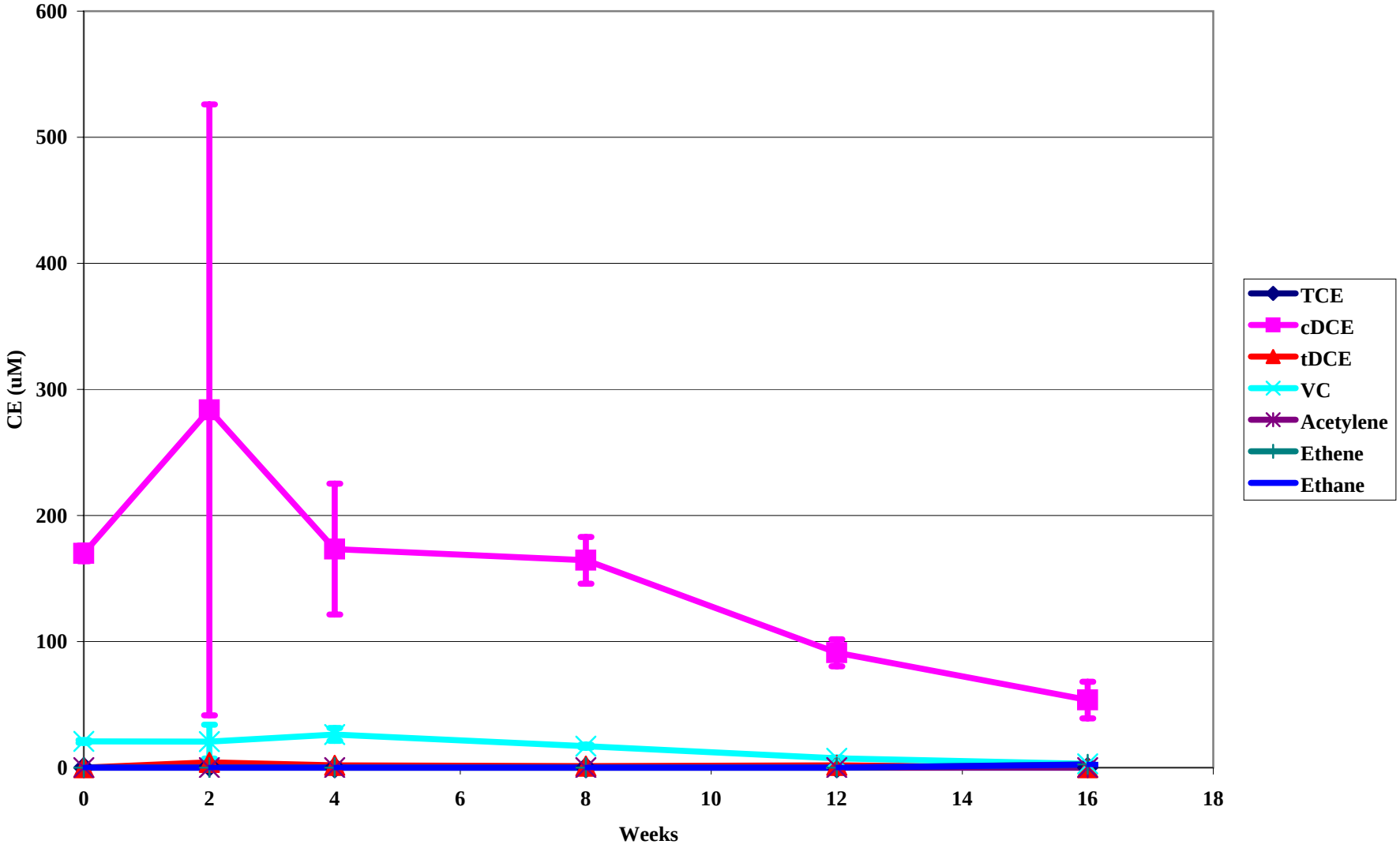


Figure 23 Plume Nano EZVI CE Average +/- Standard Deviation

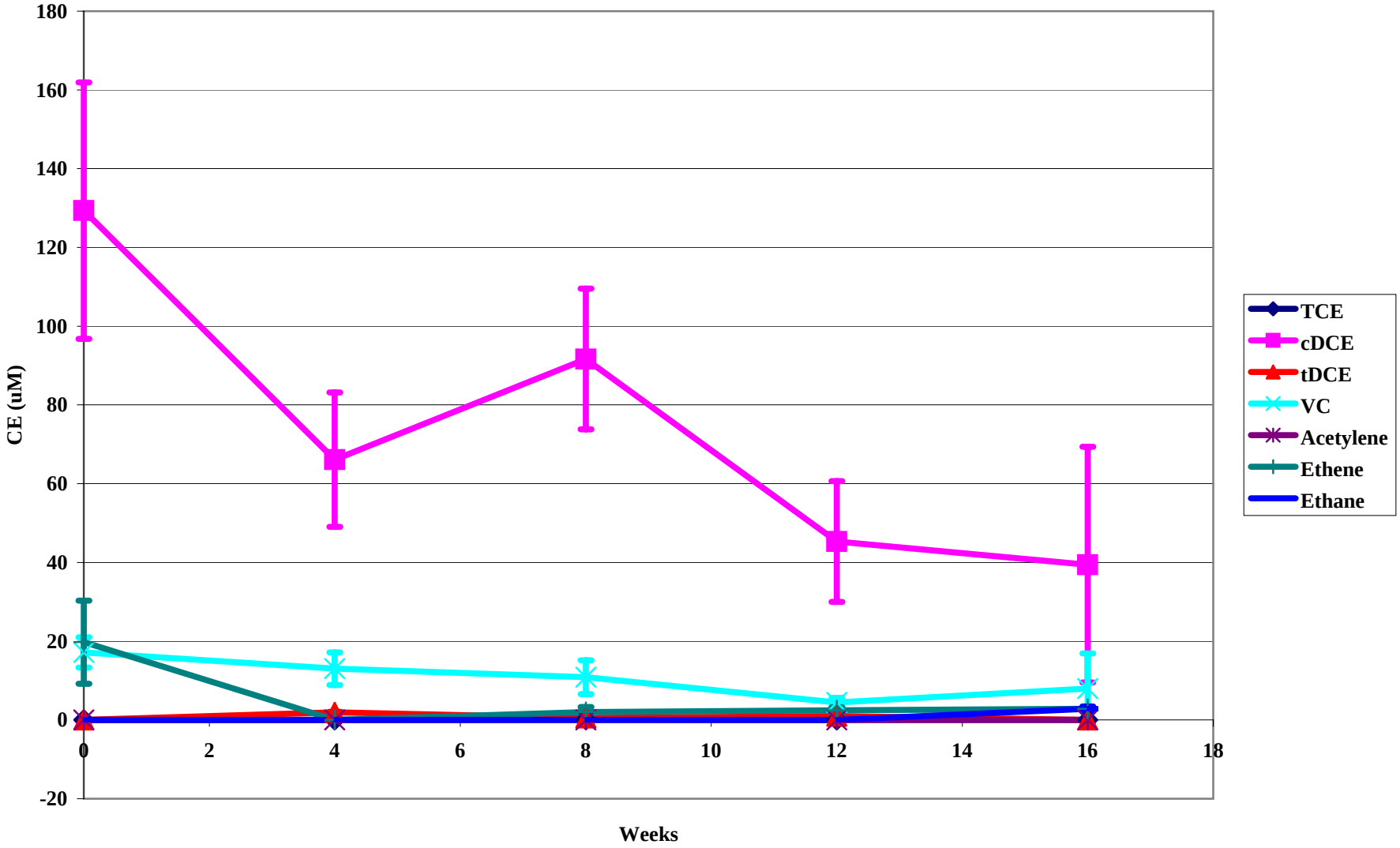


Figure 24 Plume Micro EZVI CE Average +/- Standard Deviation

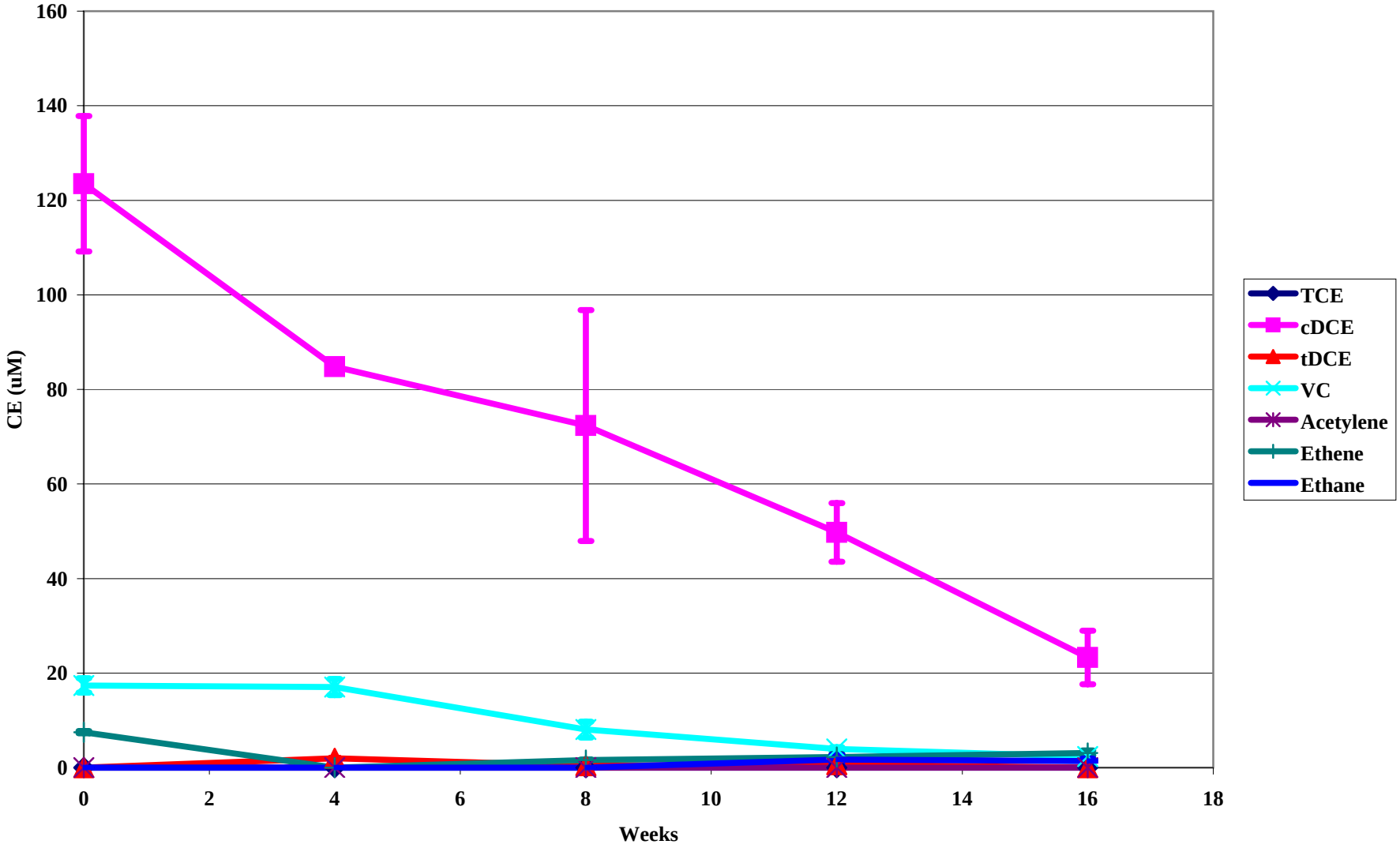


Figure 25 Plume EHC CE Average +/- Standard Deviation

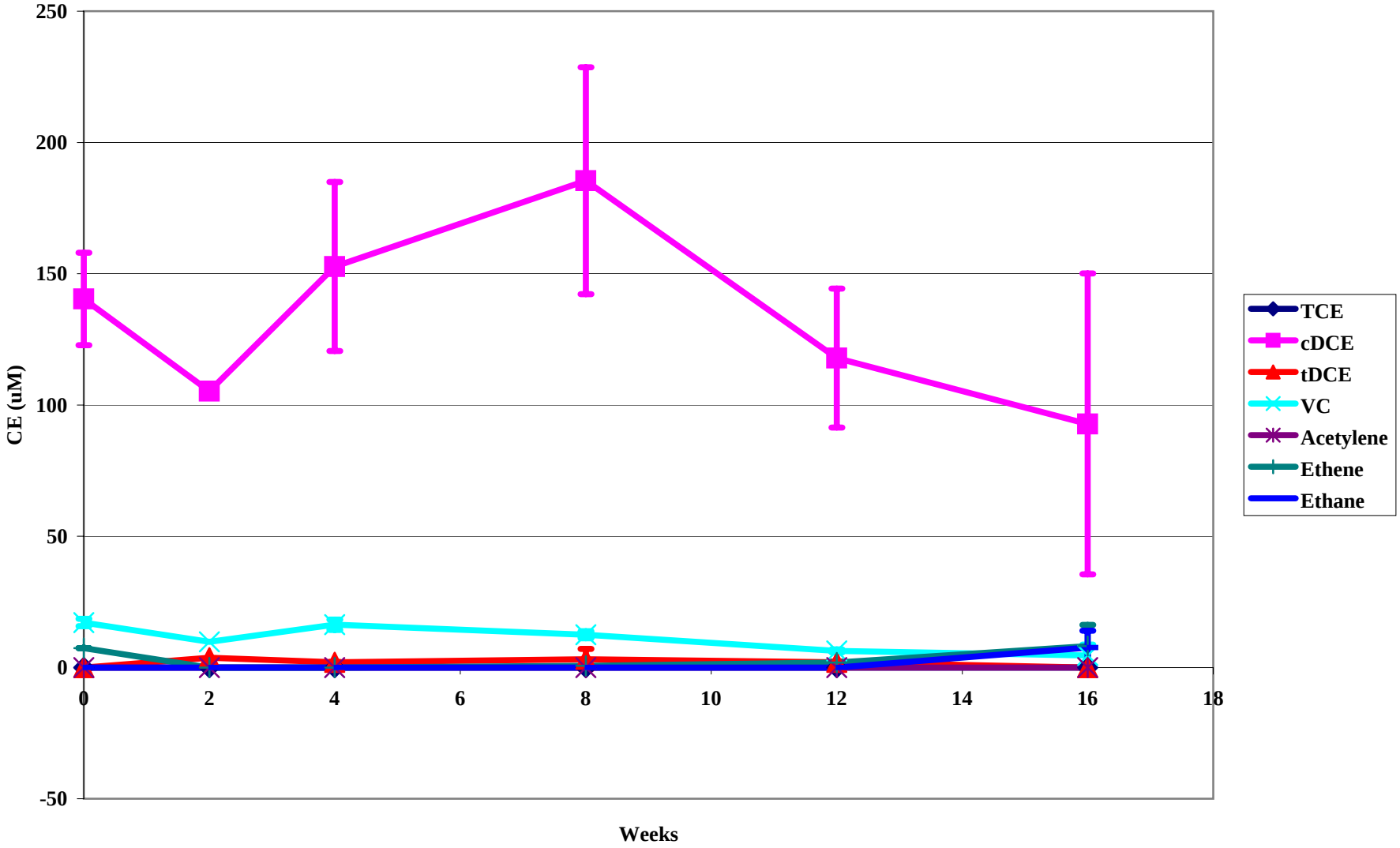


Figure 26 Source 4.5 g/L Micro EZVI CE

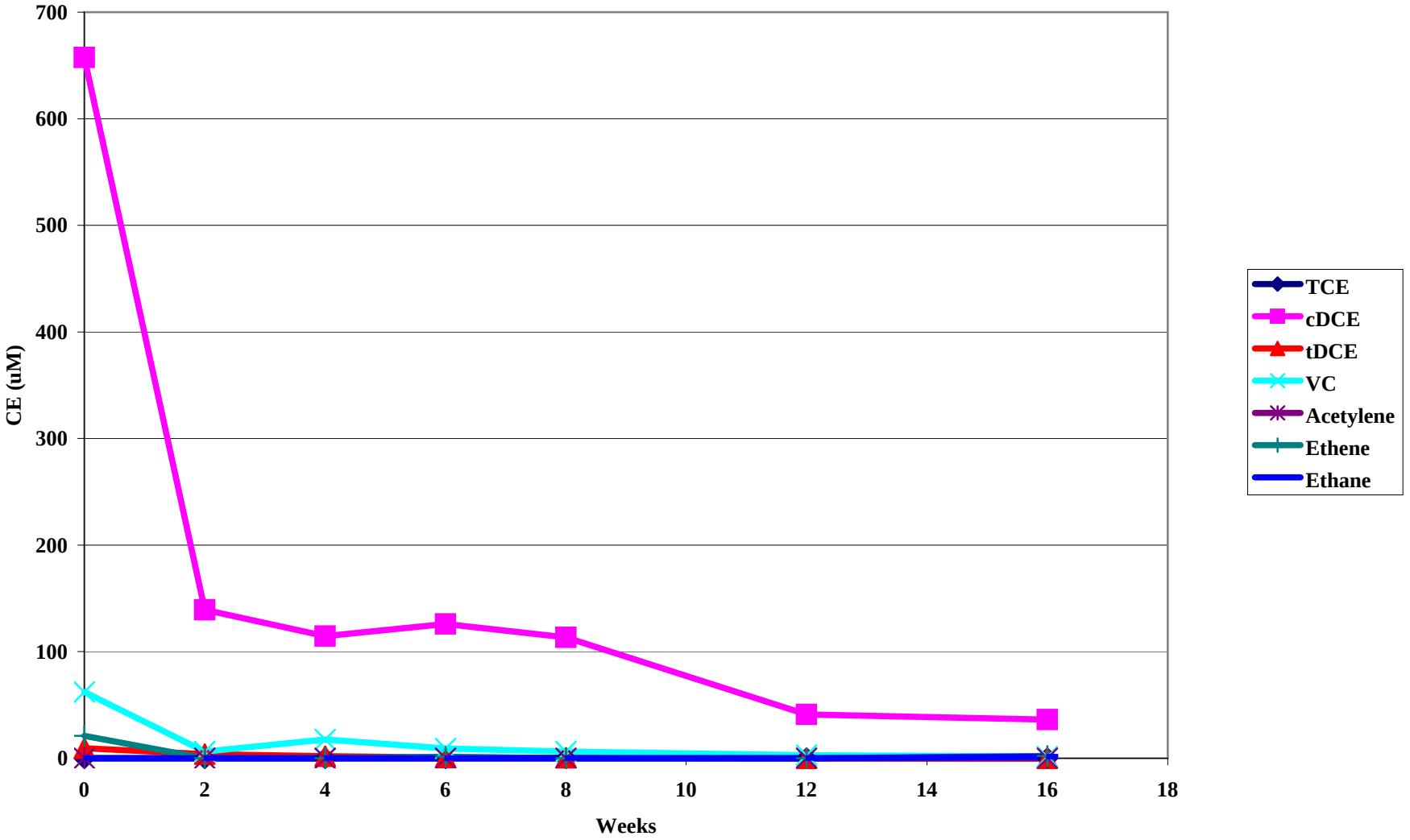


Figure 27 Source 22 g/L Micro EZVI CE

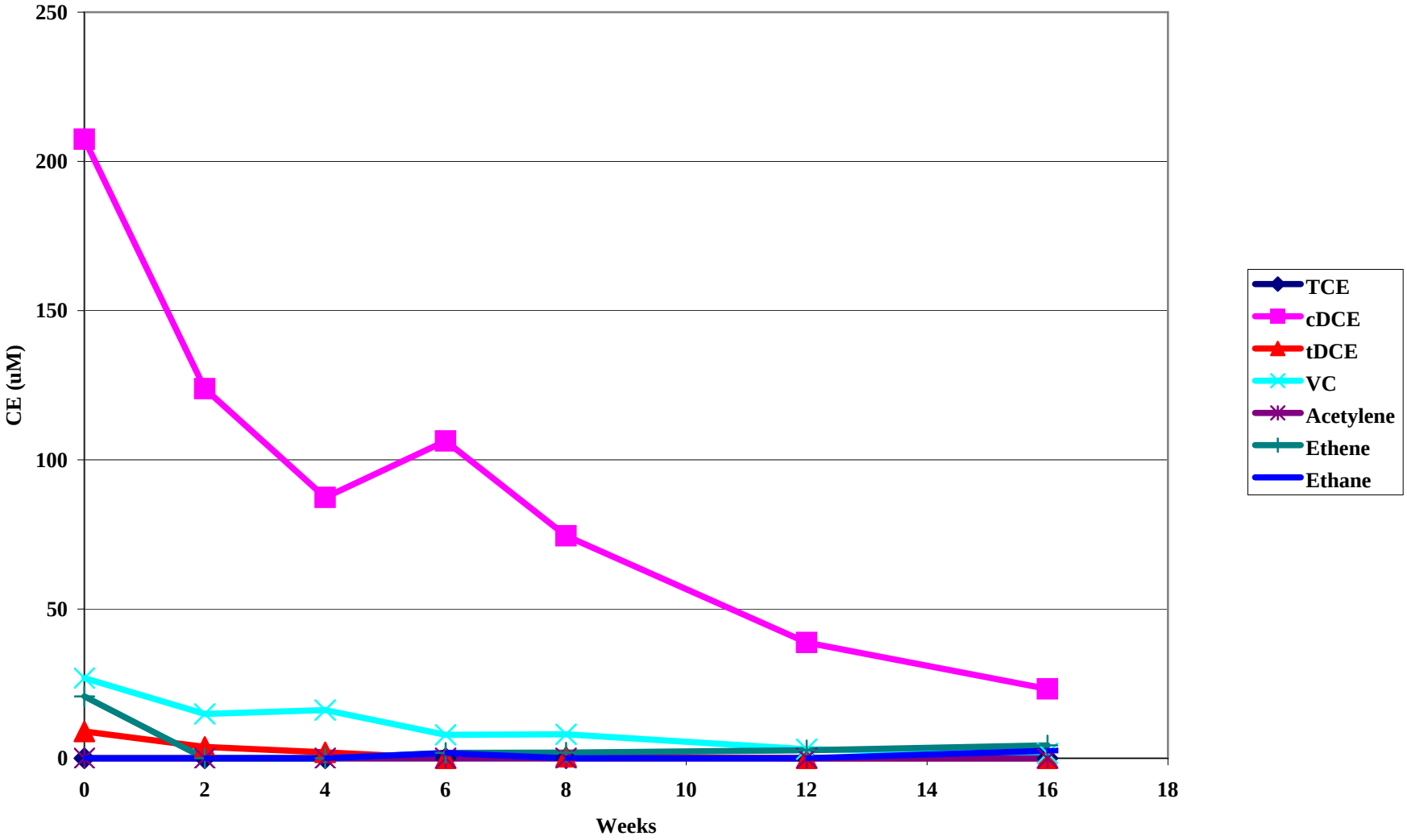


Figure 28 Source 88 g/L Micro EZVI CE

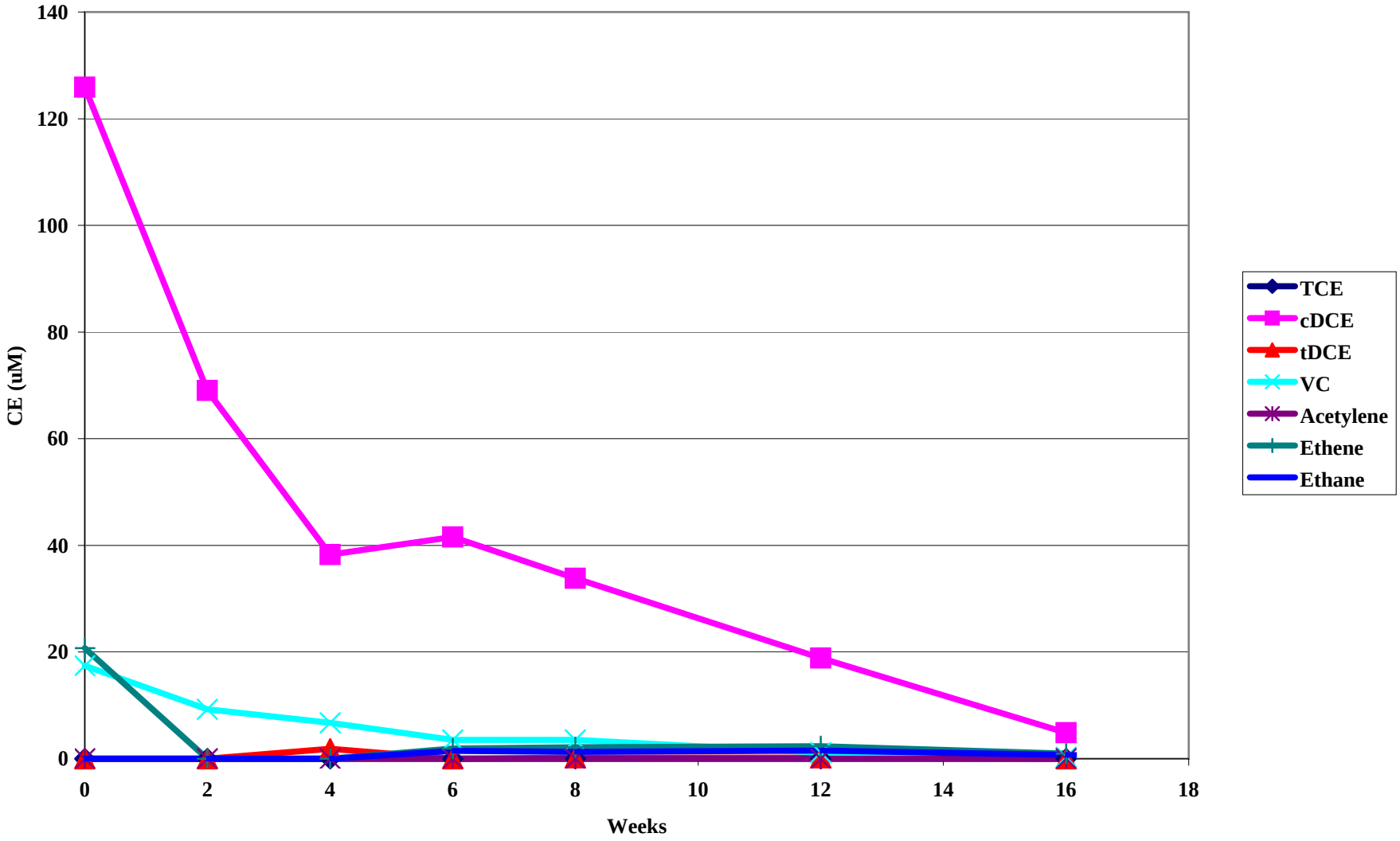


Figure 29 Source Sterile Control CA Average +/- Standard Deviation

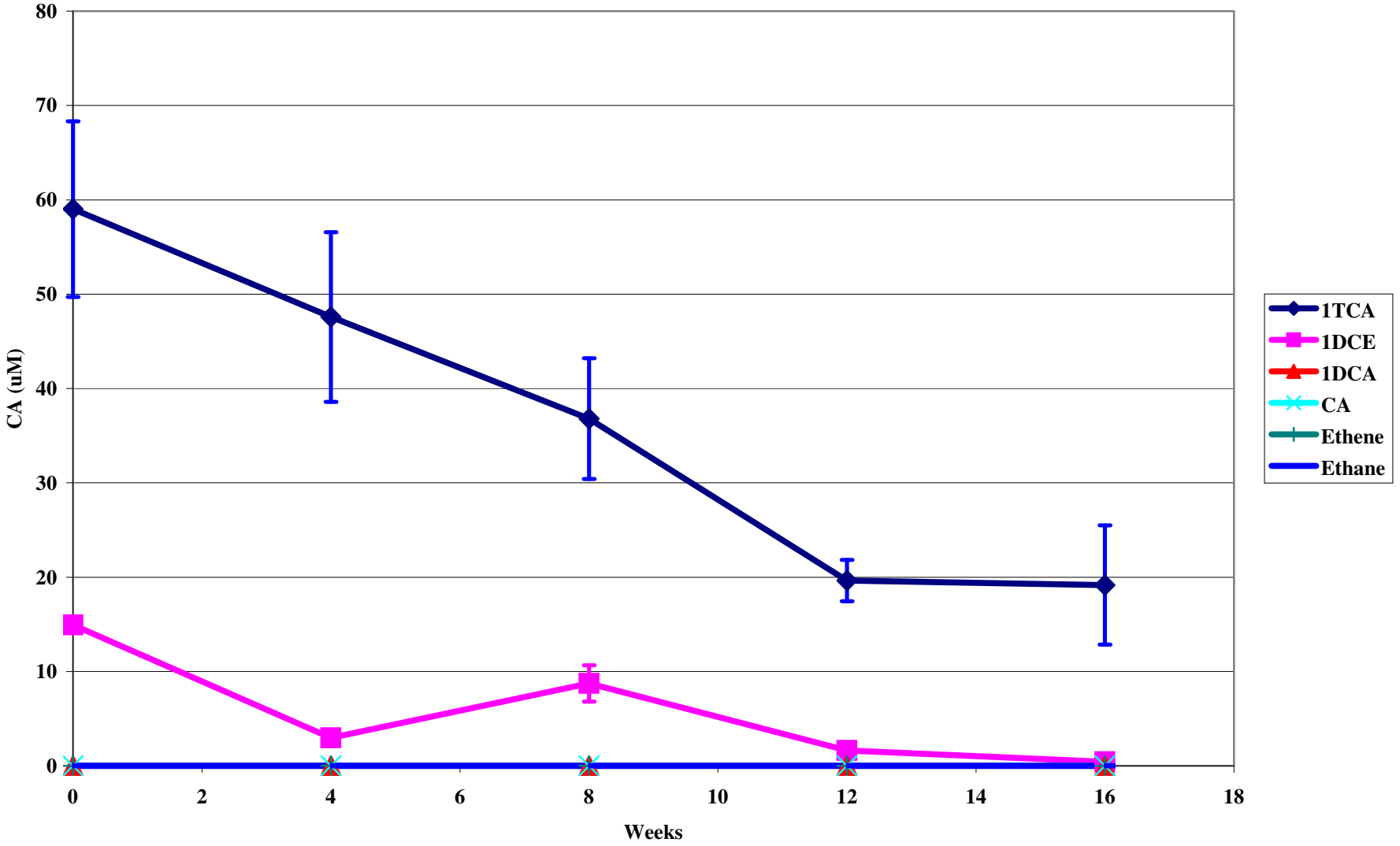


Figure 30 Source Unamended Control CA Average +/- Standard Deviation

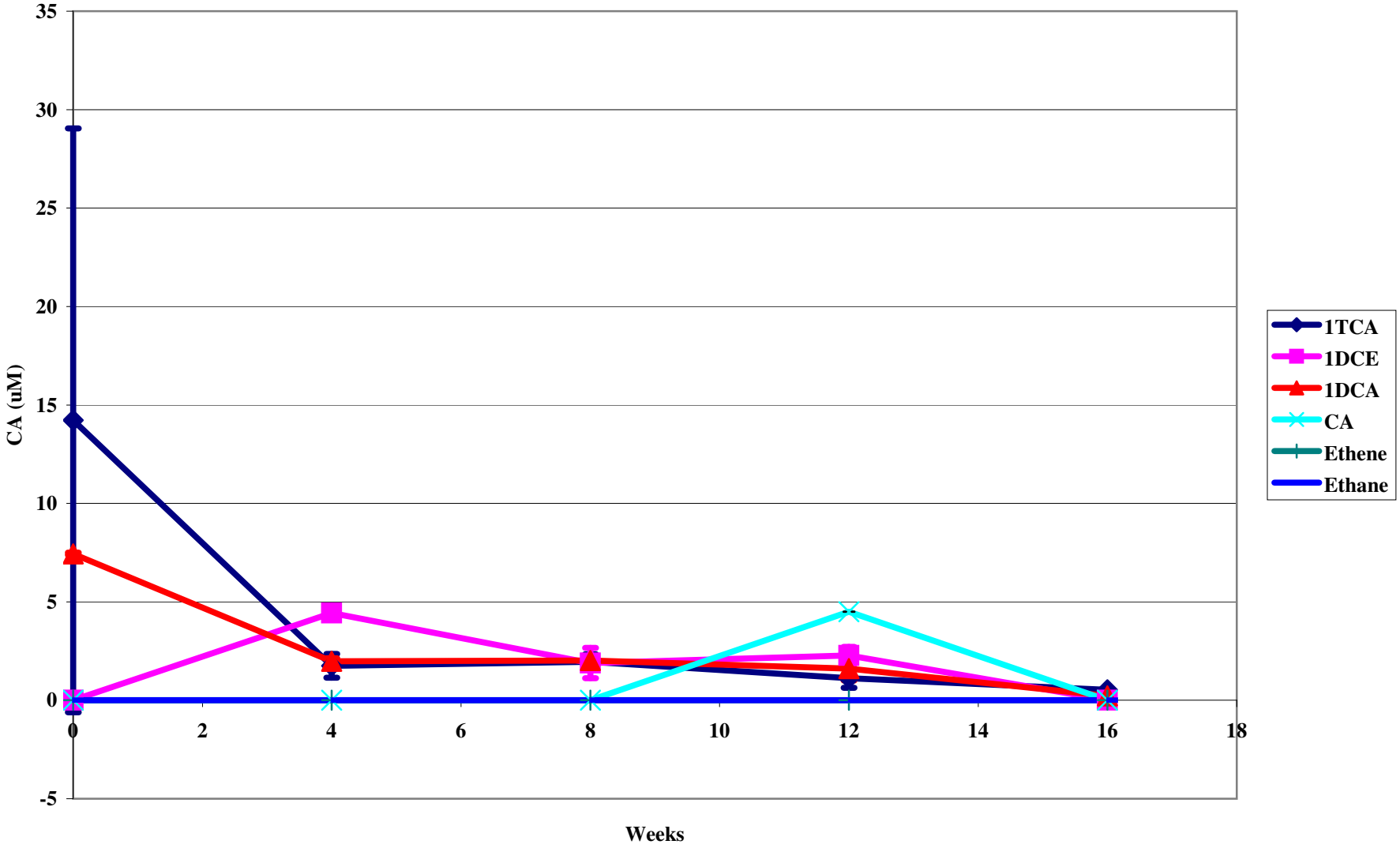


Figure 31 Source SRS CA Average +/- Standard Deviation

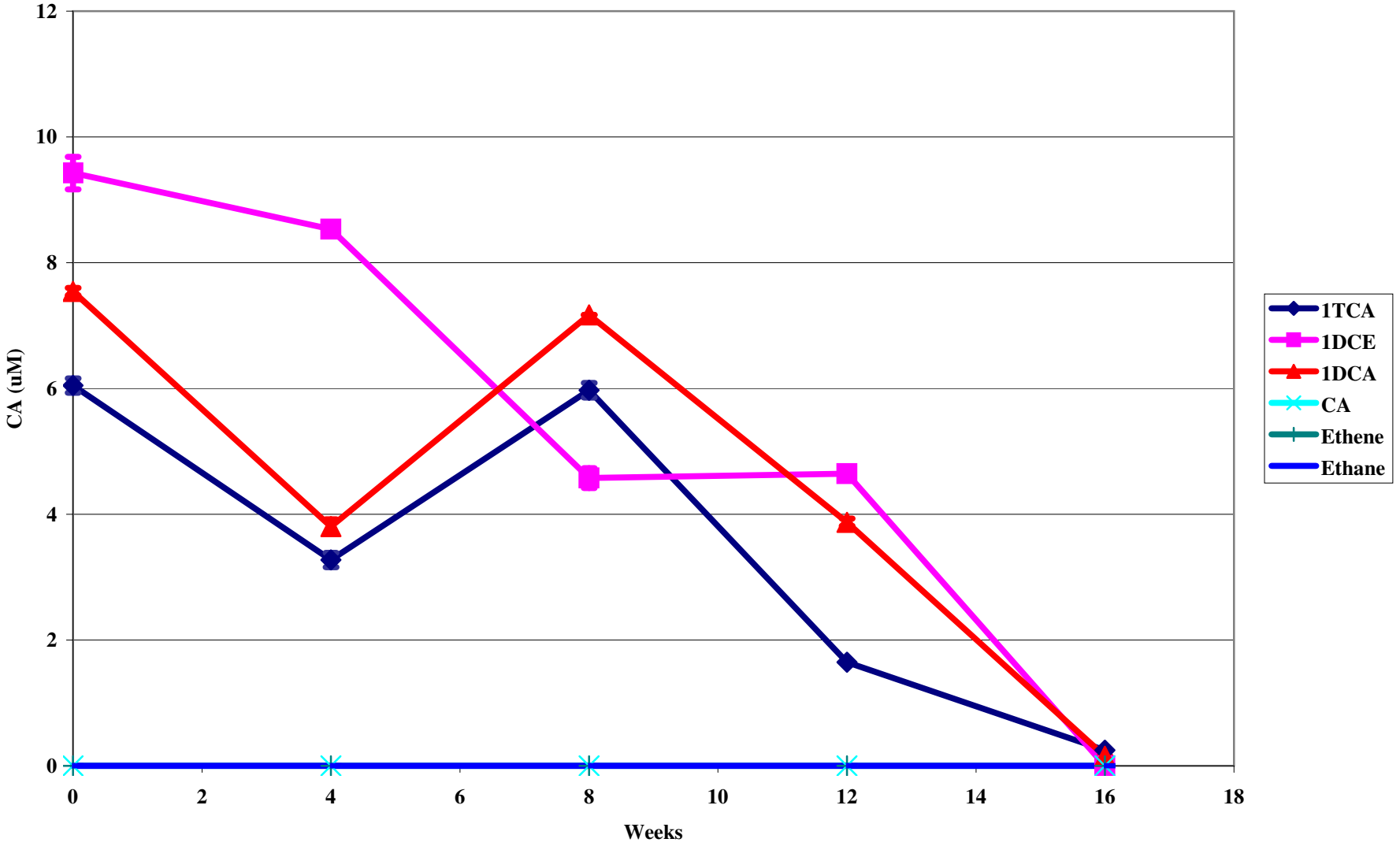


Figure 32 Source SRS + Bioaugmentation CA Average +/- Standard Deviation

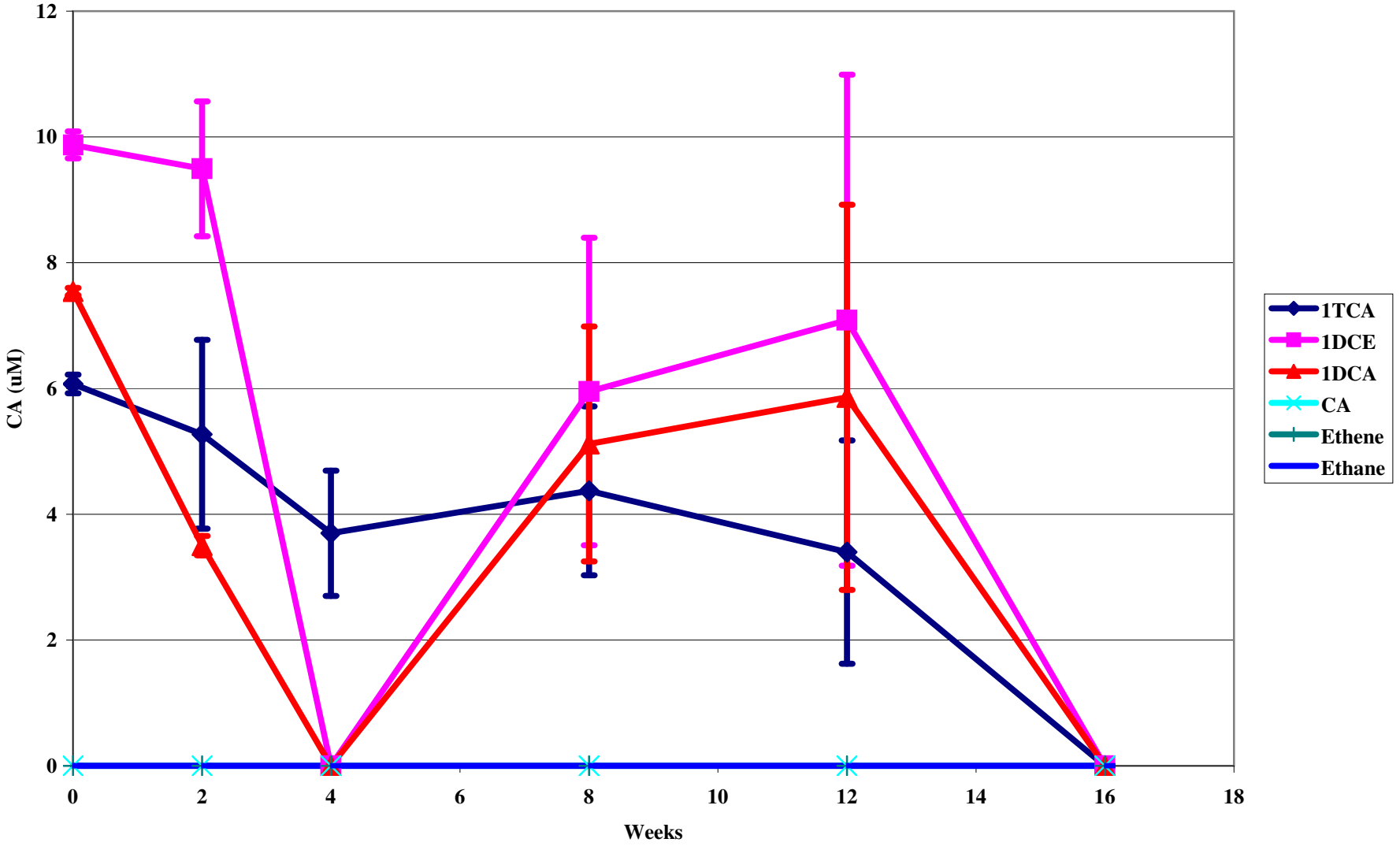


Figure 33 Source Nano EZVI CA Average +/- Standard Deviation

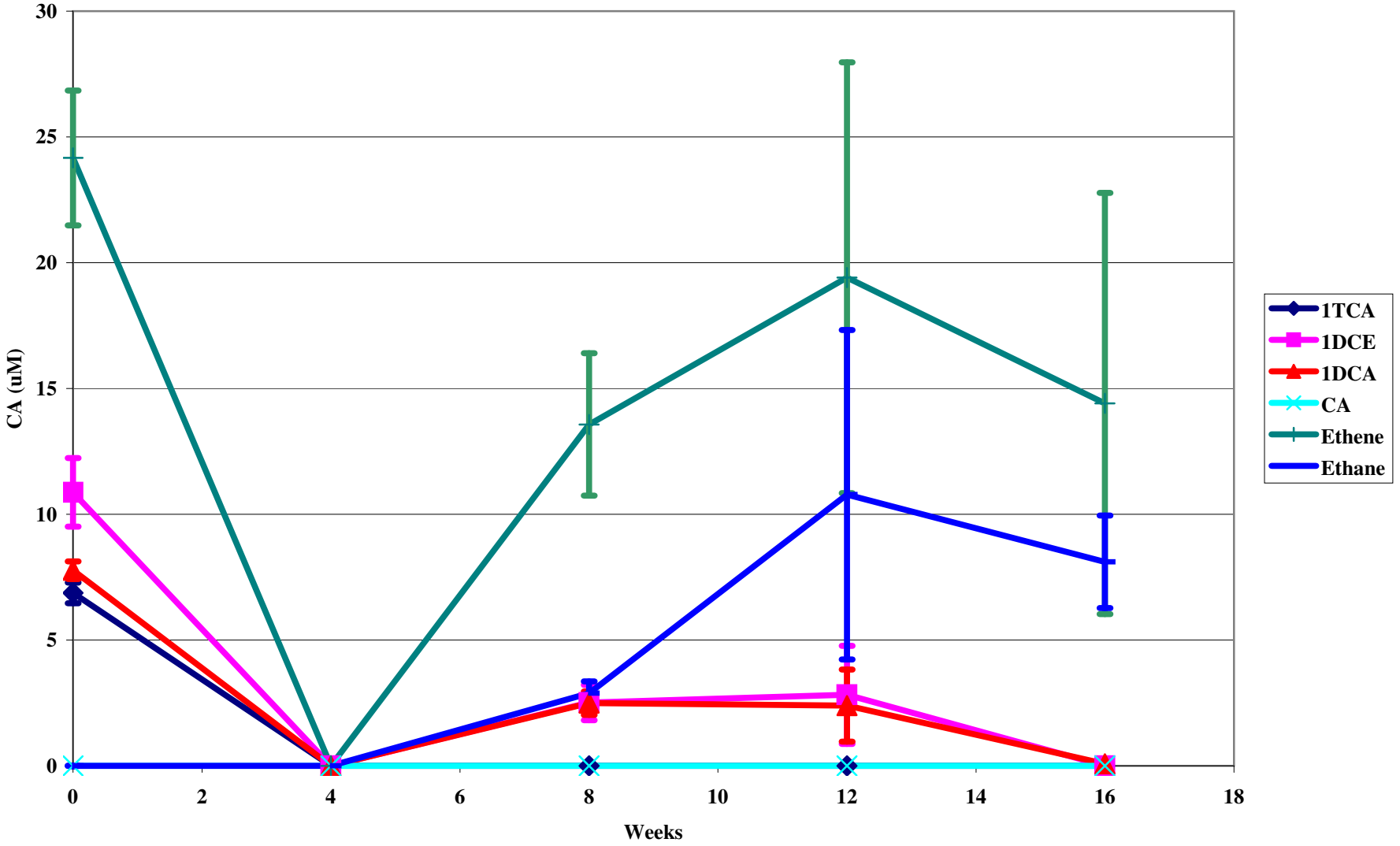


Figure 34 Source Micro EZVI CA Average +/- Standard Deviation

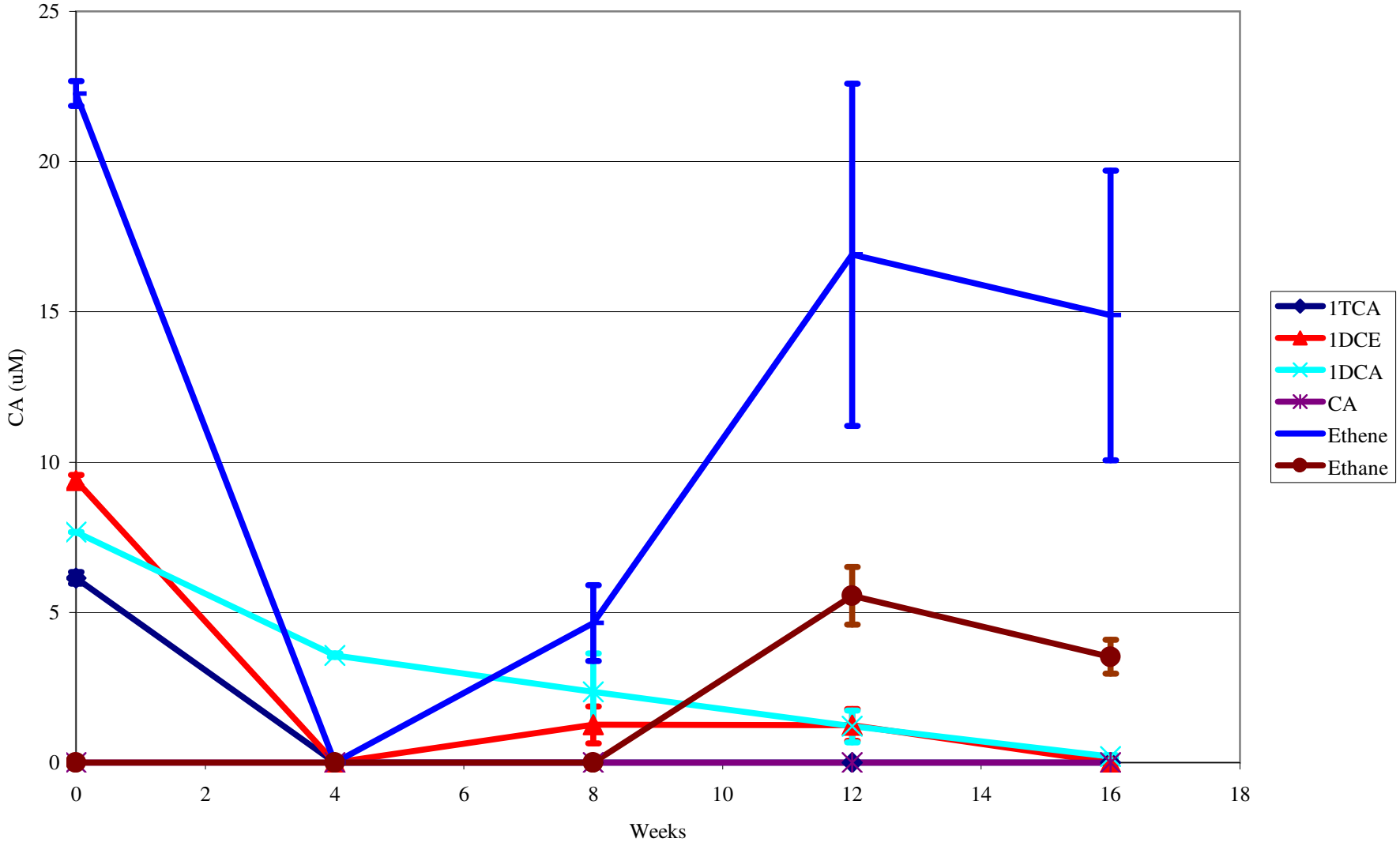


Figure 35 Source EHC CA Average +/- Standard Deviation

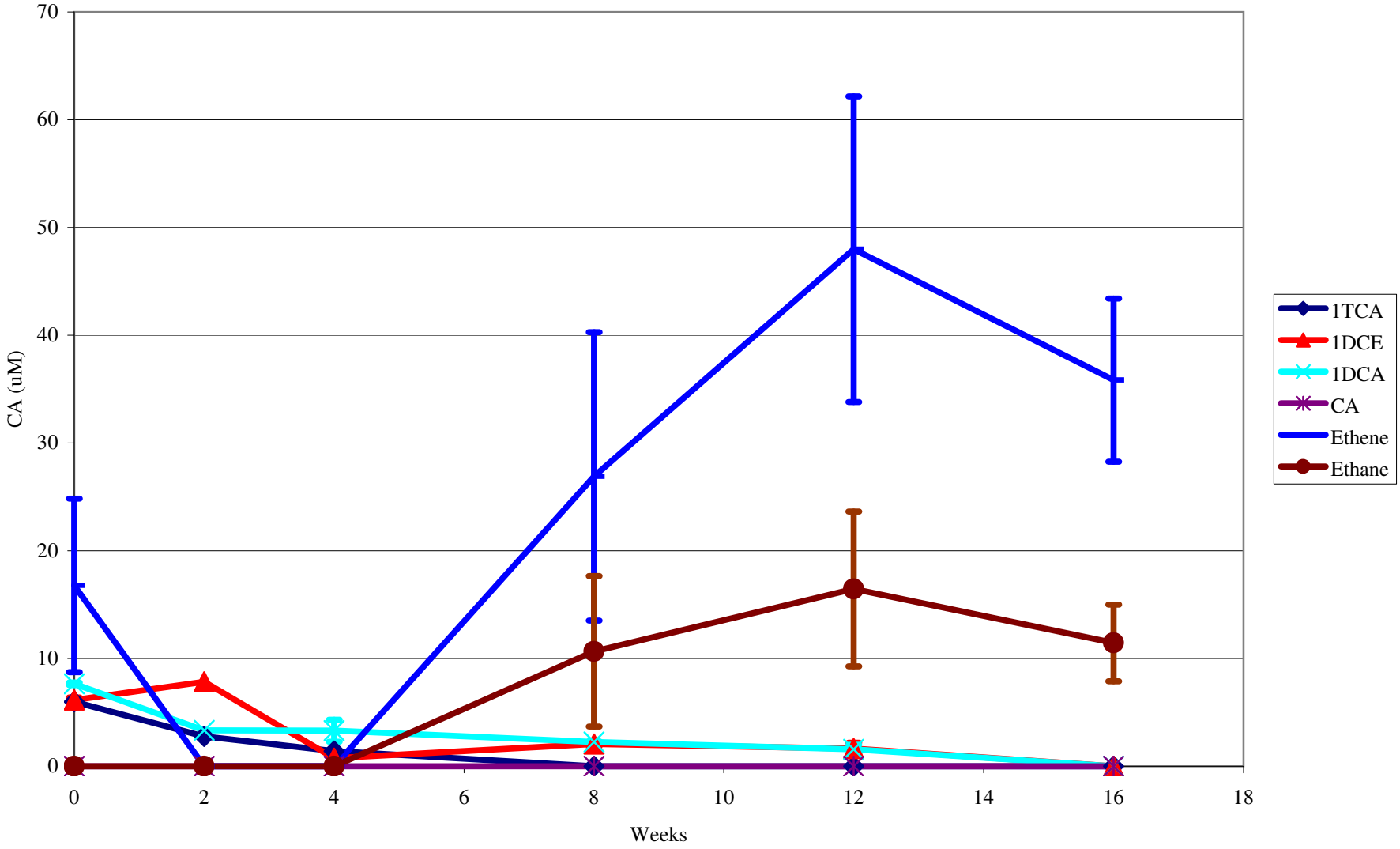


Figure 36 Source 4.5 g/L Nano EZVI CA

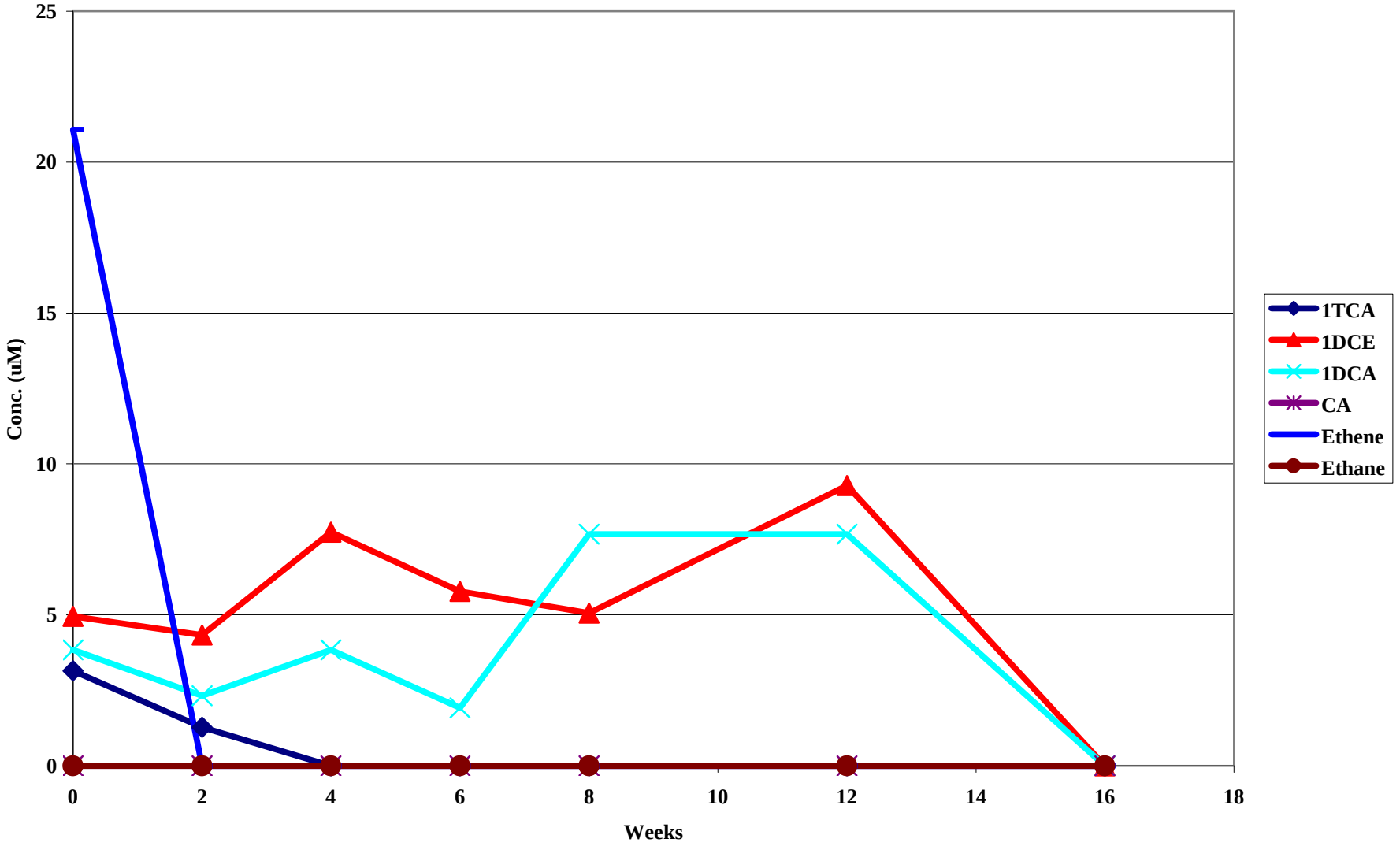


Figure 37 Source 22 g/L Nano EZVI CA

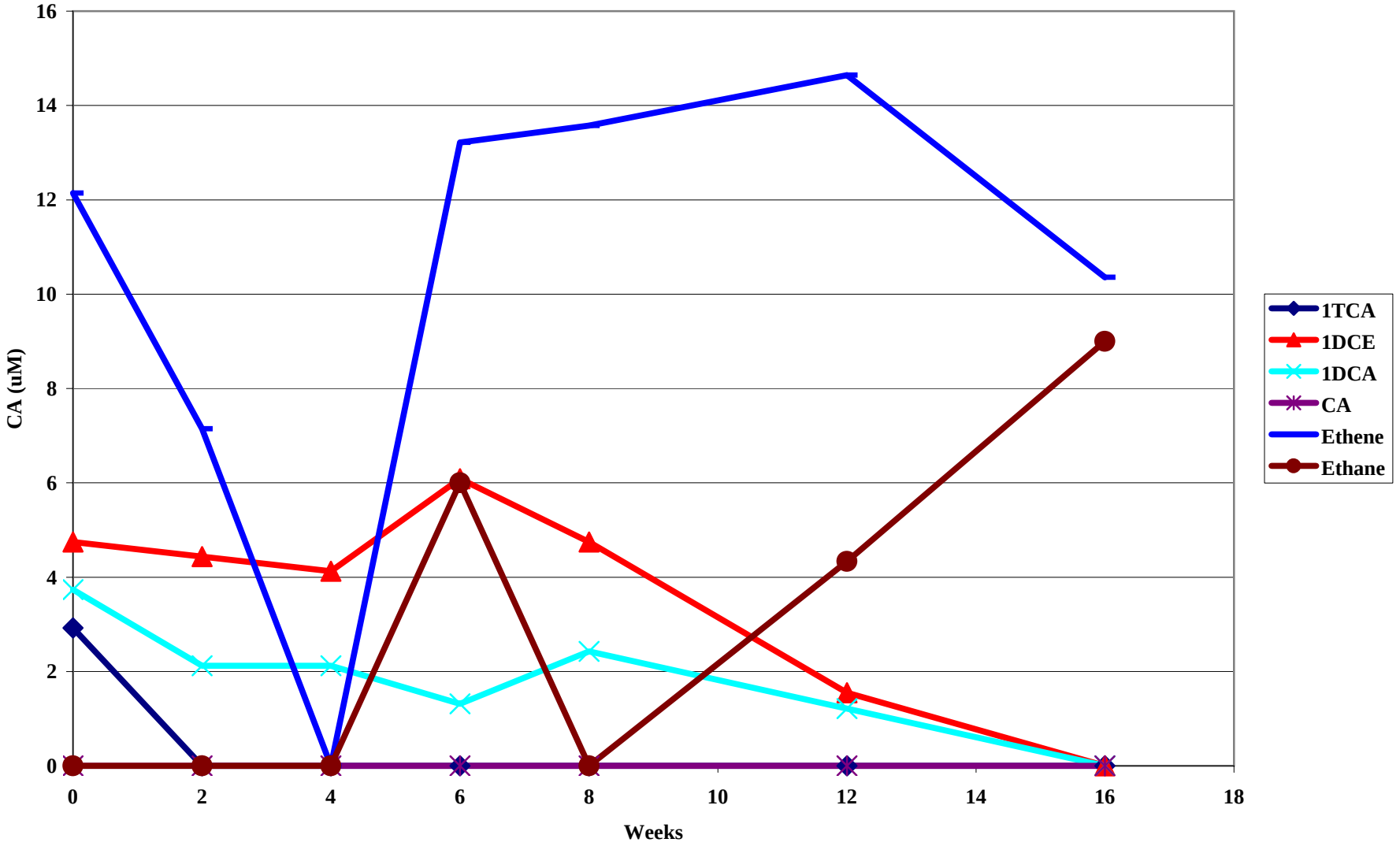


Figure 38 Source 88 g/L Nano EZVI CA

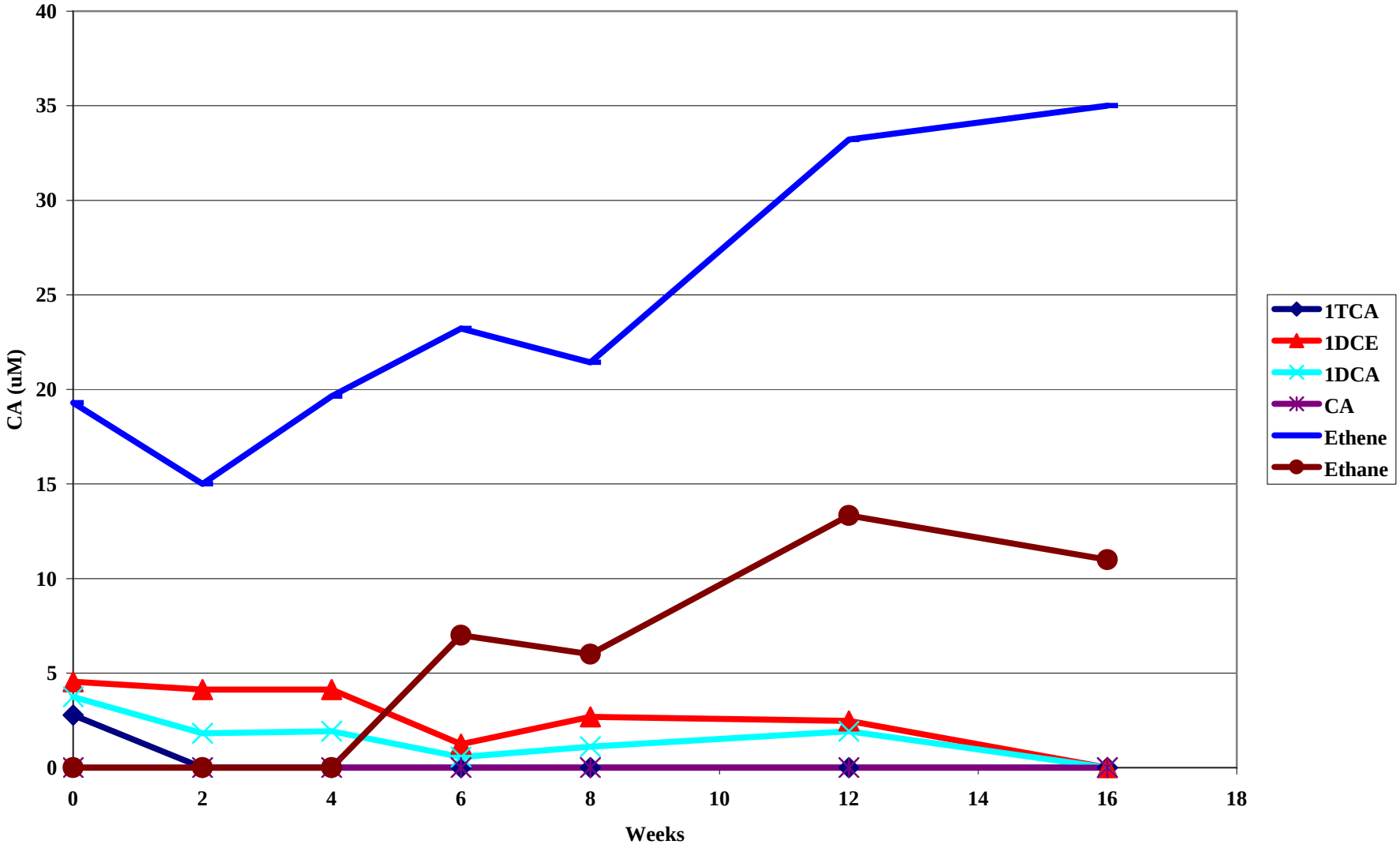


Figure 39 Plume Sterile Control CA Average +/- Standard Deviation

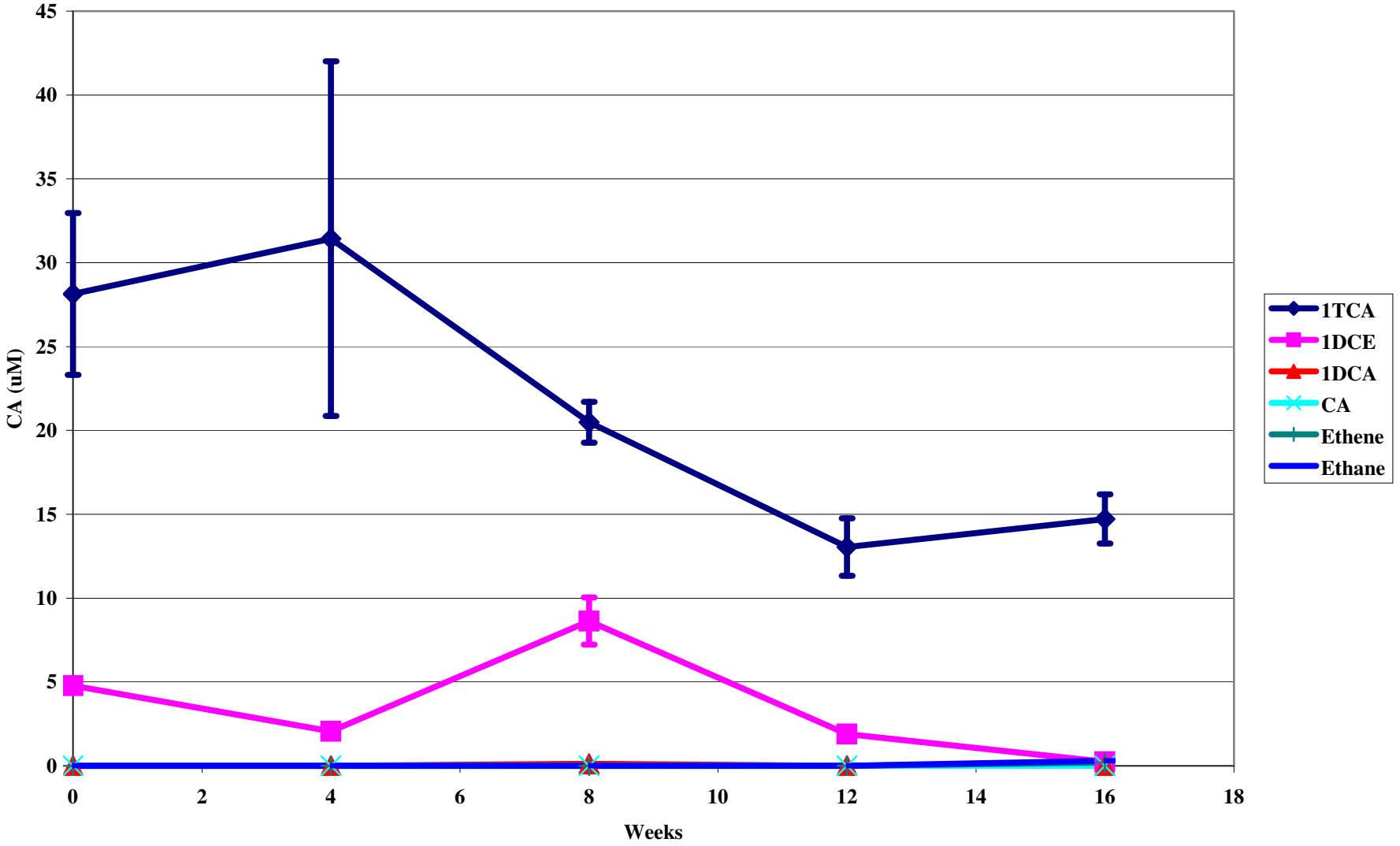


Figure 40 Plume Unamended Control CAAverage +/- Standard Deviation

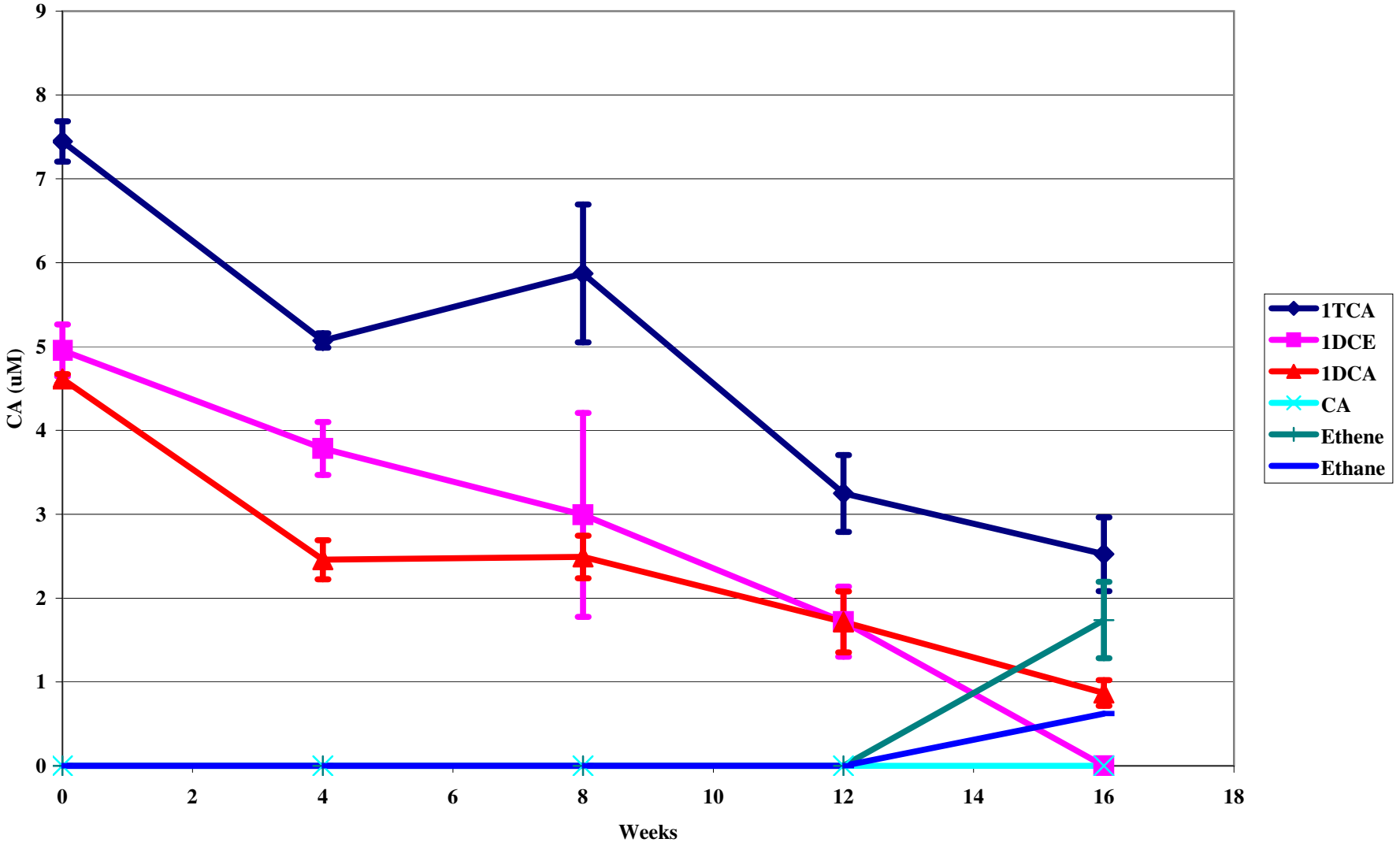


Figure 41 Plume SRS CA Average +/- Standard Deviation

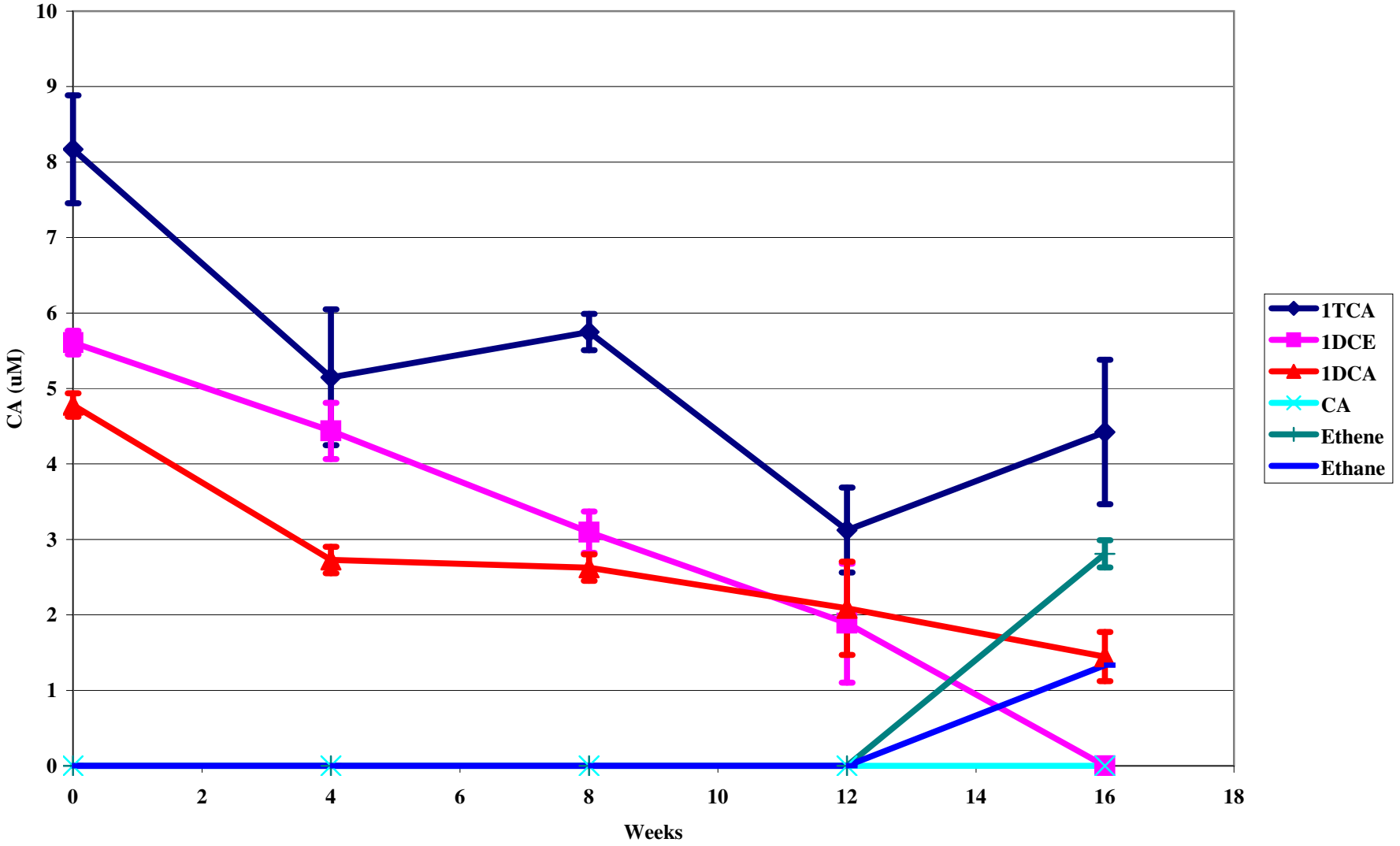


Figure 42 Plume SRS + Bioaugmentation CA Average +/- Standard Deviation

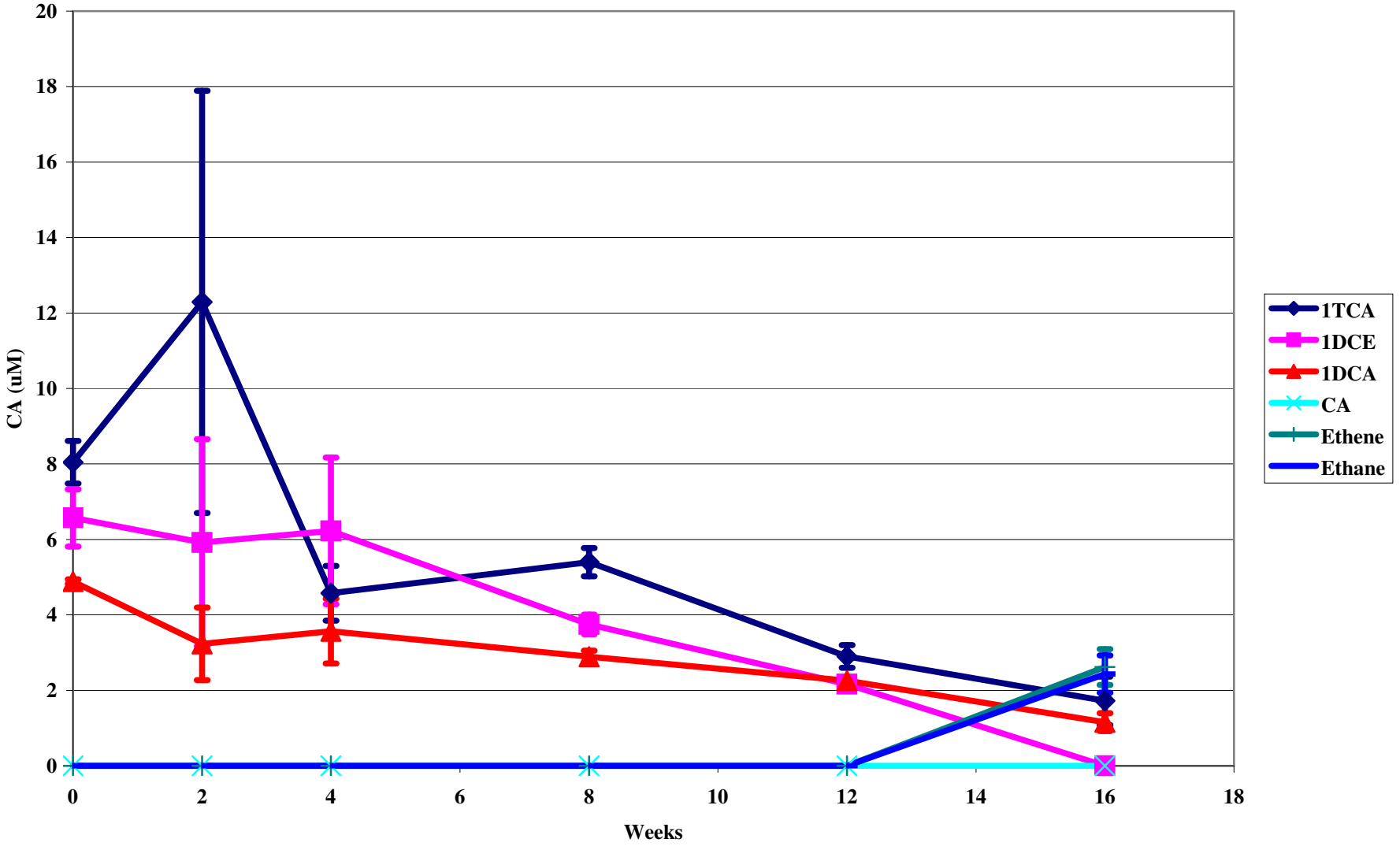


Figure 43 Plume Nano EZVI CA Average +/- Standard Deviation

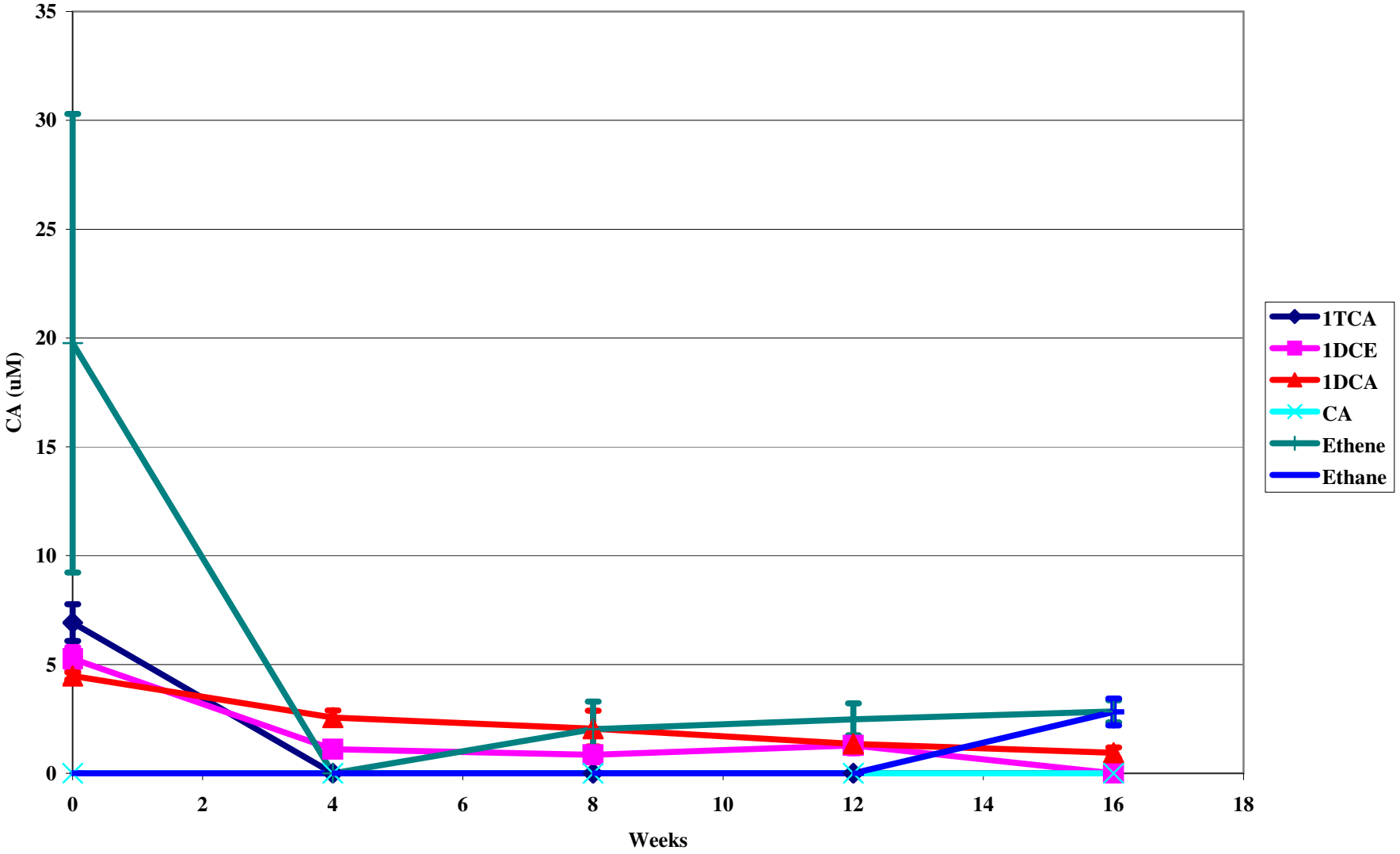


Figure 44 Plume Micro EZVI CA Average +/- Standard Deviation

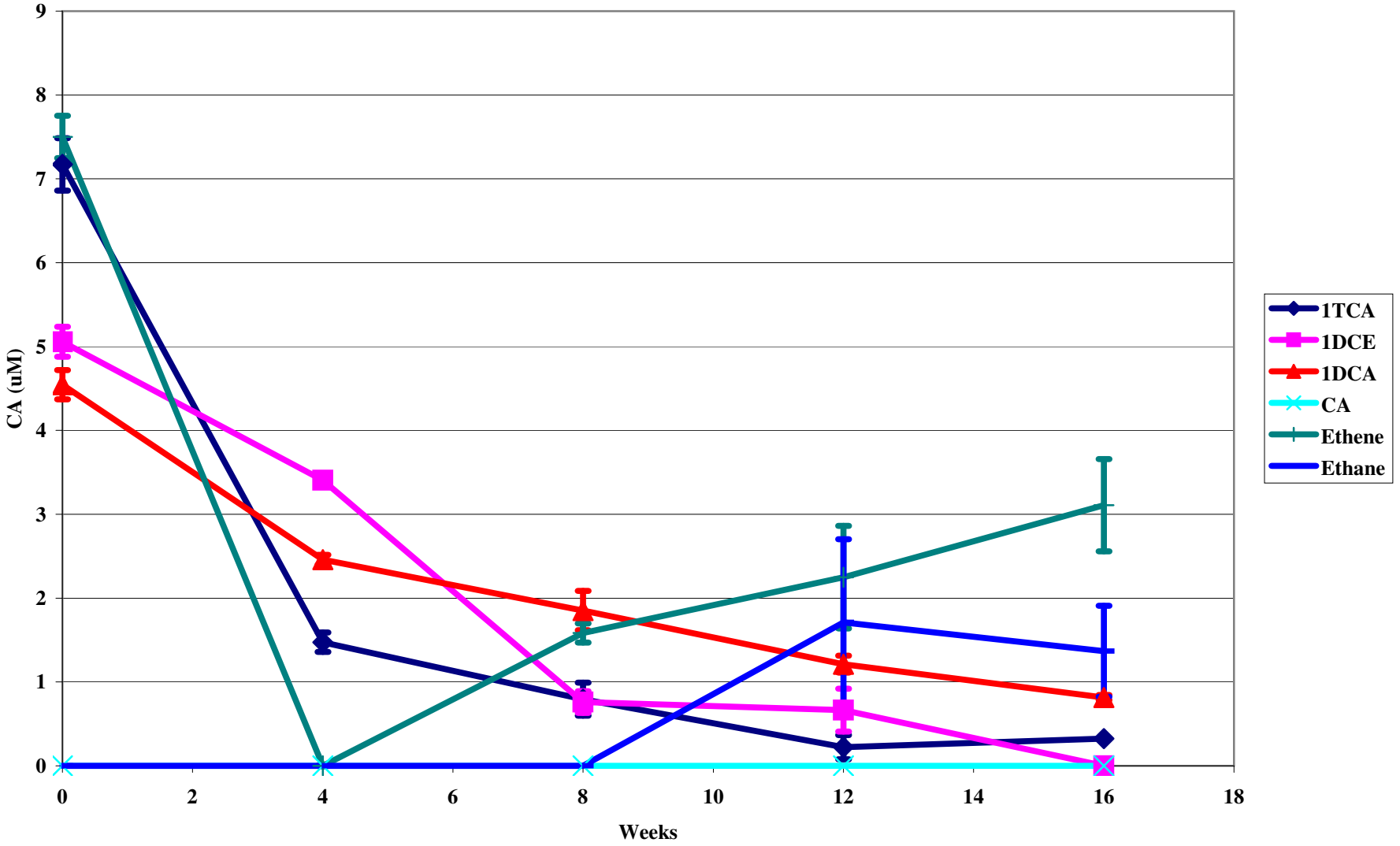
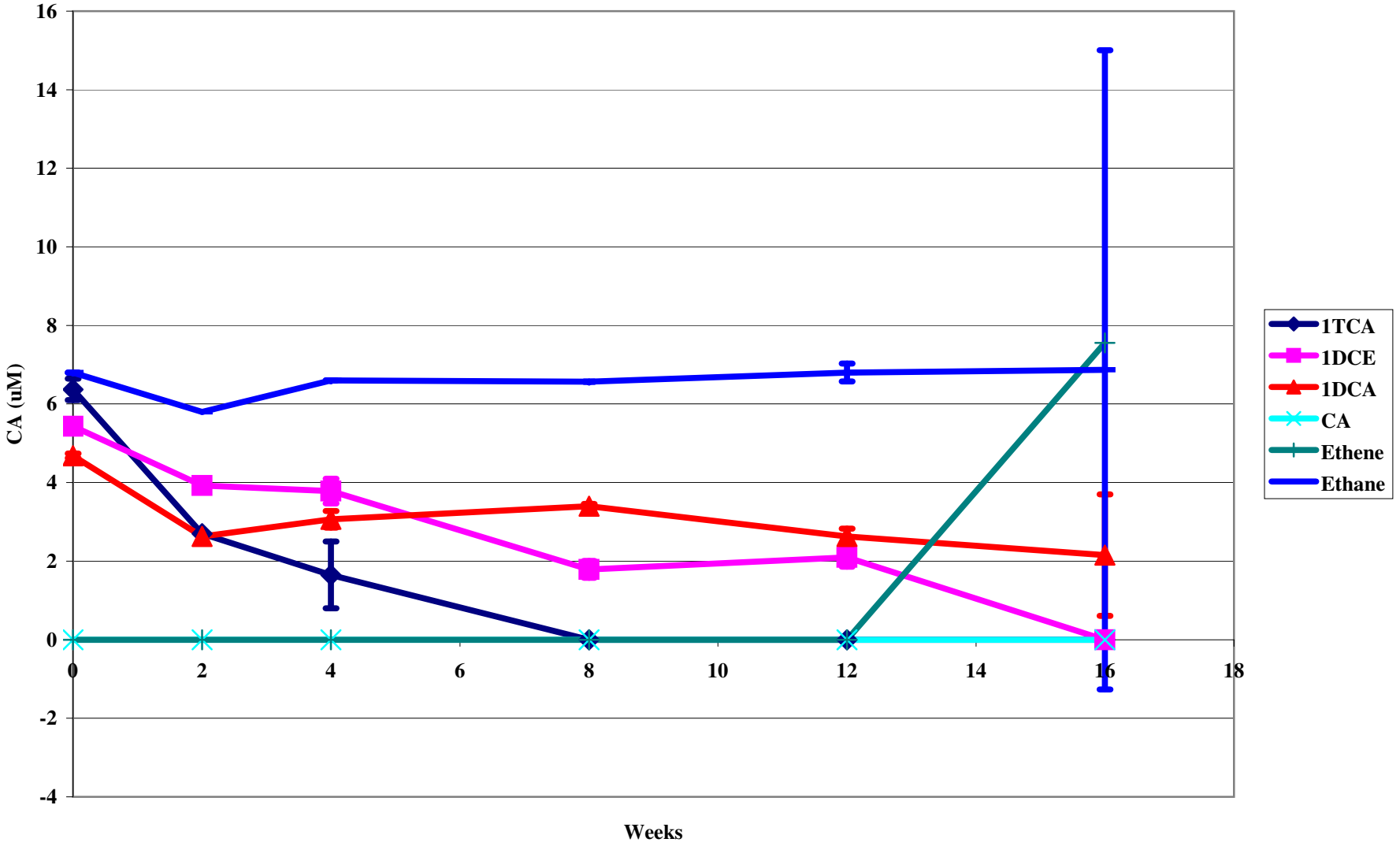


Figure 45 Plume EHC CA Average +/- Standard Deviation



APPENDIX I

CONCENTRATIONS OF CHLORINATED ETHENES, LIGHT HYDROCARBON GASES, ALKALINITY, SULFATE, pH, AND ORP

Ekonol Microcosm

1-A	Sterile Control Source Zone RMW-4D Groundwater and MW-7D Rock						
Compound	Week	0	4	8	12	16	16 Soil
PCE	µg/L	910	160	<20	<20	<10	12
TCE	µg/L	9790	6510	2850	1690	590	68
cDCE	µg/L	1570	1360	490	220	240	13
tDCE	µg/L	<100	<25	<20	<20	<10	<2.0
1TCA	µg/L	9160	7590	5200	2870	1590	72
1DCE	µg/L	1520	220	680	120	<10	<2.0
1DCA	µg/L	<100	<25	<20	<20	<10	<2.0
CA	µg/L	<100	<25	<20	<20	<10	<2.0
VC	µg/L	<100	<25	<20	<20	<10	<2.0
Methane	µg/L	210	<17	<13	<13	<6.7	<1.3
Acetylene	µg/L	<100	<25	<20	<20	<10	<2.0
Ethene	µg/L	<120	<30	<24	<24	<12	<2.4
Ethane	µg/L	<120	<30	<24	<24	<12	9.2
PCE	µM	5.5	1.0	<0.12	<0.12	<0.060	0.072
TCE	µM	74.5	49.5	21.7	12.9	4.5	0.52
cDCE	µM	16.2	14.0	5.1	2.3	2.5	0.13
tDCE	µM	<1.0	<0.26	<0.21	<0.21	<0.10	<0.021
1TCA	µM	68.7	56.9	39.0	21.5	11.9	0.54
1DCE	µM	15.7	2.3	7.0	1.2	<0.10	<0.021
1DCA	µM	<1.0	<0.25	<0.20	<0.20	<0.10	<0.020
CA	µM	<1.6	<0.39	<0.31	<0.31	<0.31	<0.031
VC	µM	<1.6	<0.40	<0.32	<0.32	<0.32	<0.032
Acetylene	µM	<3.8	<0.96	<0.77	<0.77	<0.38	<0.077
Ethene	µM	<4.3	<1.1	<0.86	<0.86	<0.043	<0.086
Ethane	µM	<4.0	<1.0	<0.80	<0.80	<0.080	0.31
Sum CE	µM	96.2	64.5	26.7	15.1	7.0	0.72
Sum CA	µM	84.4	59.2	46.0	22.8	11.9	0.85
pH		6.6	6.9	7.0	7.2	7.1	
ORP	mV	255	261	231	281	297	
Alkalinity	mg/L CaCO3	190	175	170	235	260	
Sum CE-Gases	µM	96	65	27	15	7.0	0.72
Sum CA-Gases	µM	84	59	46	23	12	0.54
Sulfate	mg/L	1300				1100	

1-B	Sterile Control Source Zone RMW-4D Groundwater and MW-7D Rock					
Compound	Week	0	4	8	12	16
PCE	µg/L	890	150	<20	<20	<10
TCE	µg/L	8880	4480	3120	1520	1300
cDCE	µg/L	1420	810	650	220	300
tDCE	µg/L	<100	<25	<20	<20	<10
1TCA	µg/L	7780	6250	5580	2690	3140
1DCE	µg/L	1410	320	1050	130	<10
1DCA	µg/L	<100	<25	<20	<20	<10
CA	µg/L	<100	<25	<20	<20	<10
VC	µg/L	<100	<25	<20	<20	<10
Methane	µg/L	210	13	<13	<13	<6.7
Acetylene	µg/L	<100	<25	<20	<20	<10
Ethene	µg/L	<120	<30	<24	<24	<12
Ethane	µg/L	<120	<30	<24	<24	<12
PCE	µM	5.4	0.90	<0.12	<0.12	<0.060
TCE	µM	67.6	34.1	23.7	11.6	9.9
cDCE	µM	14.7	8.4	6.7	2.3	3.1
tDCE	µM	<1.0	<0.26	<0.21	<0.21	<0.10
1TCA	µM	58.3	46.9	41.8	20.2	23.5
1DCE	µM	14.6	3.3	10.8	1.3	<0.10
1DCA	µM	<1.0	<0.25	<0.20	<0.20	<0.10
CA	µM	<1.6	<0.39	<0.31	<0.31	<0.31
VC	µM	<1.6	<0.40	<0.32	<0.32	<0.32
Acetylene	µM	<3.8	<0.96	<0.77	<0.77	<0.38
Ethene	µM	<4.3	<1.1	<0.86	<0.86	<0.043
Ethane	µM	<4.0	<1.0	<0.80	<0.80	<0.080
Sum CE	µM	87.6	43.4	30.5	13.8	13.0
Sum CA	µM	72.9	50.2	52.7	21.5	23.5
pH		6.7	6.9	6.9	7.1	7.0
ORP	mV	260	250	258	276	281
Alkalinity	mg/L CaCO3	195	175	150	230	220
Sum CE-Gases	µM	88	43	30	14	13.0
Sum CA-Gases	µM	73	50	53	22	24
Sulfate	mg/L	1300				1100

1-C	Sterile Control Source Zone RMW-4D Groundwater and MW-7D Rock					
Compound	Week	0	4	8	12	16
PCE	µg/L	890	160	<20	<20	<10
TCE	µg/L	9160	3990	2080	1620	1400
cDCE	µg/L	1370	780	500	290	340
tDCE	µg/L	<100	<25	<20	<20	<10
1TCA	µg/L	6680	5200	3950	2300	2940
1DCE	µg/L	1410	320	810	220	42
1DCA	µg/L	<100	<25	<20	<20	<10
CA	µg/L	<100	<25	<20	<20	<10
VC	µg/L	<100	<25	<20	<20	<10
Methane	µg/L	210	6.5	<13	<13	<6.7
Acetylene	µg/L	<100	<25	<20	<20	<10
Ethene	µg/L	<120	<30	<24	<24	<12
Ethane	µg/L	<120	<30	<24	<24	<12
PCE	µM	5.4	1.0	<0.12	<0.12	<0.060
TCE	µM	69.7	30.4	15.8	12.3	10.7
cDCE	µM	14.1	8.0	5.2	3.0	3.5
tDCE	µM	<1.0	<0.26	<0.21	<0.21	<0.10
1TCA	µM	50.1	39.0	29.6	17.2	22.0
1DCE	µM	14.6	3.3	8.4	2.3	0.43
1DCA	µM	<1.0	<0.25	<0.20	<0.20	<0.10
CA	µM	<1.6	<0.39	<0.31	<0.31	<0.31
VC	µM	<1.6	<0.40	<0.32	<0.32	<0.32
Acetylene	µM	<3.8	<0.96	<0.77	<0.77	<0.38
Ethene	µM	<4.3	<1.1	<0.86	<0.86	<0.043
Ethane	µM	<4.0	<1.0	<0.80	<0.80	<0.080
Sum CE	µM	89.2	39.4	21.0	15.3	14.2
Sum CA	µM	64.6	42.3	38.0	19.5	22.5
pH		6.7	6.9	7.0	7.1	7.0
ORP	mV	265	267	264	285	280
Alkalinity	mg/L CaCO3	200	190	175	250	220
Sum CE-Gases	µM	89	39	21	15	14.2
Sum CA-Gases	µM	65	42	38	20	22
Sulfate	mg/L	1300				1100

2-A	Unamended Control Source Zone RMW-4D Groundwater and MW-7D Rock					
Compound	Week	0	4	8	12	16
PCE	µg/L	2040	640	330	280	200
TCE	µg/L	23100	16700	14200	17200	12000
cDCE	µg/L	21400	21400	23400	30700	11600
tDCE	µg/L	<100	240	160	250	<100
1TCA	µg/L	4180	310	290	210	<100
1DCE	µg/L	<100	410	260	250	<100
1DCA	µg/L	740	200	210	220	<100
CA	µg/L	<100	<50	<50	290	<100
VC	µg/L	1060	540	650	320	<100
Methane	µg/L	220	42	<34	<34	<34
Acetylene	µg/L	<100	<50	<50	<50	<50
Ethene	µg/L	<120	<60	<60	<60	<60
Ethane	µg/L	<120	<60	<60	<60	<60
PCE	µM	12.3	3.9	2.0	1.7	1.2
TCE	µM	175.8	127.1	108.1	130.9	91.3
cDCE	µM	220.8	220.8	241.5	316.8	119.7
tDCE	µM	<1.0	2.5	1.7	2.6	<1.0
1TCA	µM	31.3	2.3	2.2	1.6	<0.75
1DCE	µM	<1.0	4.2	2.7	2.6	<1.0
1DCA	µM	7.5	2.0	2.1	2.2	<1.0
CA	µM	<1.6	<0.78	<0.78	4.5	<1.6
VC	µM	17.0	8.6	10.4	5.1	<1.6
Acetylene	µM	<3.8	<1.9	<1.9	<1.9	<1.9
Ethene	µM	<4.3	<2.1	<2.1	<2.1	<2.1
Ethane	µM	<4.0	<2.0	<2.0	<2.0	<2.0
Sum CE	µM	425.9	362.9	363.6	457.1	212.2
Sum CA	µM	38.8	8.6	7.0	10.9	0.0
pH		6.6	6.8	6.7	7.1	7.1
ORP	mV	191	205	202	226	238
Alkalinity	mg/L CaCO3	325	285	285	320	305
Sum CE-Gases	µM	426	363	364	457	212.2
Sum CA-Gases	µM	39	8.6	7.0	10.9	0.00
Sulfate	mg/L	1300				1000

2-B	Unamended Control Source Zone RMW-4D Groundwater and MW-7D Rock						
Compound	Week	0	4	8	12	16	16 Soil
PCE	µg/L	1660	450	170	120	45	51
TCE	µg/L	17000	9130	4690	3180	2180	1140
cDCE	µg/L	17600	15100	10800	5180	6610	740
tDCE	µg/L	<100	230	95	110	<20	<4.0
1TCA	µg/L	750	150	200	81	<20	7.0
1DCE	µg/L	<100	470	110	<25	<20	<4.0
1DCA	µg/L	740	180	190	99	12	<4.0
CA	µg/L	<100	<50	<50	<25	<20	<4.0
VC	µg/L	1100	200	470	130	<20	<4.0
Methane	µg/L	220	18	<34	<17	<13	17
Acetylene	µg/L	<100	<50	<50	25	<20	<4.0
Ethene	µg/L	<120	<60	<60	<30	<24	<4.8
Ethane	µg/L	<120	<60	<60	<30	<24	21
PCE	µM	10.0	2.7	1.0	0.72	0.27	0.31
TCE	µM	129.4	69.5	35.7	24.2	16.6	8.7
cDCE	µM	181.6	155.8	111.5	53.5	68.2	7.6
tDCE	µM	<1.0	2.4	1.0	1.1	<0.21	<0.041
1TCA	µM	5.6	1.1	1.5	0.61	<0.15	0.052
1DCE	µM	<1.0	4.9	1.1	<0.25	<0.21	<0.041
1DCA	µM	7.5	1.8	1.9	1.0	0.12	<0.040
CA	µM	<1.6	<0.78	<0.78	<0.39	<0.31	<0.062
VC	µM	17.6	3.2	7.5	2.1	<0.32	<0.064
Acetylene	µM	<3.8	<1.9	<1.9	<0.96	<0.77	<0.15
Ethene	µM	<4.3	<2.1	<2.1	<1.1	<0.71	<0.14
Ethane	µM	<4.0	<2.0	<2.0	<1.0	<0.67	0.70
Sum CE	µM	338.6	233.6	156.7	81.6	85.1	16.6
Sum CA	µM	13.1	7.8	4.6	1.6	0.1	0.8
pH		6.7	7.0	7.0	7.2	7.1	
ORP	mV	160	189	181	188	214	
Alkalinity	mg/L CaCO3	300	120	265	290	305	
Sum CE-Gases	µM	339	234	157	82	85.1	16.6
Sum CA-Gases	µM	13	7.8	4.6	1.6	0.1	0.1
Sulfate	mg/L	1300				1000	

2-C	Unamended Control Source Zone RMW-4D Groundwater and MW-7D Rock					
Compound	Week	0	4	8	12	16
PCE	µg/L	1780	660	280	220	79
TCE	µg/L	18700	18200	9880	7030	5360
cDCE	µg/L	19200	25500	17500	9260	10100
tDCE	µg/L	<100	250	130	190	<25
1TCA	µg/L	760	240	290	160	71
1DCE	µg/L	<100	410	180	190	<25
1DCA	µg/L	730	210	200	160	31
CA	µg/L	<100	<50	<50	<40	<25
VC	µg/L	1030	560	640	240	<25
Methane	µg/L	210	38	<34	<27	<17
Acetylene	µg/L	<100	<50	<50	<40	<25
Ethene	µg/L	<120	<60	<60	<48	<30
Ethane	µg/L	<120	<60	<60	<48	<30
PCE	µM	10.7	4.0	1.7	1.3	0.5
TCE	µM	142.3	138.5	75.2	53.5	40.8
cDCE	µM	198.1	263.2	180.6	95.6	104.2
tDCE	µM	<1.0	2.6	1.3	2.0	<0.26
1TCA	µM	5.7	1.8	2.2	1.2	0.53
1DCE	µM	<1.0	4.2	1.9	2.0	<0.26
1DCA	µM	7.4	2.1	2.0	1.6	0.3
CA	µM	<1.6	<0.78	<0.78	<0.62	<0.62
VC	µM	16.5	9.0	10.2	3.8	<0.40
Acetylene	µM	<3.8	<1.9	<1.9	<1.5	<0.96
Ethene	µM	<4.3	<2.1	<2.1	<1.7	<1.1
Ethane	µM	<4.0	<2.0	<2.0	<1.3	<1.0
Sum CE	µM	367.7	417.2	269.1	156.2	145.5
Sum CA	µM	13.1	8.2	6.1	4.8	0.8
pH		6.7	6.9	6.8	7.1	7.1
ORP	mV	122	187	125	186	208
Alkalinity	mg/L CaCO3	270	115	285	315	330
Sum CE-Gases	µM	368	417	269	156	145.5
Sum CA-Gases	µM	13	8.2	6.1	4.8	0.8
Sulfate	mg/L	1300				990

3-A	SRS Source Zone RMW-4D Groundwater and MW-7D Rock						
Compound	Week	0	4	8	12	16	16 Soil
PCE	µg/L	2530	820	<200	<100	<100	64
TCE	µg/L	25200	1090	640	490	<100	150
cDCE	µg/L	23500	66900	46900	25100	22300	1180
tDCE	µg/L	<100	880	790	490	<100	<10
1TCA	µg/L	820	420	800	330	<100	<10
1DCE	µg/L	910	820	440	450	<100	<10
1DCA	µg/L	750	370	710	380	<100	<10
CA	µg/L	<100	<100	<200	<100	<100	<10
VC	µg/L	1250	1130	2040	590	<100	<10
Methane	µg/L	220	62	<130	<67	<67	<6.7
Acetylene	µg/L	<100	<100	<200	<100	<100	<10
Ethene	µg/L	<120	<120	<240	<120	<120	<12
Ethane	µg/L	<120	<120	<240	<120	<120	<12
PCE	µM	15.3	4.9	<1.2	<0.60	<0.60	0.39
TCE	µM	191.8	8.3	4.9	3.7	<0.76	1.1
cDCE	µM	242.5	690.4	484.0	259.0	230.1	12.2
tDCE	µM	<1.0	9.1	8.2	5.1	<1.0	<0.10
1TCA	µM	6.1	3.1	6.0	2.5	<0.75	<0.075
1DCE	µM	9.4	8.5	4.5	4.6	<1.0	<0.10
1DCA	µM	7.6	3.7	7.2	3.8	<1.0	<0.10
CA	µM	<1.6	<1.6	<3.2	<1.6	<1.6	<0.16
VC	µM	20.0	18.1	32.6	9.4	<1.6	<0.16
Acetylene	µM	<3.8	<3.8	<7.6	<3.8	<3.8	<0.38
Ethene	µM	<4.3	<4.3	<8.6	<4.3	<4.3	<0.43
Ethane	µM	<4.0	<4.0	<8.0	<4.0	<4.0	<0.40
Sum CE	µM	469.6	730.8	529.7	277.3	230.1	13.7
Sum CA	µM	23.1	15.3	17.7	11.0	0.0	0.0
pH		6.6	6.8	6.7	7.3	7.1	
ORP	mV	-51	-286	-338	-385	-388	
Alkalinity	mg/L CaCO3	320	375	525	800	1070	1070
Sum CE-Gases	µM	470	731	530	277	230.1	13.7
Sum CA-Gases	µM	23	15	18	11	0	
Sulfate	mg/L	1300				11	

3-B	SRS Source Zone RMW-4D Groundwater and MW-7D Rock					
Compound	Week	0	4	8	12	16
PCE	µg/L	2280	690	<200	<100	<100
TCE	µg/L	24300	870	<200	500	<100
cDCE	µg/L	23500	64400	44300	30200	19300
tDCE	µg/L	<100	910	810	500	<100
1TCA	µg/L	810	450	780	330	<100
1DCE	µg/L	890	830	430	450	<100
1DCA	µg/L	740	390	710	390	<100
CA	µg/L	<100	<100	<200	<100	<100
VC	µg/L	1210	1040	2030	600	<100
Methane	µg/L	220	35	<130	<67	<67
Acetylene	µg/L	<100	<100	<200	<100	<100
Ethene	µg/L	<120	<120	<240	<120	<120
Ethane	µg/L	<120	<120	<240	<120	<120
PCE	µM	13.8	4.2	<1.2	<0.60	<0.60
TCE	µM	184.9	6.6	<1.5	3.8	<0.76
cDCE	µM	242.5	664.6	457.2	311.7	199.2
tDCE	µM	<1.0	9.4	8.4	5.2	<1.0
1TCA	µM	6.1	3.4	5.8	2.5	<0.75
1DCE	µM	9.2	8.6	4.4	4.6	<1.0
1DCA	µM	7.5	3.9	7.2	3.9	<1.0
CA	µM	<1.6	<1.6	<3.2	<1.6	<1.6
VC	µM	19.4	16.6	32.5	9.6	<1.6
Acetylene	µM	<3.8	<3.8	<7.6	<3.8	<3.8
Ethene	µM	<4.3	<4.3	<8.6	<4.3	<4.3
Ethane	µM	<4.0	<4.0	<8.0	<4.0	<4.0
Sum CE	µM	460.6	701.4	498.0	330.2	199.2
Sum CA	µM	22.7	15.9	17.5	11.1	0.0
pH		6.7	6.8	6.6	7.2	7.0
ORP	mV	80	119	-293	-359	-383
Alkalinity	mg/L CaCO3	320	200	385	600	1000
Sum CE-Gases	µM	461	701	498	330	199.2
Sum CA-Gases	µM	23	16	17	11	0.0
Sulfate	mg/L	1300				360

3-C	SRS Source Zone RMW-4D Groundwater and MW-7D Rock					
Compound	Week	0	4	8	12	16
PCE	µg/L	2430	770	<200	<100	63
TCE	µg/L	25600	960	<200	<100	140
cDCE	µg/L	23900	62800	45800	23700	23100
tDCE	µg/L	<100	910	830	490	<25
1TCA	µg/L	790	440	810	<100	100
1DCE	µg/L	940	830	460	450	<25
1DCA	µg/L	750	370	710	380	45
CA	µg/L	<100	<100	<200	<100	<25
VC	µg/L	1240	1120	2370	570	72
Methane	µg/L	220	40	<130	<67	<17
Acetylene	µg/L	<100	<100	<200	<100	<25
Ethene	µg/L	<120	<120	<240	<120	<30
Ethane	µg/L	<120	<120	<240	<120	<30
PCE	µM	14.7	4.6	<1.2	<0.60	0.38
TCE	µM	194.8	7.3	<1.5	<0.76	1.1
cDCE	µM	246.6	648.1	472.7	244.6	238.4
tDCE	µM	<1.0	9.4	8.6	5.1	<0.26
1TCA	µM	5.9	3.3	6.1	<0.75	0.75
1DCE	µM	9.7	8.6	4.7	4.6	<0.26
1DCA	µM	7.6	3.7	7.2	3.8	0.45
CA	µM	<1.6	<1.6	<3.2	<1.6	<1.6
VC	µM	19.8	17.9	37.9	9.1	1.2
Acetylene	µM	<3.8	<3.8	<7.6	<3.8	<3.8
Ethene	µM	<4.3	<4.3	<8.6	<4.3	<4.3
Ethane	µM	<4.0	<4.0	<8.0	<4.0	<4.0
Sum CE	µM	476.0	687.4	519.1	258.8	241.0
Sum CA	µM	23.2	15.6	18.0	8.5	1.2
pH		6.9	6.7	6.8	7.0	6.9
ORP	mV	72	-265	-246	-284	-344
Alkalinity	mg/L CaCO3	315	210	370	480	715
Sum CE-Gases	µM	476	687	519	259	241.0
Sum CA-Gases	µM	23	16	18	8	1
Sulfate	mg/L	1300				750

4-A	SRS + Bioaugmentation Source Zone RMW-4D Groundwater and MW-7D Rock							
Compound	Week	0	2	4	8	12	16	16 Soil
PCE	µg/L	2570	1900	<200	<200	<200	<100	95
TCE	µg/L	26600	1440	<200	630	940	<100	240
cDCE	µg/L	25800	74900	61800	58500	42000	21500	380
tDCE	µg/L	<100	990	1030	640	920	<100	<10
1TCA	µg/L	830	630	570	790	600	<100	<10
1DCE	µg/L	940	980	<200	850	910	<100	<10
1DCA	µg/L	750	350	<200	720	760	<100	<10
CA	µg/L	<100	<100	<200	<200	<200	<100	<10
VC	µg/L	1360	1200	1120	2120	1160	700	<10
Methane	µg/L	220	83	40	<130	<130	2400	48
Acetylene	µg/L	<100	<100	<200	<200	<200	<100	<10
Ethene	µg/L	<120	<120	<240	<240	<240	<120	<12
Ethane	µg/L	<120	<120	<240	<240	<240	<120	<12
PCE	µM	15.5	11.5	<1.2	<1.2	<1.2	<0.60	0.57
TCE	µM	202.4	11.0	<1.5	4.8	7.2	<0.76	1.8
cDCE	µM	266.3	773.0	637.8	603.7	433.4	221.9	3.9
tDCE	µM	<1.0	10.2	10.6	6.6	9.5	<1.0	<0.10
1TCA	µM	6.2	4.7	4.3	5.9	4.5	<0.75	<0.075
1DCE	µM	9.7	10.1	<2.1	8.8	9.4	<1.0	<0.10
1DCA	µM	7.6	3.5	<2.0	7.3	7.7	<1.0	<0.10
CA	µM	<1.6	<1.6	<3.1	<3.2	<3.2	<1.6	<0.16
VC	µM	21.8	19.2	17.9	33.9	18.6	11.2	<0.16
Acetylene	µM	<3.8	<3.8	<7.7	<7.6	<7.6	<3.8	<0.38
Ethene	µM	<4.3	<4.3	<8.6	<8.6	<8.6	<4.3	<0.43
Ethane	µM	<4.0	<4.0	<8.0	<8.0	<8.0	<4.0	<0.40
Sum CE	µM	505.9	824.8	666.3	649.0	468.6	233.1	6.3
Sum CA	µM	23.5	18.4	4.3	22.0	21.6	0.0	0.0
pH		6.9	6.7	6.6	7.0	7.2	6.9	6.8
ORP	mV	-164	-250	-358	-406	-409	-410	-398
Alkalinity	mg/L CaCO3	325	325	590	1140	1370	1435	1560
Sum CE-Gases	µM	506	825	666	649	468.6	233.1	6.3
Sum CA-Gases	µM	23	18	4.3	22	22	0.0	0.0
Sulfate	mg/L	1300					4.9	

4-B	SRS + Bioaugmentation Source Zone RMW-4D Groundwater and MW-7D Rock						
Compound	Week	0	2	4	8	12	16
PCE	µg/L	2500	3080	<200	<200	<200	<100
TCE	µg/L	28800	2350	<200	360	<200	<100
cDCE	µg/L	26100	84700	47000	74000	35300	18100
tDCE	µg/L	<100	1340	1180	1140	950	<100
1TCA	µg/L	810	930	570	490	580	<100
1DCE	µg/L	950	980	<200	430	900	<100
1DCA	µg/L	750	360	<200	390	750	<100
CA	µg/L	<100	<100	<200	<200	<200	<100
VC	µg/L	1280	1200	1300	1290	1150	5420
Methane	µg/L	210	83	110	<130	<130	3700
Acetylene	µg/L	<100	<100	<200	<200	<200	<100
Ethene	µg/L	<120	<120	<240	<240	<240	<120
Ethane	µg/L	<120	<120	<240	<240	<240	<120
PCE	µM	15.1	18.6	<1.2	<1.2	<1.2	<0.60
TCE	µM	219.2	17.9	<1.5	2.7	<1.5	<0.76
cDCE	µM	269.3	874.1	485.0	763.7	364.3	186.8
tDCE	µM	<1.0	13.8	12.2	11.8	9.8	<1.0
1TCA	µM	6.1	7.0	4.3	3.7	4.3	<0.75
1DCE	µM	9.8	10.1	<2.1	4.4	9.3	<1.0
1DCA	µM	7.6	3.6	<2.0	3.9	7.6	<1.0
CA	µM	<1.6	<1.6	<3.1	<3.2	<3.2	<1.6
VC	µM	20.5	19.2	20.8	20.6	18.4	86.7
Acetylene	µM	<3.8	<3.8	<7.7	<7.6	<7.6	<3.8
Ethene	µM	<4.3	<4.3	<8.6	<8.6	<8.6	<4.3
Ethane	µM	<4.0	<4.0	<8.0	<8.0	<8.0	<4.0
Sum CE	µM	524.1	943.6	518.0	798.8	392.5	273.5
Sum CA	µM	23.5	20.7	4.3	12.1	21.2	0.0
pH		6.6	6.7	6.5	6.9	7.1	6.8
ORP	mV	-172	-254	-393	-411	-401	-398
Alkalinity	mg/L CaCO3	305	330	655	1255	1440	1560
Sum CE-Gases	µM	524	944	518	799	392.5	273.5
Sum CA-Gases	µM	23	21	4.3	12	21	0.00
Sulfate	mg/L	1300					4.5

4-C	SRS + Bioaugmentation Source Zone RMW-4D Groundwater and MW-7D Rock						
Compound	Week	0	2	4	8	12	16
PCE	µg/L	2180	1450	<100	<100	<50	<100
TCE	µg/L	24800	990	<100	350	280	<100
cDCE	µg/L	25200	46800	43600	58300	33400	14900
tDCE	µg/L	<100	920	640	710	270	<100
1TCA	µg/L	790	550	340	470	180	<100
1DCE	µg/L	980	800	<100	450	250	<100
1DCA	µg/L	740	330	<100	410	230	<100
CA	µg/L	<100	<100	<100	<100	<50	<100
VC	µg/L	1250	970	890	1500	450	25100
Methane	µg/L	220	86	72	<67	1100	5200
Acetylene	µg/L	<100	<100	<100	<100	<50	<100
Ethene	µg/L	<120	<120	<120	<120	<60	<120
Ethane	µg/L	<120	<120	<120	<120	<60	<120
PCE	µM	13.1	8.7	<0.60	<0.60	<0.30	<0.60
TCE	µM	188.7	7.5	<0.76	2.7	2.1	<0.76
cDCE	µM	260.1	483.0	449.9	601.7	344.7	153.8
tDCE	µM	<1.0	9.5	6.6	7.3	2.8	<1.0
1TCA	µM	5.9	4.1	2.5	3.5	1.3	<0.75
1DCE	µM	10.1	8.3	<1.0	4.6	2.6	<1.0
1DCA	µM	7.5	3.3	<1.0	4.1	2.3	<1.0
CA	µM	<1.6	<1.6	<1.6	<1.6	<0.78	<1.6
VC	µM	20.0	15.5	14.2	24.0	7.2	401.6
Acetylene	µM	<3.8	<3.8	<3.8	<3.8	<1.9	<3.8
Ethene	µM	<4.3	<4.3	<4.3	<4.3	<2.1	<4.3
Ethane	µM	<4.0	<4.0	<4.0	<4.0	<2.0	<4.0
Sum CE	µM	481.9	524.3	470.8	635.6	356.8	555.4
Sum CA	µM	23.5	15.7	2.5	12.3	6.3	0.0
pH		6.7	6.7	6.6	7.2	7.3	6.9
ORP	mV	-172	-186	-370	-422	-411	-408
Alkalinity	mg/L CaCO3	325	315	435	1010	1320	1375
Sum CE-Gases	µM	482	524	471	636	356.8	555.4
Sum CA-Gases	µM	24	16	2.5	12.3	6.3	0.0
Sulfate	mg/L	1300					5.3

5-A	Nanoscale EZVI Source Zone RMW-4D Groundwater and MW-7D Rock						
Compound	Week	0	4	8	12	16	16 Soil
PCE	µg/L	4140	<200	150	110	40	17
TCE	µg/L	74900	3020	1680	330	140	55
cDCE	µg/L	76100	32100	13400	8080	9640	390
tDCE	µg/L	950	1030	430	120	<20	<4.0
1TCA	µg/L	920	<200	<50	<25	<20	<4.0
1DCE	µg/L	1170	<200	220	110	<20	<4.0
1DCA	µg/L	790	<200	220	110	25	<4.0
CA	µg/L	<100	<200	<50	<25	<20	<4.0
VC	µg/L	1560	1320	870	210	46	<4.0
Methane	µg/L	210	110	<33	<17	<13	<2.7
Acetylene	µg/L	<100	<200	<50	<25	<20	<4.0
Ethene	µg/L	600	<240	350	400	310	11
Ethane	µg/L	<120	<240	140	200	180	23
PCE	µM	25.0	<1.2	0.90	0.66	0.24	0.10
TCE	µM	570.0	23.0	12.8	2.5	1.1	0.42
cDCE	µM	785.3	331.3	138.3	83.4	99.5	4.0
tDCE	µM	9.8	10.6	4.4	1.2	<0.21	<0.041
1TCA	µM	6.9	<1.5	<0.75	<0.19	<0.15	<0.030
1DCE	µM	12.1	<2.1	2.3	1.1	<0.21	<0.041
1DCA	µM	8.0	<2.0	2.2	1.1	0.25	<0.040
CA	µM	<1.6	<3.1	<1.6	<0.39	<0.31	<0.062
VC	µM	25.0	21.1	13.9	3.4	0.74	<0.064
Acetylene	µM	<3.8	<7.7	<7.7	<0.96	<0.96	<0.15
Ethene	µM	21.4	<8.6	12.5	14.3	11.1	0.39
Ethane	µM	<4.0	<8.0	4.7	6.7	6.0	0.77
Sum CE	µM	1436.5	386.0	182.8	105.4	112.6	4.9
Sum CA	µM	27.0	0.0	9.2	8.9	6.3	0.8
pH		6.6	7.0	6.9	6.9	7.4	
ORP	mV	-114	-270	-303	-325	-291	
Alkalinity	mg/L CaCO3	330	210	205	220	200	
Sum CE-Gases	µM	1415	386	170	91	101.5	
Sum CA-Gases	µM	27	0.0	4.5	2.2	0.3	
Sulfate	mg/L	1300				810	

5-B	Nanoscale EZVI Source Zone RMW-4D Groundwater and MW-7D Rock					
Compound	Week	0	4	8	12	16
PCE	µg/L	3470	<200	<80	210	<50
TCE	µg/L	65200	3120	770	590	120
cDCE	µg/L	69400	27100	21400	23600	4810
tDCE	µg/L	920	960	290	230	<50
1TCA	µg/L	970	<200	<80	<50	<50
1DCE	µg/L	1080	<200	190	230	<50
1DCA	µg/L	790	<200	300	210	<50
CA	µg/L	<100	<200	<80	<50	<50
VC	µg/L	1160	1160	1010	420	<50
Methane	µg/L	220	78	<54	<34	<33
Acetylene	µg/L	<100	<200	<80	<50	<50
Ethene	µg/L	750	<240	320	410	230
Ethane	µg/L	<120	<240	<96	220	270
PCE	µM	20.9	<1.2	<0.48	1.3	<0.30
TCE	µM	496.2	23.7	5.9	4.5	0.91
cDCE	µM	716.2	279.7	220.8	243.6	49.6
tDCE	µM	9.5	9.9	3.0	2.4	<0.52
1TCA	µM	7.3	<1.5	<0.60	<0.37	<0.37
1DCE	µM	11.1	<2.1	2.0	2.4	<0.52
1DCA	µM	8.0	<2.0	3.0	2.1	<0.51
CA	µM	<1.6	<3.1	<3.1	<3.1	<0.78
VC	µM	18.6	18.6	16.2	6.7	<0.80
Acetylene	µM	<3.8	<7.7	<7.7	<7.7	<1.9
Ethene	µM	26.8	<8.6	11.4	14.6	8.2
Ethane	µM	<4.0	<8.0	<8.0	7.3	9.0
Sum CE	µM	1288.2	331.9	257.3	273.0	58.8
Sum CA	µM	26.4	0.0	5.0	7.3	9.0
pH		6.6	6.9	6.9	7.3	7.3
ORP	mV	-169	-275	-281	-263	-270
Alkalinity	mg/L CaCO3	325	220	190	210	195
Sum CE-Gases	µM	1261	332	246	258	50.6
Sum CA-Gases	µM	26	0.0	5.0	4.5	0.0
Sulfate	mg/L	1300				830

5-C	Nanoscale EZVI Source Zone RMW-4D Groundwater and MW-7D Rock					
Compound	Week	0	4	8	12	16
PCE	µg/L	2550	1250	150	430	<50
TCE	µg/L	33100	7440	3320	2660	120
cDCE	µg/L	29600	19300	29700	22800	4960
tDCE	µg/L	730	<200	130	450	<50
1TCA	µg/L	860	<200	<50	<100	<50
1DCE	µg/L	910	<200	320	480	<50
1DCA	µg/L	730	<200	220	390	<50
CA	µg/L	<100	<200	<50	610	<50
VC	µg/L	1160	1240	730	640	<50
Methane	µg/L	220	100	<33	<67	<33
Acetylene	µg/L	<100	<200	100	<100	<50
Ethene	µg/L	680	<240	470	820	670
Ethane	µg/L	<120	<240	120	550	280
PCE	µM	15.4	7.5	0.90	2.6	<0.30
TCE	µM	251.9	56.6	25.3	20.2	0.91
cDCE	µM	305.5	199.2	306.5	235.3	51.2
tDCE	µM	7.5	<2.1	1.3	4.6	<0.52
1TCA	µM	6.4	<1.5	<0.37	<0.75	<0.37
1DCE	µM	9.4	<2.1	3.3	5.0	<0.52
1DCA	µM	7.4	<2.0	2.2	3.9	<0.51
CA	µM	<1.6	<3.1	<0.78	<0.78	<0.78
VC	µM	18.6	19.8	11.7	10.2	<0.80
Acetylene	µM	<3.8	<7.7	3.8	<3.8	<1.9
Ethene	µM	24.3	<8.6	16.8	29.3	23.9
Ethane	µM	<4.0	<8.0	4.0	18.3	9.3
Sum CE	µM	623.1	283.2	366.3	302.3	76.0
Sum CA	µM	23.2	0.0	9.5	27.2	9.3
pH		6.6	6.9	6.9	7.3	7.2
ORP	mV	-201	-269	-268	-254	-277
Alkalinity	mg/L CaCO3	330	210	195	220	195
Sum CE-Gases	µM	599	283	346	273	52.1
Sum CA-Gases	µM	23	0.0	5.5	8.9	0.0
Sulfate	mg/L	1300				800

6-A	Microscale EZVI Source Zone RMW-4D Groundwater and MW-7D Rock						
Compound	Week	0	4	8	12	16	16 Soil
PCE	µg/L	2620	680	100	81	39	35
TCE	µg/L	31100	7500	1200	690	250	130
cDCE	µg/L	26400	14900	6500	5250	5400	300
tDCE	µg/L	<100	<100	<40	90	<20	<4.0
1TCA	µg/L	830	<100	<40	<20	<20	<4.0
1DCE	µg/L	900	<100	94	92	<20	<4.0
1DCA	µg/L	760	360	160	89	34	<4.0
CA	µg/L	<100	<100	<40	<20	<20	<4.0
VC	µg/L	1120	810	460	160	12	<4.0
Methane	µg/L	210	48	<27	<13	<13	20
Acetylene	µg/L	<100	<100	<40	<20	<20	<4.0
Ethene	µg/L	630	<120	170	430	550	16
Ethane	µg/L	<120	<120	<48	150	120	34
PCE	µM	15.8	4.1	0.60	0.49	0.24	0.21
TCE	µM	236.7	57.1	9.1	5.3	1.9	0.99
cDCE	µM	272.4	153.8	67.1	54.2	55.7	3.1
tDCE	µM	<1.0	<1.0	<0.41	0.93	<0.21	<0.041
1TCA	µM	6.2	<0.75	<0.30	<0.15	<0.15	<0.030
1DCE	µM	9.3	<1.0	1.0	0.95	<0.21	<0.041
1DCA	µM	7.7	3.6	1.6	0.90	0.34	<0.040
CA	µM	<1.6	<1.6	<0.64	<0.31	<0.31	<0.062
VC	µM	17.9	13.0	7.4	2.6	0.19	<0.064
Acetylene	µM	<3.8	<3.8	<1.5	<0.77	<0.77	<0.15
Ethene	µM	22.5	<4.3	6.1	15.4	19.6	0.57
Ethane	µM	<4.0	<4.0	<1.6	5.0	4.0	1.1
Sum CE	µM	565.3	227.9	90.2	78.8	77.7	4.9
Sum CA	µM	23.2	3.6	2.6	6.8	4.3	1.1
pH		6.6	6.9	7.0	7.3	7.3	
ORP	mV	-206.0	-262	-266	-44	-216	
Alkalinity	mg/L CaCO3	310	240	290	365	325	
Sum CE-Gases	µM	543	228	84	63	58.1	4.3
Sum CA-Gases	µM	23	3.6	2.6	1.8	0.3	0.0
Sulfate	mg/L	1300				5000	

6-B	Microscale EZVI Source Zone RMW-4D Groundwater and MW-7D Rock					
Compound	Week	0	4	8	12	16
PCE	µg/L	2720	630	97	82	13
TCE	µg/L	31800	5920	1220	530	130
cDCE	µg/L	29000	13400	5520	4450	4480
tDCE	µg/L	<100	<100	<40	<20	<4.0
1TCA	µg/L	790	<100	<40	<20	<4.0
1DCE	µg/L	900	<100	81	92	<4.0
1DCA	µg/L	760	350	160	89	29
CA	µg/L	<100	<100	<40	<20	<4.0
VC	µg/L	1120	720	430	150	28
Methane	µg/L	210	32	<27	<13	14
Acetylene	µg/L	<100	<100	<40	trace	8.3
Ethene	µg/L	610	<120	220	650	420
Ethane	µg/L	<120	<120	<48	150	110
PCE	µM	16.4	3.8	0.59	0.49	0.078
TCE	µM	242.0	45.1	9.3	4.0	0.99
cDCE	µM	299.3	138.3	57.0	45.9	46.2
tDCE	µM	<1.0	<1.0	<0.41	<0.20	<0.041
1TCA	µM	5.9	<0.75	<0.30	<0.15	<0.030
1DCE	µM	9.3	<1.0	0.84	0.95	<0.041
1DCA	µM	7.7	3.5	1.6	0.90	<0.040
CA	µM	<1.6	<1.6	<0.64	<0.31	<0.062
VC	µM	17.9	11.5	6.9	2.4	0.45
Acetylene	µM	<3.8	<3.8	<1.5	<0.77	0.32
Ethene	µM	21.8	<4.3	7.9	23.2	15.0
Ethane	µM	<4.0	<4.0	<1.6	5.0	3.7
Sum CE	µM	597.4	198.7	81.6	76.1	63.1
Sum CA	µM	22.9	3.5	2.5	6.8	3.7
pH		6.5	6.9	6.9	7.2	6.7
ORP	mV	-210	-261	-252	-45	-33
Alkalinity	mg/L CaCO3	275	200	285	325	285
Sum CE-Gases	µM	576	199	74	53	47.7
Sum CA-Gases	µM	23	3.5	2.5	1.8	0.0
Sulfate	mg/L	1300				820

6-C	Microscale EZVI Source Zone RMW-4D Groundwater and MW-7D Rock					
Compound	Week	0	4	8	12	16
PCE	µg/L	3040	610	240	170	<20
TCE	µg/L	35700	3950	720	240	<20
cDCE	µg/L	31300	36000	16700	15300	8880
tDCE	µg/L	<100	<100	220	180	<20
1TCA	µg/L	840	400	<100	<40	<20
1DCE	µg/L	930	<100	190	180	<20
1DCA	µg/L	760	350	380	180	26
CA	µg/L	<100	<100	<100	<40	<20
VC	µg/L	1190	1150	1000	280	28
Methane	µg/L	230	91	<67	<27	<13
Acetylene	µg/L	<100	<100	<100	<40	<20
Ethene	µg/L	630	<120	200	340	280
Ethane	µg/L	<120	<120	<120	200	87
PCE	µM	18.3	3.7	1.4	1.0	<0.12
TCE	µM	271.7	30.1	5.5	1.8	<0.15
cDCE	µM	323.0	371.5	172.3	157.9	91.6
tDCE	µM	<1.0	<1.0	2.3	1.9	<0.21
1TCA	µM	6.3	<0.75	<0.75	<0.30	<0.15
1DCE	µM	9.6	<1.0	2.0	1.9	<0.21
1DCA	µM	7.7	3.5	3.8	1.8	0.26
CA	µM	<1.6	<1.6	<1.6	<0.62	<0.31
VC	µM	19.0	18.4	16.0	4.5	0.45
Acetylene	µM	<3.8	<3.8	<3.8	<1.5	<0.77
Ethene	µM	22.5	<4.3	<4.3	12.1	10.0
Ethane	µM	<4.0	<4.0	<4.0	6.7	2.9
Sum CE	µM	654.6	423.7	197.5	179.2	102.1
Sum CA	µM	23.6	3.5	5.8	10.3	3.2
pH		6.6	6.9	7.0	7.4	7.2
ORP	mV	-192	-252	-245	-45	-94
Alkalinity	mg/L CaCO3	270	155	315	370	350
Sum CE-Gases	µM	632	424	198	167	92.1
Sum CA-Gases	µM	24	3.5	5.8	3.7	0.3
Sulfate	mg/L	1300				800

7-A	EHC Source Zone RMW-4D Groundwater and MW-7D Rock							
Compound	Week	0	2	4	8	12	16	16 Soil
PCE	µg/L	2500	1130	790	170	160	<40	26
TCE	µg/L	31600	15100	14000	340	190	<40	82
cDCE	µg/L	30800	20900	25300	17300	15900	7140	1230
tDCE	µg/L	<100	720	<100	220	180	<40	<5.0
1TCA	µg/L	820	370	270	<50	<40	<40	<5.0
1DCE	µg/L	<100	760	<100	180	190	<40	<5.0
1DCA	µg/L	770	330	390	220	180	<40	<5.0
CA	µg/L	<100	<100	<100	<50	<40	<40	<5.0
VC	µg/L	1320	940	770	590	300	<40	<5.0
Methane	µg/L	220	77	29	<33	<27	<27	<3.3
Acetylene	µg/L	<100	trace	270	1050	560	250	20
Ethene	µg/L	610	<120	<120	1090	1430	830	70
Ethane	µg/L	<120	<120	<120	550	510	250	76
PCE	µM	15.1	6.8	4.8	1.0	1.0	<0.24	0.2
TCE	µM	240.5	114.9	106.5	2.6	1.4	<0.30	0.6
cDCE	µM	317.9	215.7	261.1	178.5	164.1	73.7	12.7
tDCE	µM	<1.0	7.4	<1.0	2.3	1.9	<0.41	<0.052
1TCA	µM	6.1	2.8	2.0	<0.37	<0.30	<0.30	<0.037
1DCE	µM	<1.0	7.8	<1.0	1.9	2.0	<0.41	<0.052
1DCA	µM	7.8	3.3	3.9	2.2	1.8	<0.40	<0.051
CA	µM	<1.6	<1.6	<1.6	<0.78	<0.62	<0.62	<0.078
VC	µM	21.1	15.0	12.3	9.4	4.8	<0.64	<0.080
Acetylene	µM	<3.8	<3.8	10.4	40.4	21.5	9.6	0.77
Ethene	µM	21.8	<4.3	<4.3	38.9	51.1	29.6	2.5
Ethane	µM	<4.0	<4.0	<4.0	18.3	17.0	8.3	2.5
Sum CE	µM	616.3	359.9	395.1	273.2	245.8	112.9	16.7
Sum CA	µM	13.9	14.0	6.0	22.4	20.8	8.3	2.5
pH		6.6	5.6	6.5	6.6	6.8	6.5	
ORP	mV	-136	-1	-239	-216	-27	-82	
Alkalinity	mg/L CaCO3	295	460	875	935	1050	1210	
Sum CE-Gases	µM	595	360	385	194	173.2	73.7	13.5
Sum CA-Gases	µM	14	14	6.0	4.1	3.8	0.0	0.0
Sulfate	mg/L	1300					2.9	

7-B	EHC Source Zone RMW-4D Groundwater and MW-7D Rock					
Compound	Week	0	4	8	12	16
PCE	µg/L	2240	780	400	180	<40
TCE	µg/L	30100	15900	3960	250	<40
cDCE	µg/L	28000	25700	18500	13300	9780
tDCE	µg/L	900	<100	94	180	<40
1TCA	µg/L	810	290	<50	<40	<40
1DCE	µg/L	910	<100	220	190	<40
1DCA	µg/L	750	380	230	180	<40
CA	µg/L	<100	<100	<50	<40	<40
VC	µg/L	1210	850	640	280	<40
Methane	µg/L	220	58	<33	<27	<27
Acetylene	µg/L	<100	200	1110	460	220
Ethene	µg/L	590	<120	820	1690	1240
Ethane	µg/L	<120	<120	270	700	460
PCE	µM	13.5	4.7	2.4	1.1	<0.24
TCE	µM	229.1	121.0	30.1	1.9	<0.30
cDCE	µM	289.0	265.2	190.9	137.3	100.9
tDCE	µM	9.3	<1.0	1.0	1.9	<0.41
1TCA	µM	6.1	2.2	<0.37	<0.30	<0.30
1DCE	µM	9.4	<1.0	2.3	2.0	<0.41
1DCA	µM	7.6	3.8	2.3	1.8	<0.40
CA	µM	<1.6	<1.6	<0.78	<0.62	<0.62
VC	µM	19.4	13.6	10.2	4.5	<0.64
Acetylene	µM	<3.8	7.7	43	18	8.5
Ethene	µM	21.1	<4.3	29.3	60.4	44.3
Ethane	µM	<4.0	<4.0	9.0	23.3	15.3
Sum CE	µM	581.3	412.2	306.7	224.6	153.7
Sum CA	µM	23.0	6.0	13.6	27.1	15.3
pH		6.6	5.8	6.7	6.8	6.6
ORP	mV	-66	-217	-272	-125	-101
Alkalinity	mg/L CaCO3	300	785	1175	1335	1330
Sum CE-Gases	µM	560	405	235	147	100.9
Sum CA-Gases	µM	23	6.0	4.6	3.8	0.0
Sulfate	mg/L	1300				3.5

7-C	EHC Source Zone RMW-4D Groundwater and MW-7D Rock					
Compound	Week	0	4	8	12	16
PCE	µg/L	1750	180	330	110	<40
TCE	µg/L	22500	2820	5270	280	<40
cDCE	µg/L	23700	16900	19900	12600	7650
tDCE	µg/L	910	100	130	92	<40
1TCA	µg/L	770	<50	<50	<20	<40
1DCE	µg/L	880	220	200	99	<40
1DCA	µg/L	750	210	220	110	<40
CA	µg/L	<100	<50	<50	<20	<40
VC	µg/L	1120	610	590	170	<40
Methane	µg/L	210	<33	<33	<13	<27
Acetylene	µg/L	<100	<50	880	760	310
Ethene	µg/L	210	150	350	910	940
Ethane	µg/L	<120	<60	140	270	320
PCE	µM	10.6	1.1	2.0	0.66	<0.24
TCE	µM	171.2	21.5	40.1	2.1	<0.30
cDCE	µM	244.6	174.4	205.4	130.0	78.9
tDCE	µM	9.4	1.0	1.3	0.95	<0.41
1TCA	µM	5.8	<0.37	<0.37	<0.15	<0.30
1DCE	µM	9.1	2.3	2.1	1.0	<0.41
1DCA	µM	7.6	2.1	2.2	1.1	<0.40
CA	µM	<1.6	<1.6	<1.6	<0.31	<0.62
VC	µM	17.9	9.8	9.4	2.7	<0.64
Acetylene	µM	<3.8	<3.8	34	29	11.9
Ethene	µM	7.5	<4.3	13	33	33.6
Ethane	µM	<4.0	<4.0	4.7	9.0	10.7
Sum CE	µM	461.2	207.7	304.6	198.2	124.4
Sum CA	µM	22.4	4.4	9.0	11.1	10.7
pH		6.6	6.0	6.5	7.0	6.8
ORP	mV	-19	-225	-230	-180	-126
Alkalinity	mg/L CaCO3	300	585	1010	1490	1410
Sum CE-Gases	µM	454	208	258	136	78.9
Sum CA-Gases	µM	22	4.4	4.3	2.1	0.0
Sulfate	mg/L	1300				2.9

15A	1.8 g Nanoscale EZVI Source Zone RMW-4D Groundwater and MW-7D Rock							
Compound	Week	0	2	4	6	8	12	16
PCE	µg/L	1120	610	<100	660	<200	<200	<100
TCE	µg/L	15900	5690	<100	530	<200	<200	<100
cDCE	µg/L	15600	44300	33500	88000	74200	34100	10900
tDCE	µg/L	470	560	590	690	4370	940.0	<100
1TCA	µg/L	420	170	<100	<100	<200	<200	<100
1DCE	µg/L	480	420	750	560	490	900	<100
1DCA	µg/L	380	230	380	190	760	760	<100
CA	µg/L	<50	<50	<100	<100	<200	<200	<100
VC	µg/L	700	700	740	1260	2110	1110	<100
Methane	µg/L	110	45	<67	<67	<130	<130	<67
Acetylene	µg/L	<50	<50	<100	<100	<200	<200	<100
Ethene	µg/L	590	<60	<120	<120	<240	<240	270
Ethane	µg/L	<60	<60	<120	<120	<240	<240	<120
PCE	µM	6.8	3.7	<0.60	4.0	<1.2	<1.2	<0.60
TCE	µM	121.0	43.3	<0.76	4.0	<1.5	<1.5	<0.76
cDCE	µM	161.0	457.2	345.7	908.2	765.7	351.9	112.5
tDCE	µM	4.9	5.8	6.1	7.1	45.1	9.7	<1.0
1TCA	µM	3.1	1.3	<0.75	<0.75	<1.5	<1.5	<0.75
1DCE	µM	5.0	4.3	7.7	5.8	5.1	9.3	<1.0
1DCA	µM	3.8	2.3	3.8	1.9	7.7	7.7	<1.0
CA	µM	<0.78	<0.78	<1.6	<1.6	<3.2	<3.2	<1.6
VC	µM	11.2	11.2	11.8	20.2	33.8	17.8	<1.6
Acetylene	µM	<1.9	<1.9	<3.8	<3.8	<7.7	<7.7	<3.8
Ethene	µM	21.1	<2.1	<4.2	<4.2	<8.6	<8.6	<4.2
Ethane	µM	<2.0	<2.0	<3.3	<3.3	<8.0	<8.0	<3.3
Sum CE	µM	325.9	521.1	363.6	943.4	844.6	379.4	112.5
Sum CA	µM	11.9	7.9	11.6	7.7	12.7	17.0	0.0
pH		6.8	6.8	6.8	6.7	6.9	7.1	7.0
ORP	mV	-128	-132	-129	-107	-210	-217	-195
Alkalinity	mg/L CaCO3	315	300	300	300	410	505	550
Sum CE w/o Gases	µM	304.8	521.1	363.6	943.4	844.6	379.4	112.5
Sum CA w/o Gases	µM	11.9	7.9	11.6	7.7	12.7	17.0	0.0

15B	8.8 g Nanoscale EZVI Source Zone RMW-4D Groundwater and MW-7D Rock							
Compound	Week	0	2	4	6	8	12	16
PCE	µg/L	930	540	330	300	150	110	<50
TCE	µg/L	11600	9210	3760	9220	2800	690	<50
cDCE	µg/L	12000	21600	12500	63900	31700	16300	9440
tDCE	µg/L	460	380	230	140	110	120	<50
1TCA	µg/L	390	<50	<100	<40	<50	<25	<50
1DCE	µg/L	460	430	400	590	460	150	<50
1DCA	µg/L	370	210	210	130	240	120	<50
CA	µg/L	<50	<50	<100	<40	<50	<25	<50
VC	µg/L	660	720	530	1160	870	290	310
Methane	µg/L	110	<33	<67	<27	<33	<17	<33
Acetylene	µg/L	<50	<50	<100	65	<50	<25	<50
Ethene	µg/L	340	200	<120	370	380	410	290
Ethane	µg/L	<60	<60	<120	180	<60	130	270
PCE	µM	5.6	3.3	2.0	1.8	0.90	0.66	<0.30
TCE	µM	88.3	70.1	28.6	70.2	21.3	5.3	<0.38
cDCE	µM	123.8	222.9	129.0	659.4	327.1	168.2	97.4
tDCE	µM	4.7	3.9	2.4	1.4	1.1	1.2	<0.52
1TCA	µM	2.9	<0.37	<0.75	<0.30	<0.37	<0.19	<0.19
1DCE	µM	4.7	4.4	4.1	6.1	4.7	1.5	<0.52
1DCA	µM	3.7	2.1	2.1	1.3	2.4	1.2	<0.51
CA	µM	<0.78	<0.78	<1.6	<0.62	<0.78	<0.39	<0.39
VC	µM	10.6	11.5	8.5	18.6	13.9	4.6	5.0
Acetylene	µM	<1.9	<1.9	<3.8	2.5	<1.9	<0.96	<0.96
Ethene	µM	12.1	7.1	<4.2	13.2	13.6	14.6	10.4
Ethane	µM	<2.0	<2.0	<3.3	6.0	<2.0	4.3	9.0
Sum CE	µM	245.2	318.8	170.5	767.1	378.0	194.7	112.7
Sum CA	µM	11.4	6.6	6.2	13.4	7.2	7.1	9.0
pH		6.7	6.9	6.9	6.9	7.0	7.2	7.2
ORP	mV	-109	-120	-126	-63	-200	-202	-187
Alkalinity	mg/L CaCO3	305	300	170	265	285	355	425
Sum CE w/o Gases	µM	233.0	311.7	170.5	751.4	364.4	180.0	102.4
Sum CA w/o Gases	µM	11.4	6.6	6.2	7.4	7.2	2.8	0.0

15C	35.2 g Nanoscale EZVI Source Zone RMW-4D Groundwater and MW-7D Rock								
Compound	Week	0	2	4	6	8	12	16	16 Soil
PCE	µg/L	880	510	310	110	<20	<50	<5.0	32
TCE	µg/L	10900	6770	2390	2020	870	280	15	87
cDCE	µg/L	11300	14300	9660	6640	24400	11900	2690	1170
tDCE	µg/L	460	380	<100	<20	52	<50	<5.0	<5.0
1TCA	µg/L	370	<50	<100	<20	<20	<50	<5.0	<5.0
1DCE	µg/L	440	400	400	120	260.0	240	<5.0	<5.0
1DCA	µg/L	370	180	190	56	110	190	<5.0	5.7
CA	µg/L	<50	<50	<100	<20	<20	<50	<5.0	<5.0
VC	µg/L	550	620	560	290	200	340	140	8.4
Methane	µg/L	110	<33	<67	<13	<13	<33	15	<3.3
Acetylene	µg/L	<50	110	140	50	44	<50	11	trace
Ethene	µg/L	540	420	550	650	600	930	980	88
Ethane	µg/L	<60	<60	<120	210	180	400	330	82
PCE	µM	5.3	3.1	1.9	0.66	<0.12	<0.30	<0.030	<0.030
TCE	µM	83.0	51.5	18.2	15.4	6.6	2.1	0.11	0.66
cDCE	µM	116.6	147.6	99.7	68.5	251.8	122.8	27.8	12.1
tDCE	µM	4.7	3.9	<1.0	<0.21	0.54	<0.52	<0.052	<0.052
1TCA	µM	2.8	<0.37	<0.75	<0.15	<0.15	<0.15	<0.015	<0.015
1DCE	µM	4.5	4.1	4.1	1.2	2.7	2.5	<0.052	<0.052
1DCA	µM	3.7	1.8	1.9	0.57	1.11	1.92	<0.051	0.058
CA	µM	<0.78	<0.78	<1.6	<0.31	<0.31	<0.78	<0.078	<0.078
VC	µM	8.8	9.9	9.0	4.6	3.2	5.4	2.2	0.13
Acetylene	µM	<1.9	4.2	5.4	1.9	1.7	<1.9	0.4	<0.19
Ethene	µM	19.3	15.0	19.6	23.2	21.4	33.2	35.0	3.1
Ethane	µM	<2.0	<2.0	<3.3	7.0	6.0	13.3	11.0	2.7
Sum CE	µM	237.7	235.2	153.7	114.3	285.3	163.6	65.5	16.0
Sum CA	µM	11.1	5.9	6.0	8.8	9.8	17.7	11.0	2.8
pH		6.6	6.9	6.7	6.6	6.4	6.5	6.4	
ORP	mV	-30	-112	-98	-90	-199	-186	-89	
Alkalinity	mg/L CaCO3	310	275	165	115	105	105	165	
Sum CE w/o Gases	µM	218.4	216.0	128.7	89.2	262.2	130.4	30.1	12.9
Sum CA w/o Gases	µM	11.1	5.9	6.0	1.8	3.8	4.4	0.0	0.1

8-A	Sterile Control Plume Zone MW-20D Groundwater and MW-21D Rock						
Compound	Week	0	4	8	12	16	16 Soil
PCE	µg/L	<50	<20	<20	<10	<5.0	5.5
TCE	µg/L	5650	4770	1680	1300	730	28
cDCE	µg/L	635	960	180	210	100	20
tDCE	µg/L	<50	<20	<20	<10	<5.0	<2.0
1TCA	µg/L	4350	5770	2860	1910	1910	140
1DCE	µg/L	720	230	690	190	12	<2.0
1DCA	µg/L	<50	<20	<20	<10	<5.0	20
CA	µg/L	<50	<20	<20	<10	<5.0	<2.0
VC	µg/L	<50	<20	<20	<10	<5.0	<2.0
Methane	µg/L	100	6.2	<13	<6.7	<3.3	<1.3
Acetylene	µg/L	<50	<20	<20	<10	<5.0	<2.0
Ethene	µg/L	<60	<24	<24	<12	<6.0	<2.4
Ethane	µg/L	<60	<24	<24	<12	<6.0	<2.4
PCE	µM	<0.30	<0.12	<0.12	<0.060	<0.030	0.033
TCE	µM	43.0	36.3	12.8	9.9	5.6	0.21
cDCE	µM	6.6	9.9	1.9	2.2	1.0	0.21
tDCE	µM	<0.52	<0.21	<0.21	<0.10	<0.052	<0.021
1TCA	µM	32.6	43.3	21.4	14.3	14.3	1.0
1DCE	µM	7.4	2.4	7.1	2.0	0.12	<0.021
1DCA	µM	<0.51	<0.20	<0.20	<0.10	<0.051	0.20
CA	µM	<0.78	<0.31	<0.31	<0.16	<0.078	<0.031
VC	µM	<0.80	<0.32	<0.32	<0.16	<0.080	<0.032
Acetylene	µM	<1.9	<0.77	<0.77	<0.38	<0.19	<0.077
Ethene	µM	<2.1	<0.86	<0.86	<0.43	<0.21	<0.086
Ethane	µM	<2.0	<0.80	<0.80	<0.40	<0.20	<0.080
Sum CE	µM	49.6	46.2	14.6	12.1	6.6	0.5
Sum CA	µM	40.0	45.6	28.6	16.3	14.4	1.3
pH		6.4	6.6	6.7	6.8	6.9	
ORP	mV	258	229	245	294	296	
Alkalinity	mg/L CaCO3	125	145	155	205	230	
Sum CE-Gases	µM	50	46	15	12	6.6	0.5
Sum CA-Gases	µM	40	46	29	16	14	1.3
Sulfate	mg/L	1200				1400	

8-B	Sterile Control Plume Zone MW-20D Groundwater and MW-21D Rock					
Compound	Week	0	4	8	12	16
PCE	µg/L	<50	<20	<20	<10	<5.0
TCE	µg/L	3560	2220	1730	1260	960
cDCE	µg/L	680	360	180	150	110
tDCE	µg/L	<50	<20	<20	<10	<5.0
1TCA	µg/L	3070	3760	2790	1830	2180
1DCE	µg/L	670	180	860	180	12
1DCA	µg/L	<50	<20	<20	<10	<5.0
CA	µg/L	<50	<20	<20	<10	<5.0
VC	µg/L	<50	<20	<20	<10	<5.0
Methane	µg/L	110	7.6	<13	<6.7	<3.3
Acetylene	µg/L	<50	<20	<20	<10	<5.0
Ethene	µg/L	<60	<24	<24	<12	<6.0
Ethane	µg/L	<60	<24	<24	<12	<6.0
PCE	µM	<0.30	<0.12	<0.12	<0.060	<0.030
TCE	µM	27.1	16.9	13.2	9.6	7.3
cDCE	µM	7.0	3.7	1.9	1.5	1.1
tDCE	µM	<0.52	<0.21	<0.21	<0.10	<0.052
1TCA	µM	23.0	28.2	20.9	13.7	16.3
1DCE	µM	6.9	1.9	8.9	1.9	0.12
1DCA	µM	<0.51	<0.20	<0.20	<0.10	<0.051
CA	µM	<0.78	<0.31	<0.31	<0.16	<0.078
VC	µM	<0.80	<0.32	<0.32	<0.16	<0.080
Acetylene	µM	<1.9	<0.77	<0.77	<0.38	<0.19
Ethene	µM	<2.1	<0.86	<0.86	<0.43	<0.21
Ethane	µM	<2.0	<0.40	<0.40	<0.40	<0.20
Sum CE	µM	34.1	20.6	15.0	11.1	8.4
Sum CA	µM	29.9	30.0	29.8	15.6	16.5
pH		6.4	6.6	6.7	6.9	6.9
ORP	mV	272	268	260	292	304
Alkalinity	mg/L CaCO3	125	140	155	210	220
Sum CE-Gases	µM	34	21	15	11	8.4
Sum CA-Gases	µM	30	30	30	16	16
Sulfate	mg/L	1200				1400

8-C	Sterile Control Plume Zone MW-20D Groundwater and MW-21D Rock					
Compound	Week	0	4	8	12	16
PCE	µg/L	<50	<20	<20	<10	<5.0
TCE	µg/L	3130	1710	1540	1000	880
cDCE	µg/L	570	310	730	180	140
tDCE	µg/L	<50	<20	<20	<10	<5.0
1TCA	µg/L	3840	3050	2550	1480	1800
1DCE	µg/L	<50	190	960	180	44
1DCA	µg/L	<50	<20	35	<10	<5.0
CA	µg/L	<50	<20	<20	<10	<5.0
VC	µg/L	<50	<20	<20	<10	<5.0
Methane	µg/L	100	9.0	<13	<6.7	<3.3
Acetylene	µg/L	<50	<20	<20	<10	<5.0
Ethene	µg/L	<60	<24	<24	<12	17
Ethane	µg/L	<60	<24	<24	<12	27
PCE	µM	<0.30	<0.12	<0.12	<0.060	<0.030
TCE	µM	23.8	13.0	11.7	7.6	6.7
cDCE	µM	5.9	3.2	7.5	1.9	1.4
tDCE	µM	<0.52	<0.21	<0.21	<0.10	<0.052
1TCA	µM	28.8	22.9	19.1	11.1	13.5
1DCE	µM	<0.52	2.0	9.9	1.9	0.45
1DCA	µM	<0.51	<0.20	0.35	<0.10	<0.051
CA	µM	<0.78	<0.31	<0.31	<0.16	<0.078
VC	µM	<0.80	<0.32	<0.32	<0.16	<0.080
Acetylene	µM	<1.9	<0.77	<0.77	<0.38	<0.19
Ethene	µM	<2.1	<0.86	<0.86	<0.43	0.61
Ethane	µM	<2.0	<0.40	<0.40	<0.40	0.90
Sum CE	µM	29.7	16.2	19.3	9.5	8.7
Sum CA	µM	28.8	24.8	29.4	13.0	14.8
pH		6.5	6.6	6.8	6.8	6.9
ORP	mV	276	265	267	298	310
Alkalinity	mg/L CaCO3	120	145	150	215	220
Sum CE-Gases	µM	30	16	19	9.5	8.1
Sum CA-Gases	µM	29	25	29	13	14
Sulfate	mg/L	1200				1700

9-A	Unamended Control Plume Zone MW-20D Groundwater and MW-21D Rock						
Compound	Week	0	4	8	12	16	16 Soil
PCE	µg/L	<50	<40	<40	<40	<20	34
TCE	µg/L	<50	<40	<40	<40	<20	77
cDCE	µg/L	13700	11300	16000	5470	6590	1180
tDCE	µg/L	450	<40	190	190	<20	<4.0
1TCA	µg/L	1030	670	720	420	270	200
1DCE	µg/L	480	340	420	190	<20	<4.0
1DCA	µg/L	460	230	270	180	98	18
CA	µg/L	<50	<40	<40	<40	<20	<4.0
VC	µg/L	950	720	<40	<40	<20	<4.0
Methane	µg/L	100	39	<27	<27	<13	<2.7
Acetylene	µg/L	<50	<40	<40	<40	<20	<4.0
Ethene	µg/L	<60	<48	<48	<48	55	11
Ethane	µg/L	<60	<48	<48	<48	<24	36
PCE	µM	<0.30	<0.24	<0.24	<0.24	<0.12	0.21
TCE	µM	<0.38	<0.30	<0.30	<0.30	<0.15	0.59
cDCE	µM	141.4	116.6	165.1	56.4	68.0	12.2
tDCE	µM	4.6	<0.41	2.0	2.0	<0.21	<0.041
1TCA	µM	7.7	5.0	5.4	3.1	2.0	1.5
1DCE	µM	5.0	3.5	4.3	2.0	<0.21	<0.041
1DCA	µM	4.6	2.3	2.7	1.8	1.0	0.18
CA	µM	<0.78	<0.62	<0.62	<0.62	<0.31	<0.062
VC	µM	15.2	11.5	<0.64	<0.64	<0.32	<0.064
Acetylene	µM	<1.9	<1.5	<1.5	<1.5	<0.77	<0.15
Ethene	µM	<2.1	<1.7	<1.7	<1.7	2.0	0.39
Ethane	µM	<2.0	<1.6	<1.6	<1.6	<0.67	1.2
Sum CE	µM	161.2	128.1	167.1	58.4	70.0	13.4
Sum CA	µM	17.3	10.9	12.5	6.9	3.0	2.9
pH		6.6	6.6	6.8	7.2	7.0	
ORP	mV	220	193	178	235	270	
Alkalinity	mg/L CaCO3	210	125	290	345	360	
Sum CE-Gases	µM	161	128	167	58	68.0	13.0
Sum CA-Gases	µM	17	11	12	6.9	3.0	1.7
Sulfate	mg/L	1200				1600	

9-B	Unamended Control Plume Zone MW-20D Groundwater and MW-21D Rock					
Compound	Week	0	4	8	12	16
PCE	µg/L	<50	<40	<40	<25	<10
TCE	µg/L	<50	<40	<40	<25	<10
cDCE	µg/L	13500	12400	11200	3890	6590
tDCE	µg/L	460	200	120	120	<10
1TCA	µg/L	970	670	720	380	360
1DCE	µg/L	450	360	190	120	<10
1DCA	µg/L	450	230	220	130	91
CA	µg/L	<50	<40	<40	<25	<10
VC	µg/L	900	<40	<40	<25	<10
Methane	µg/L	110	7.5	<27	<17	<6.7
Acetylene	µg/L	<50	<40	<40	<25	<4.0
Ethene	µg/L	<60	<48	<48	<30	34
Ethane	µg/L	<60	<48	<48	<30	56
PCE	µM	<0.30	<0.24	<0.24	<0.15	<0.060
TCE	µM	<0.38	<0.30	<0.30	<0.19	<0.076
cDCE	µM	139.3	128.0	115.6	40.1	68.0
tDCE	µM	4.7	2.1	1.2	1.2	<0.10
1TCA	µM	7.3	5.0	5.4	2.8	2.7
1DCE	µM	4.6	3.7	2.0	1.2	<0.10
1DCA	µM	4.5	2.3	2.2	1.3	0.92
CA	µM	<0.78	<0.62	<0.62	<0.39	<0.16
VC	µM	14.4	<0.64	<0.64	<0.40	<0.16
Acetylene	µM	<1.9	<1.5	<1.5	<0.96	<0.15
Ethene	µM	<2.1	<1.7	<1.7	<1.1	1.2
Ethane	µM	<2.0	<1.6	<1.6	<1.0	1.9
Sum CE	µM	158.5	130.0	116.8	41.4	69.2
Sum CA	µM	16.5	11.1	9.6	5.4	5.5
pH		6.7	6.8	6.8	7.2	7.1
ORP	mV	160	207	168	220	254
Alkalinity	mg/L CaCO3	300	125	305	350	360
Sum CE-Gases	µM	158	130	117	41	68.0
Sum CA-Gases	µM	16	11	10	5.4	3.6
Sulfate	mg/L	1200				1300

9-C	Unamended Control Plume Zone MW-20D Groundwater and MW-21D Rock					
Compound	Week	0	4	8	12	16
PCE	µg/L	<50	<40	<40	<40	<20
TCE	µg/L	<50	<40	<40	<40	<20
cDCE	µg/L	14400	13600	13800	6090	5040
tDCE	µg/L	<50	210	190	190	<20
1TCA	µg/L	980	690	910	500	380
1DCE	µg/L	510	400	260	190	<20
1DCA	µg/L	460	270	250	200	69
CA	µg/L	<50	<40	<40	<40	<20
VC	µg/L	1070	<40	<40	<40	<20
Methane	µg/L	110	5.9	<27	<27	<13
Acetylene	µg/L	<50	<40	<40	<40	<20
Ethene	µg/L	<60	<48	<48	<48	57
Ethane	µg/L	<60	<48	<48	<48	<24
PCE	µM	<0.30	<0.24	<0.24	<0.24	<0.12
TCE	µM	<0.38	<0.30	<0.30	<0.30	<0.15
cDCE	µM	148.6	140.4	142.4	62.8	52.0
tDCE	µM	<0.52	2.2	2.0	2.0	<0.21
1TCA	µM	7.3	5.2	6.8	3.7	2.8
1DCE	µM	5.3	4.1	2.7	2.0	<0.21
1DCA	µM	4.6	2.7	2.5	2.0	0.70
CA	µM	<0.78	<0.62	<0.62	<0.62	<0.31
VC	µM	17.1	<0.64	<0.64	<0.64	<0.32
Acetylene	µM	<1.9	<1.5	<1.5	<1.5	<0.77
Ethene	µM	<2.1	<1.7	<1.7	<1.7	2.0
Ethane	µM	<2.0	<1.6	<1.6	<1.6	<0.67
Sum CE	µM	165.7	142.5	144.4	64.8	54.0
Sum CA	µM	17.3	12.0	12.0	7.7	3.5
pH		6.6	6.9	6.8	7.1	7.1
ORP	mV	200	108	163	213	246
Alkalinity	mg/L CaCO3	305	120	295	340	355
Sum CE-Gases	µM	166	143	144	65	52.0
Sum CA-Gases	µM	17	12	12	8	3.5
Sulfate	mg/L	1200				1700

10-A	SRS Plume Zone MW-20D Groundwater and MW-21D Rock						
Compound	Week	0	4	8	12	16	16 Soil
PCE	µg/L	<50	<40	<40	<40	<25	<5.0
TCE	µg/L	<50	<40	<40	<40	<25	<5.0
cDCE	µg/L	15100	15400	14700	10600	6850	580
tDCE	µg/L	<50	210	110	180	<25	<5.0
1TCA	µg/L	1080	680	780	460	730	69
1DCE	µg/L	530	420	290	200	<25	<5.0
1DCA	µg/L	470	280	270	220	180	14
CA	µg/L	<50	<40	<40	<40	<25	<5.0
VC	µg/L	1090	1570	890	320	180	<5.0
Methane	µg/L	110	10	<27	<27	75	19
Acetylene	µg/L	<50	<40	<40	<40	<25	<5.0
Ethene	µg/L	<60	<48	<48	<48	78	<6.0
Ethane	µg/L	<60	<48	<48	<48	<30	42
PCE	µM	<0.30	<0.24	<0.24	<0.24	<0.15	<0.030
TCE	µM	<0.38	<0.30	<0.30	<0.30	<0.19	<0.038
cDCE	µM	155.8	158.9	151.7	109.4	70.7	6.0
tDCE	µM	<0.52	2.2	1.1	1.9	<0.26	<0.052
1TCA	µM	8.1	5.1	5.8	3.4	5.5	0.52
1DCE	µM	5.5	4.3	3.0	2.1	<0.26	<0.052
1DCA	µM	4.7	2.8	2.7	2.2	1.8	0.14
CA	µM	<0.78	<0.62	<0.62	<0.62	<0.39	<0.078
VC	µM	17.4	25.1	14.2	5.1	2.9	<0.080
Acetylene	µM	<1.9	<1.5	<1.5	<1.5	<0.96	<0.19
Ethene	µM	<2.1	<1.7	<1.7	<1.7	2.8	<0.21
Ethane	µM	<2.0	<1.6	<1.6	<1.6	<1.0	1.4
Sum CE	µM	173.3	186.2	167.1	116.4	76.4	6.0
Sum CA	µM	18.3	12.3	11.6	7.7	7.3	2.1
pH		6.6	6.8	6.8	7.0	6.6	
ORP	mV	187	-71	-318	-312	-360	
Alkalinity	mg/L CaCO3	305	255	385	495	855	
Sum CE-Gases	µM	173	186	167	116	73.6	6.0
Sum CA-Gases	µM	18	12	12	7.7	7.3	0.7
Sulfate	mg/L	1200				1200	

10-B	SRS Plume Zone MW-20D Groundwater and MW-21D Rock					
Compound	Week	0	4	8	12	16
PCE	µg/L	<50	<40	<40	<20	<25
TCE	µg/L	<50	<40	<40	<20	<25
cDCE	µg/L	17000	16700	14200	10200	5420
tDCE	µg/L	<50	230	120	94	<25
1TCA	µg/L	1190	810	790	330	480
1DCE	µg/L	560	470	280	100	<25
1DCA	µg/L	490	280	270	140	120
CA	µg/L	<50	<40	<40	<20	<25
VC	µg/L	1240	1850	930	220	110
Methane	µg/L	110	16	<27	<13	<17
Acetylene	µg/L	<50	<40	<40	<20	<25
Ethene	µg/L	<60	<48	<48	<24	84
Ethane	µg/L	<60	<48	<48	<24	120
PCE	µM	<0.30	<0.24	<0.24	<0.12	<0.15
TCE	µM	<0.38	<0.30	<0.30	<0.15	<0.19
cDCE	µM	175.4	172.3	146.5	105.3	55.9
tDCE	µM	<0.52	2.4	1.2	1.0	<0.26
1TCA	µM	8.9	6.1	5.9	2.5	3.6
1DCE	µM	5.8	4.9	2.9	1.0	<0.26
1DCA	µM	4.9	2.8	2.7	1.4	1.2
CA	µM	<0.78	<0.62	<0.62	<0.31	<0.39
VC	µM	19.8	29.6	14.9	3.5	1.8
Acetylene	µM	<1.9	<1.5	<1.5	<0.77	<0.96
Ethene	µM	<2.1	<1.7	<1.7	<0.71	3.0
Ethane	µM	<2.0	<1.6	<1.6	<0.67	4.0
Sum CE	µM	195.3	204.3	162.7	109.8	60.7
Sum CA	µM	19.6	13.8	11.5	4.9	8.8
pH		6.7	6.7	6.7	7.0	6.6
ORP	mV	180	-256	-333	-322	-364
Alkalinity	mg/L CaCO3	315	345	450	550	1115
Sum CE-Gases	µM	195	204	163	110	57.7
Sum CA-Gases	µM	20	14	12	4.9	4.8
Sulfate	mg/L	1200				460

10-C	SRS Plume Zone MW-20D Groundwater and MW-21D Rock					
Compound	Week	0	4	8	12	16
PCE	µg/L	<50	<40	<25	<50	<25
TCE	µg/L	<50	<40	<25	<50	<25
cDCE	µg/L	38600	12200	20400	12000	5670
tDCE	µg/L	<50	210	140	230	<25
1TCA	µg/L	1000	570	730	460	560
1DCE	µg/L	540	400	330	250	<25
1DCA	µg/L	460	250	240	260	130
CA	µg/L	<50	<40	<40	<50	<25
VC	µg/L	1070	1360	860	430	110
Methane	µg/L	110	33	<17	<34	<17
Acetylene	µg/L	<50	<40	<25	<50	<25
Ethene	µg/L	<60	<48	<30	<60	74
Ethane	µg/L	<60	<48	<30	<60	<30
PCE	µM	<0.30	<0.24	<0.15	<0.30	<0.15
TCE	µM	<0.38	<0.30	<0.19	<0.38	<0.19
cDCE	µM	398.3	125.9	210.5	123.8	58.5
tDCE	µM	<0.52	2.2	1.4	2.4	<0.26
1TCA	µM	7.5	4.3	5.5	3.4	4.2
1DCE	µM	5.6	4.1	3.4	2.6	<0.26
1DCA	µM	4.6	2.5	2.4	2.6	1.3
CA	µM	<0.78	<0.62	<0.39	<0.78	<0.39
VC	µM	17.1	21.8	13.8	6.9	1.8
Acetylene	µM	<1.9	<1.5	<0.96	<1.9	<0.96
Ethene	µM	<2.1	<1.7	<1.1	<2.1	2.6
Ethane	µM	<2.0	<1.6	<1.0	<2.0	<1.0
Sum CE	µM	415.5	149.8	225.7	133.1	62.9
Sum CA	µM	17.7	10.9	11.3	8.7	5.5
pH		6.6	6.7	6.6	7.0	6.7
ORP	mV	176	-283	-333	-345	-298
Alkalinity	mg/L CaCO3	310	315	440	570	885
Sum CE-Gases	µM	415	150	226	133	60.3
Sum CA-Gases	µM	18	11	11	8.7	5.5
Sulfate	mg/L	1200				730

11-A	SRS + Bioaugmentation Plume Zone MW-20D Groundwater and MW-21D Rock							
Compound	Week	0	2	4	8	12	16	16 Soil
PCE	µg/L	<50	<50	<100	<40	<40	<25	13
TCE	µg/L	<50	480	<100	<40	<40	<25	20
cDCE	µg/L	17100	54600	14900	17800	10000	6680	1230
tDCE	µg/L	<50	490	<100	110	180	<25	<5.0
1TCA	µg/L	1150	2500	650	770	430	320	130
1DCE	µg/L	610	880	820	390	210	<25	<5.0
1DCA	µg/L	490	430	450	290	230	140	28
CA	µg/L	<50	<50	<50	<40	<40	<25	<5.0
VC	µg/L	1370	2260	1500	1050	450	230	5.2
Methane	µg/L	110	<33	23	<27	<27	<17	<3.3
Acetylene	µg/L	<50	<50	<100	<40	<40	<25	<5.0
Ethene	µg/L	<60	<60	<120	<48	<48	88	<6.0
Ethane	µg/L	<60	<60	<120	<48	<48	120	38
PCE	µM	<0.30	<0.30	<0.60	<0.24	<0.24	<0.15	0.078
TCE	µM	<0.38	3.7	<0.76	<0.30	<0.30	<0.19	0.15
cDCE	µM	176.5	563.5	153.8	183.7	103.2	68.9	12.7
tDCE	µM	<0.52	5.1	<1.0	1.1	1.9	<0.26	<0.052
1TCA	µM	8.6	18.7	4.9	5.8	3.2	2.4	0.97
1DCE	µM	6.3	9.1	8.5	4.0	2.2	<0.26	<0.052
1DCA	µM	4.9	4.3	4.5	2.9	2.3	1.4	0.28
CA	µM	<0.78	<0.78	<1.6	<0.62	<0.62	<0.39	<0.078
VC	µM	21.9	36.2	24.0	16.8	7.2	3.7	0.083
Acetylene	µM	<1.9	<1.9	<3.8	<1.5	<1.5	<0.96	<0.19
Ethene	µM	<2.1	<2.1	<4.2	<1.7	<1.7	3.1	<0.21
Ethane	µM	<2.0	<2.0	<4.0	<1.6	<1.6	4.0	1.3
Sum CE	µM	198.4	608.3	177.8	201.6	112.3	75.8	13.0
Sum CA	µM	19.9	32.2	17.9	12.7	7.7	7.8	2.5
pH		6.6	6.7	6.5	6.4	6.8	6.5	
ORP	mV	172	-420	-327	-381	-376	-372	
Alkalinity	mg/L CaCO3	310	325	405	815	985	1180	
Sum CE-Gases	µM	198	608	178	202	112.3	72.6	13.0
Sum CA-Gases	µM	20	32	18	13	7.7	3.8	1.3
Sulfate	mg/L	1200					430	

11-B	SRS + Bioaugmentation Plume Zone MW-20D Groundwater and MW-21D Rock						
Compound	Week	0	2	4	8	12	16
PCE	µg/L	<50	<50	<50	<40	<40	<25
TCE	µg/L	<50	<50	<50	<40	<40	<25
cDCE	µg/L	16400	14400	13000	15800	8480	5050
tDCE	µg/L	<50	360	240	91	180	<25
1TCA	µg/L	1070	1260	500	720	380	220
1DCE	µg/L	580	420	480	360	210	<25
1DCA	µg/L	480	260	290	270	220	110
CA	µg/L	<50	<50	<50	<40	<40	<25
VC	µg/L	1290	800	1430	1000	500	190
Methane	µg/L	100	<33	38	<27	<27	<17
Acetylene	µg/L	<50	<50	<50	<40	<40	<25
Ethene	µg/L	<60	<60	<60	<48	<48	62
Ethane	µg/L	<60	<60	<60	<48	<48	<30
PCE	µM	<0.30	<0.30	<0.30	<0.24	<0.24	<0.15
TCE	µM	<0.38	<0.38	<0.38	<0.30	<0.30	<0.19
cDCE	µM	169.2	148.6	134.2	163.1	87.5	52.1
tDCE	µM	<0.52	3.7	2.5	0.94	1.86	<0.26
1TCA	µM	8.0	9.4	3.7	5.4	2.8	1.6
1DCE	µM	6.0	4.3	5.0	3.7	2.2	<0.26
1DCA	µM	4.8	2.6	2.9	2.7	2.2	1.1
CA	µM	<0.78	<0.78	<0.78	<0.62	<0.62	<0.39
VC	µM	20.6	12.8	22.9	16.0	8.0	3.0
Acetylene	µM	<1.9	<1.9	<1.9	<1.5	<1.5	<0.96
Ethene	µM	<2.1	<2.1	<2.1	<1.7	<1.7	2.2
Ethane	µM	<2.0	<2.0	<2.0	<1.6	<1.6	<1.0
Sum CE	µM	189.9	165.1	159.5	180.0	97.4	57.4
Sum CA	µM	18.9	16.4	11.6	11.8	7.2	2.8
pH		6.7	6.7	6.6	6.5	6.7	6.4
ORP	mV	164	-180	-334	-382	-366	-362
Alkalinity	mg/L CaCO3	310	310	405	640	875	1040
Sum CE-Gases	µM	190	165	160	180	97.4	55.2
Sum CA-Gases	µM	19	16	12	12	7.2	2.8
Sulfate	mg/L	1200					1400

11-C	SRS + Bioaugmentation Plume Zone MW-20D Groundwater and MW-21D Rock						
Compound	Week	0	2	4	8	12	16
PCE	µg/L	<50	<50	<50	<50	<40	<25
TCE	µg/L	<50	<50	<50	<50	<40	<25
cDCE	µg/L	15900	13500	22500	14200	8000	3870
tDCE	µg/L	<50	370	290	140	190	<25
1TCA	µg/L	1000	1160	680	670	350	150
1DCE	µg/L	720	420	510	340	210	<25
1DCA	µg/L	480	270	320	300	220	94
CA	µg/L	<50	<50	<50	<50	<40	<25
VC	µg/L	1230	820	2010	1150	440	160
Methane	µg/L	110	<33	<33	<33	<27	<17
Acetylene	µg/L	<50	<50	<50	<50	<40	<25
Ethene	µg/L	<60	<60	<60	<60	<48	70
Ethane	µg/L	<60	<60	<60	<60	<48	99
PCE	µM	<0.30	<0.30	<0.30	<0.30	<0.24	<0.15
TCE	µM	<0.38	<0.38	<0.38	<0.38	<0.30	<0.19
cDCE	µM	164.1	139.3	232.2	146.5	82.6	39.9
tDCE	µM	<0.52	3.8	3.0	1.4	2.0	<0.26
1TCA	µM	7.5	8.7	5.1	5.0	2.6	1.1
1DCE	µM	7.4	4.3	5.3	3.5	2.2	<0.26
1DCA	µM	4.8	2.7	3.2	3.0	2.2	0.95
CA	µM	<0.78	<0.78	<0.78	<0.78	<0.62	<0.39
VC	µM	19.7	13.1	32.2	18.4	7.0	2.6
Acetylene	µM	<1.9	<1.9	<1.9	<1.9	<1.5	<0.96
Ethene	µM	<2.1	<2.1	<2.1	<2.1	<1.7	2.5
Ethane	µM	<2.0	<2.0	<2.0	<2.0	<1.6	3.3
Sum CE	µM	183.8	156.3	267.4	166.4	91.6	45.0
Sum CA	µM	19.8	15.8	13.6	11.6	7.0	5.4
pH		6.6	6.7	6.6	6.4	6.7	6.5
ORP	mV	166	-178	-357	-298	-367	-370
Alkalinity	mg/L CaCO3	315	315	410	755	890	1170
Sum CE-Gases	µM	184	156	267	166	91.6	42.5
Sum CA-Gases	µM	20	15.8	13.6	11.6	7.0	2.1
Sulfate	mg/L	1200					840

12-A	Nanoscale EZVI Plume Zone MW-20D Groundwater and MW-21D Rock						
Compound	Week	0	4	8	12	16	16 Soil
PCE	µg/L	<50	<40	<20	<25	<10	<2.0
TCE	µg/L	<50	<40	<20	<25	<10	<2.0
cDCE	µg/L	11400	6130	10500	5970	7160	360
tDCE	µg/L	<50	180	59	110	<10	<2.0
1TCA	µg/L	800	<40	<20	<25	<10	<2.0
1DCE	µg/L	540	<40	100	120	<10	<2.0
1DCA	µg/L	440	240	240	170	120	9.8
CA	µg/L	<50	<40	<20	<25	<10	<2.0
VC	µg/L	1100	800	860	360	1140	1.2
Methane	µg/L	110	<27	<13	<17	34	6.5
Acetylene	µg/L	<50	<40	<20	<25	<10	<2.0
Ethene	µg/L	890	<48	55	89	96	5.1
Ethane	µg/L	<60	<48	<24	<30	90	16
PCE	µM	<0.30	<0.24	<0.12	<0.15	<0.060	<0.012
TCE	µM	<0.38	<0.30	<0.15	<0.19	<0.076	<0.015
cDCE	µM	117.6	63.3	108.4	61.6	73.9	3.7
tDCE	µM	<0.52	1.9	0.61	1.1	<0.10	<0.021
1TCA	µM	6.0	<0.30	<0.15	<0.19	<0.075	<0.015
1DCE	µM	5.6	<0.41	1.0	1.2	<0.10	<0.020
1DCA	µM	4.4	2.4	2.4	1.7	1.2	0.10
CA	µM	<0.78	<0.62	<0.31	<0.39	<0.16	<0.031
VC	µM	17.6	12.8	13.8	5.8	18.2	0.019
Acetylene	µM	<1.9	<1.5	<0.77	<0.96	<0.38	<0.077
Ethene	µM	31.8	<1.7	2.0	3.2	3.4	0.18
Ethane	µM	<2.0	<1.6	<0.83	<1.0	3.0	0.53
Sum CE	µM	167.0	77.9	124.7	71.7	95.6	3.9
Sum CA	µM	16.0	2.4	3.5	3.0	4.2	0.63
pH		6.7	6.9	6.9	7.0	6.5	
ORP	mV	-20	-259	-245	-295	-123	
Alkalinity	mg/L CaCO3	290	220	215	195	195	
Sum CE-Gases	µM	135	78	123	69	92.1	
Sum CA-Gases	µM	16	2.4	3.5	3.0	1.2	
Sulfate	mg/L	1200				1000	

12-B	Nanoscale EZVI Plume Zone MW-20D Groundwater and MW-21D Rock					
Compound	Week	0	4	8	12	16
PCE	µg/L	<50	<40	<10	<20	<10
TCE	µg/L	<50	<40	35	<20	<10
cDCE	µg/L	16100	4910	7060	4180	2370
tDCE	µg/L	<50	190	46	92	<10
1TCA	µg/L	1020	<40	<10	<20	<10
1DCE	µg/L	540	<40	62	160	<10
1DCA	µg/L	460	230	110	110	72
CA	µg/L	<50	<40	<10	<20	<10
VC	µg/L	1300	560	370	240	140
Methane	µg/L	110	<27	<6.7	<13	<6.7
Acetylene	µg/L	<50	<40	<10	<20	<10
Ethene	µg/L	340	<48	22	48	71
Ethane	µg/L	<60	<48	<12	<24	100
PCE	µM	<0.30	<0.24	<0.060	<0.12	<0.060
TCE	µM	<0.38	<0.30	0.27	<0.15	<0.076
cDCE	µM	166.2	50.7	72.9	43.1	24.5
tDCE	µM	<0.52	2.0	0.47	0.95	<0.10
1TCA	µM	7.6	<0.30	<0.075	<0.15	<0.075
1DCE	µM	5.6	<0.41	0.64	1.7	<0.10
1DCA	µM	4.6	2.3	1.1	1.1	0.73
CA	µM	<0.78	<0.62	<0.16	<0.31	<0.16
VC	µM	20.8	9.0	5.9	3.8	2.2
Acetylene	µM	<1.9	<1.5	<0.38	<0.77	<0.38
Ethene	µM	12.1	<1.7	0.79	1.7	2.5
Ethane	µM	<2.0	<1.6	<0.40	<0.67	3.3
Sum CE	µM	199.1	61.6	80.3	49.6	29.2
Sum CA	µM	17.9	2.3	1.8	2.8	4.1
pH		6.6	6.9	6.9	6.9	7.1
ORP	mV	16	-256	-242	-297	-183
Alkalinity	mg/L CaCO3	295	180	200	185	195
Sum CE-Gases	µM	187	62	80	48	26.7
Sum CA-Gases	µM	18	2.3	1.8	2.8	0.7
Sulfate	mg/L	1200				800

12-C	Nanoscale EZVI Plume Zone MW-20D Groundwater and MW-21D Rock					
Compound	Week	0	4	8	12	16
PCE	µg/L	<50	<40	<20	<20	<2.5
TCE	µg/L	<50	<40	<20	<20	<2.5
cDCE	µg/L	10100	8180	9090	3020	1930
tDCE	µg/L	<50	200	53	89	<2.5
1TCA	µg/L	950	<40	<20	<20	<2.5
1DCE	µg/L	450	320	85	91	<2.5
1DCA	µg/L	430	290	260	120	88
CA	µg/L	<50	<40	<20	<20	<2.5
VC	µg/L	820	1080	810	230	220
Methane	µg/L	110	<27	<13	<13	18
Acetylene	µg/L	<50	<40	<20	<20	trace
Ethene	µg/L	430	<48	93	71	72
Ethane	µg/L	<60	<48	<24	<24	64
PCE	µM	<0.30	<0.24	<0.12	<0.12	<0.015
TCE	µM	<0.38	<0.30	<0.15	<0.15	<0.019
cDCE	µM	104.2	84.4	93.8	31.2	19.9
tDCE	µM	<0.52	2.1	0.55	0.92	<0.026
1TCA	µM	7.1	<0.30	<0.15	<0.15	<0.019
1DCE	µM	4.6	3.3	0.88	0.94	<0.026
1DCA	µM	4.3	2.9	2.6	1.2	0.89
CA	µM	<0.78	<0.62	<0.31	<0.31	<0.039
VC	µM	13.1	17.3	13.0	3.7	3.5
Acetylene	µM	<1.9	<1.5	<0.77	<0.77	<0.096
Ethene	µM	15.4	<1.7	3.3	2.5	2.6
Ethane	µM	<2.0	<1.6	<0.83	<0.67	2.1
Sum CE	µM	132.7	103.8	110.6	38.3	26.0
Sum CA	µM	16.1	6.2	3.5	2.2	3.0
pH		6.7	6.8	6.8	6.8	7.2
ORP	mV	-1	-274	-247	-293	-165
Alkalinity	mg/L CaCO3	290	190	195	195	160
Sum CE-Gases	µM	117	104	107	36	23.4
Sum CA-Gases	µM	16	6.2	3.5	2.2	0.9
Sulfate	mg/L	1200				860

13-A	Microscale EZVI Plume Zone MW-20D Groundwater and MW-21D Rock						
Compound	Week	0	4	8	12	16	16 Soil
PCE	µg/L	<50	<40	<20	<10	<20	10
TCE	µg/L	<50	<40	<20	<10	<20	28
cDCE	µg/L	11600	8290	4850	5490	2770	140
tDCE	µg/L	<50	190	37	46	<20	<4.0
1TCA	µg/L	970	210	130	31	130	<4.0
1DCE	µg/L	480	330	62	50	<20	<4.0
1DCA	µg/L	440	240	170	110	79	<4.0
CA	µg/L	<50	<40	<20	<10	<20	<4.0
VC	µg/L	1090	1000	400	220	120	<4.0
Methane	µg/L	100	<27	<13	44	<13	18
Acetylene	µg/L	<50	<40	<20	<10	<20	<4.0
Ethene	µg/L	320	<48	42	47	91	9.9
Ethane	µg/L	<60	<48	<24	<12	74	35
PCE	µM	<0.30	<0.24	<0.12	<0.060	<0.12	0.060
TCE	µM	<0.38	<0.30	<0.15	<0.076	<0.15	0.21
cDCE	µM	119.7	85.6	50.1	56.7	28.6	1.4
tDCE	µM	<0.52	2.0	0.38	0.47	<0.21	<0.041
1TCA	µM	7.3	1.6	1.0	0.23	1.0	<0.030
1DCE	µM	5.0	3.4	0.64	0.52	<0.21	<0.041
1DCA	µM	4.4	2.4	1.7	1.1	0.80	<0.040
CA	µM	<0.78	<0.62	<0.31	<0.16	<0.31	<0.062
VC	µM	17.4	16.0	6.4	3.5	1.9	<0.064
Acetylene	µM	<1.9	<1.5	<0.77	<0.38	<0.77	<0.15
Ethene	µM	11.4	<1.7	1.5	1.7	3.3	0.35
Ethane	µM	<2.0	<1.6	<0.83	<0.33	<0.83	1.2
Sum CE	µM	148.6	103.5	58.3	62.3	33.8	2.1
Sum CA	µM	16.7	7.4	3.3	1.9	1.8	1.2
pH		6.7	6.9	6.9	7.1	7.1	
ORP	mV	9	-212	-239	-284	-136	
Alkalinity	mg/L CaCO3	300	250	330	325	335	
Sum CE-Gases	µM	137	104	57	61	30.5	1.7
Sum CA-Gases	µM	17	7.4	3.3	1.9	1.8	0.000
Sulfate	mg/L	1200				1400	

13-B	Microscale EZVI Plume Zone MW-20D Groundwater and MW-21D Rock					
Compound	Week	0	4	8	12	16
PCE	µg/L	<50	<40	<20	<20	<2.5
TCE	µg/L	<50	<40	<20	<20	<2.5
cDCE	µg/L	10800	8210	9540	4330	2320
tDCE	µg/L	<50	190	47	90	<2.5
1TCA	µg/L	910	200	110	58	<2.5
1DCE	µg/L	480	330	87	93	<2.5
1DCA	µg/L	440	240	170	130	84
CA	µg/L	<50	<40	<20	<20	<2.5
VC	µg/L	990	1010	610	260	170
Methane	µg/L	110	<27	<13	78	49
Acetylene	µg/L	<50	<40	<20	<20	trace
Ethene	µg/L	310	<48	48	61	70
Ethane	µg/L	<60	<48	<24	98	50
PCE	µM	<0.30	<0.24	<0.12	<0.12	<0.015
TCE	µM	<0.38	<0.30	<0.15	<0.15	<0.019
cDCE	µM	111.5	84.7	98.5	44.7	23.9
tDCE	µM	<0.52	2.0	0.49	0.93	<0.026
1TCA	µM	6.8	1.5	0.82	0.43	<0.019
1DCE	µM	5.0	3.4	0.90	0.96	<0.026
1DCA	µM	4.4	2.4	1.7	1.3	0.85
CA	µM	<0.78	<0.62	<0.31	<0.31	<0.039
VC	µM	15.8	16.2	9.8	4.2	2.7
Acetylene	µM	<1.9	<1.5	<0.77	<0.77	<0.096
Ethene	µM	11.1	<1.7	1.7	2.2	2.5
Ethane	µM	<2.0	<1.6	<0.83	3.3	1.7
Sum CE	µM	138.4	102.8	110.4	52.0	29.2
Sum CA	µM	16.2	7.3	3.4	6.0	2.5
pH		6.7	6.8	6.9	7.2	7.1
ORP	mV	33	-222	-240	-266	-126
Alkalinity	mg/L CaCO3	305	240	335	345	340
Sum CE-Gases	µM	127	103	109	50	26.7
Sum CA-Gases	µM	16	7.3	3.4	2.7	0.8
Sulfate	mg/L	1200				1700

13-C	Microscale EZVI Plume Zone MW-20D Groundwater and MW-21D Rock					
Compound	Week	0	4	8	12	16
PCE	µg/L	<50	<40	<20	<10	<10
TCE	µg/L	<50	<40	<20	<10	<10
cDCE	µg/L	13500	8160	6640	4640	1680
tDCE	µg/L	<50	190	40	46	<10
1TCA	µg/L	990	180	78	<10	<10
1DCE	µg/L	510	330	72	50	<10
1DCA	µg/L	470	250	210	120	79
CA	µg/L	<50	<40	<20	<10	<10
VC	µg/L	1180	1190	500	260	150
Methane	µg/L	100	<27	<13	54	39
Acetylene	µg/L	<50	<40	<20	<10	<10
Ethene	µg/L	<60	<48	43	81	100
Ethane	µg/L	<60	<48	<24	56	73
PCE	µM	<0.30	<0.24	<0.12	<0.060	<0.060
TCE	µM	<0.38	<0.30	<0.15	<0.076	<0.076
cDCE	µM	139.3	84.2	68.5	47.9	17.3
tDCE	µM	<0.52	2.0	0.41	0.47	<0.10
1TCA	µM	7.4	1.3	0.58	<0.075	<0.075
1DCE	µM	5.3	3.4	0.74	0.52	<0.10
1DCA	µM	4.7	2.5	2.1	1.2	0.80
CA	µM	<0.78	<0.62	<0.31	<0.16	<0.16
VC	µM	18.9	19.0	8.0	4.2	2.4
Acetylene	µM	<1.9	<1.5	<0.77	<0.38	<0.38
Ethene	µM	<2.0	<1.7	1.5	2.9	3.6
Ethane	µM	<2.0	<1.6	<0.83	1.9	2.4
Sum CE	µM	158.2	105.2	78.5	55.4	23.3
Sum CA	µM	17.4	7.3	3.4	3.6	3.2
pH		6.7	6.8	7.0	7.1	7.1
ORP	mV	7	-209	-237	-258	-56
Alkalinity	mg/L CaCO3	295	260	325	335	315
Sum CE-Gases	µM	158	105	77	53	19.7
Sum CA-Gases	µM	17	7.3	3.4	1.7	0.8
Sulfate	mg/L	1200				1000

14-A	EHC Plume Zone MW-20D Groundwater and MW-21D Rock							
Compound	Week	0	2	4	8	12	16	16 Soil
PCE	µg/L	<50	<50	<40	<25	<50	<25	<5.0
TCE	µg/L	<50	<50	<40	<25	<50	<25	<5.0
cDCE	µg/L	11800	10200	12300	22800	11400	5650	1230
tDCE	µg/L	<50	360	190	90	220	<25	<5.0
1TCA	µg/L	880	360	140	<25	<50	<25	<5.0
1DCE	µg/L	510	380	340	190	230	<25	<5.0
1DCA	µg/L	460	260	320	340	280	120	6.2
CA	µg/L	<50	<50	<40	<25	<50	<25	<5.0
VC	µg/L	1000	610	910	820	420	92	<5.0
Methane	µg/L	110	<33	<27	<17	<33	<17	<3.3
Acetylene	µg/L	<50	<50	<40	<25	<50	<25	<5.0
Ethene	µg/L	310	<60	<48	50	<60	100	14
Ethane	µg/L	<60	<60	<48	<30	<60	120	37
PCE	µM	<0.30	<0.30	<0.24	<0.15	<0.30	<0.15	<0.030
TCE	µM	<0.38	<0.38	<0.30	<0.19	<0.38	<0.19	<0.038
cDCE	µM	121.8	105.3	126.9	235.3	117.6	58.3	12.7
tDCE	µM	<0.52	3.7	2.0	0.93	2.3	<0.26	<0.052
1TCA	µM	6.6	2.7	1.0	<0.19	<0.38	<0.19	<0.037
1DCE	µM	5.3	3.9	3.5	2.0	2.4	<0.26	<0.052
1DCA	µM	4.6	2.6	3.2	3.4	2.8	1.2	0.063
CA	µM	<0.78	<0.78	<0.62	<0.39	<0.78	<0.39	<0.078
VC	µM	16.0	9.8	14.6	13.1	6.7	1.5	<0.080
Acetylene	µM	<1.9	<1.9	<1.5	<0.96	<1.9	<0.96	<0.19
Ethene	µM	11.1	<2.1	<1.7	1.8	<2.1	3.6	0.50
Ethane	µM	<2.0	<2.0	<1.6	<1.6	<2.0	4.0	1.2
Sum CE	µM	148.8	118.7	143.5	251.1	126.6	63.4	13.2
Sum CA	µM	16.5	9.2	7.8	5.4	5.2	5.2	1.3
pH		6.8	5.8	6.9	6.6	7.0	6.8	
ORP	mV	45	-180	-200	-216	-228	-10	
Alkalinity	mg/L CaCO3	300	630	945	1100	1105	1170	
Sum CE-Gases	µM	138	119	143	249	126.6	59.8	12.7
Sum CA-Gases	µM	17	9.2	7.8	5.4	5.2	1.2	0.06
Sulfate	mg/L	1200					580	

14-B	EHC Plume Zone MW-20D Groundwater and MW-21D Rock					
Compound	Week	0	4	8	12	16
PCE	µg/L	<50	<40	<40	<40	<40
TCE	µg/L	<50	<40	<40	<40	<40
cDCE	µg/L	15200	13800	15600	14000	15400
tDCE	µg/L	<50	190	90	180	<40
1TCA	µg/L	860	170	<40	<40	<40
1DCE	µg/L	540	360	180	190	<40
1DCA	µg/L	470	310	340	260	390
CA	µg/L	<50	<40	<40	<40	<40
VC	µg/L	1170	990	830	410	580
Methane	µg/L	100	<27	<27	<27	<27
Acetylene	µg/L	<50	<40	<40	trace	trace
Ethene	µg/L	<60	<48	<48	82	490
Ethane	µg/L	<60	<48	<48	<48	450
PCE	µM	<0.30	<0.24	<0.24	<0.24	<0.24
TCE	µM	<0.38	<0.30	<0.30	<0.30	<0.30
cDCE	µM	156.9	142.4	161.0	144.5	158.9
tDCE	µM	<0.52	2.0	0.93	1.9	<0.41
1TCA	µM	6.4	1.3	<0.30	<0.30	<0.30
1DCE	µM	5.6	3.7	1.9	2.0	<0.41
1DCA	µM	4.7	3.1	3.4	2.6	3.9
CA	µM	<0.78	<0.62	<0.62	<0.62	<0.62
VC	µM	18.7	15.8	13.3	6.6	9.3
Acetylene	µM	<1.9	<1.5	<1.5	<1.5	<1.5
Ethene	µM	<2.0	<1.7	<1.7	2.9	17.5
Ethane	µM	<2.0	<1.6	<1.6	<1.6	15.0
Sum CE	µM	175.6	160.2	175.2	155.8	185.7
Sum CA	µM	16.8	8.1	5.3	4.6	18.9
pH		6.8	6.6	6.5	6.7	6.9
ORP	mV	52	-164	-230	-221	-19
Alkalinity	mg/L CaCO3	300	945	1115	1325	1320
Sum CE-Gases	µM	176	160	175	153	168.2
Sum CA-Gases	µM	17	8.1	5.3	4.6	3.9
Sulfate	mg/L	1200				330

14-C	EHC Plume Zone MW-20D Groundwater and MW-21D Rock					
Compound	Week	0	4	8	12	16
PCE	µg/L	<50	<40	<40	<40	<20
TCE	µg/L	<50	<40	<40	<40	<20
cDCE	µg/L	13800	18300	15500	8870	5920
tDCE	µg/L	<50	200	740	180	<20
1TCA	µg/L	810	350	>40	>40	<20
1DCE	µg/L	530	400	150	190	<20
1DCA	µg/L	460	280	330	240	130
CA	µg/L	<50	<40	<40	<40	<20
VC	µg/L	1040	1150	680	350	180
Methane	µg/L	110	<27	<27	<27	<13
Acetylene	µg/L	<50	<40	<40	trace	trace
Ethene	µg/L	310	<48	<48	73	91
Ethane	µg/L	<60	<48	<48	<48	110
PCE	µM	<0.30	<0.24	<0.24	<0.24	<0.12
TCE	µM	<0.38	<0.30	<0.30	<0.30	<0.15
cDCE	µM	142.4	188.9	160.0	91.5	61.1
tDCE	µM	<0.52	2.1	7.6	1.9	<0.21
1TCA	µM	6.1	2.6	<0.30	<0.30	<0.15
1DCE	µM	5.5	4.1	1.5	2.0	<0.21
1DCA	µM	4.6	2.8	3.3	2.4	1.3
CA	µM	<0.78	<0.62	<0.62	<0.62	<0.31
VC	µM	16.6	18.4	10.9	5.6	2.9
Acetylene	µM	<1.9	<1.5	<1.5	<1.5	<0.77
Ethene	µM	11.1	<1.7	<1.7	2.6	3.3
Ethane	µM	<2.0	<1.6	<1.6	<1.6	3.7
Sum CE	µM	170.1	209.3	178.5	101.6	67.2
Sum CA	µM	16.2	9.6	4.9	4.4	5.0
pH		6.8	6.3	6.6	6.7	6.9
ORP	mV	30	-144	-219	-203	-8
Alkalinity	mg/L CaCO3	300	875	1055	1260	1290
Sum CE-Gases	µM	159	209	178	99	64.0
Sum CA-Gases	µM	16	10	4.9	4.4	1.3
Sulfate	mg/L	1200				540

16A	1.8 g Microscale EZVI Plume Zone MW-20D Groundwater and MW-21D Rock							
Compound	Week	0	2	4	6	8	12	16
PCE	µg/L	<100	<50	<40	<25	<25	<25	<10
TCE	µg/L	<100	<50	<40	<25	<25	<25	<10
cDCE	µg/L	63700	13500	11100	12200	11000	3990	3510
tDCE	µg/L	920	370	190	65	50	<25	<10
1TCA	µg/L	2740	620	350	190	89	<25	<10
1DCE	µg/L	1350	470	340	160	81	110	<10
1DCA	µg/L	1020	270	290	200	260	160	150
CA	µg/L	<100	<200	<40	<25	<25	<25	<10
VC	µg/L	3880	390	1110	580	400	180	96
Methane	µg/L	210	<130	14	<17	<17	<17	<6.6
Acetylene	µg/L	<100	<50	<40	<25	<25	<25	trace
Ethene	µg/L	590	<60	<48	38	<30	<30	60
Ethane	µM	<120	<60	<48	<30	<30	<30	44
PCE	µM	<0.60	<0.30	<0.24	<0.15	<0.15	<0.15	<0.060
TCE	µM	<0.76	<0.38	<0.30	<0.19	<0.19	<0.19	<0.076
cDCE	µM	657.4	139.3	114.6	125.9	113.5	41.2	36.2
tDCE	µM	9.5	3.8	2.0	0.67	0.52	<0.26	<0.10
1TCA	µM	20.5	4.6	2.6	1.4	0.67	<0.19	<0.075
1DCE	µM	13.9	4.9	3.5	1.7	0.84	1.1	<0.10
1DCA	µM	10.3	2.7	2.9	2.0	2.6	1.6	1.5
CA	µM	<1.6	<0.78	<0.62	<0.39	<0.39	<0.39	<0.16
VC	µM	62.1	6.2	17.8	9.3	6.4	2.9	1.5
Acetylene	µM	<3.8	<1.9	<1.9	<0.96	<0.96	<0.96	<0.38
Ethene	µM	21.1	<2.1	<2.1	1.4	<1.1	<1.1	2.1
Ethane	µM	<4.0	<2.0	<2.0	<1.0	<1.0	<1.0	1.5
Sum CE	µM	750.0	149.4	134.3	137.2	120.4	44.1	39.9
Sum CA		44.8	12.2	9.1	5.1	4.1	2.8	3.0
pH	mV	6.8	6.8	6.8	6.8	6.8	7.0	7.1
ORP	mg/L CaCO3	18	-69	-104	-78	-182	-184	-114
Alkalinity	µM	305	305	255	325	355	405	385
Sum CE w/o Gases	µM	729.0	149.4	134.3	135.9	120.4	44.1	37.8
Sum CA w/o Gases		44.8	12.2	9.1	5.1	4.1	2.8	1.5

16B	8.8 g Microscale EZVI Plume Zone MW-20D Groundwater and MW-21D Rock							
Compound	Week	0	2	4	6	8	12	16
PCE	µg/L	<100	<50	<40	<20	<25	<25	<10
TCE	µg/L	<100	<50	<40	<20	<25	<25	<10
cDCE	µg/L	20100	12000	8470	10300	7220	3760	2250
tDCE	µg/L	870	370	190	<20	52	<25	<10
1TCA	µg/L	1790	390	180	37	<25	<25	<10
1DCE	µg/L	920	450	320	120	75	110	<10
1DCA	µg/L	870	250	270	230	240	180	110
CA	µg/L	<100	<50	<40	<20	<25	<25	<10
VC	µg/L	1680	930	1010	490	500	190	100
Methane	µg/L	210	43	<27	<13	<17	<17	39
Acetylene	µg/L	<100	<50	<40	<20	<25	trace	trace
Ethene	µg/L	580	<60	<48	51	53	76	120
Ethane	µM	<120	<120	<48	53	<30	trace	75
PCE	µM	<0.60	<0.60	<0.24	<0.12	<0.15	<0.15	<0.060
TCE	µM	<0.76	<0.76	<0.30	<0.15	<0.19	<0.19	<0.076
cDCE	µM	207.4	123.8	87.4	106.3	74.5	38.8	23.2
tDCE	µM	9.0	3.8	2.0	<0.21	0.54	<0.26	<0.10
1TCA	µM	13.4	2.9	1.3	0.28	<0.19	<0.19	<0.075
1DCE	µM	9.5	4.6	3.3	1.2	0.77	1.1	<0.10
1DCA	µM	8.8	2.5	2.7	2.3	2.4	1.8	1.1
CA	µM	<1.6	<0.78	<0.62	<0.31	<0.39	<0.39	<0.16
VC	µM	26.9	14.9	16.2	7.8	8.0	3.0	1.6
Acetylene	µM	<3.8	<1.9	<1.9	<0.96	<0.96	<0.96	<0.38
Ethene	µM	20.7	<2.1	<2.1	1.8	1.9	2.7	4.3
Ethane	µM	<4.0	<2.0	<2.0	1.8	<1.0	<1.0	2.5
Sum CE	µM	264.0	142.5	105.5	116.0	84.9	44.6	29.1
Sum CA		31.7	10.1	7.4	5.6	3.2	3.0	3.6
pH	mV	6.7	6.8	6.8	6.8	6.8	6.9	6.9
ORP	mg/L CaCO3	-30	-77	-66	-122	-182	-174	-107
Alkalinity	µM	285	285	140	285	270	280	215
Sum CE w/o Gases	µM	243.3	142.5	105.5	114.1	83.0	41.8	24.8
Sum CA w/o Gases		31.7	10.1	7.4	3.8	3.2	3.0	1.1

16C	35.2 g Microscale EZVI Plume Zone MW-20D Groundwater and MW-21D Rock								
Compound	Week	0	2	4	6	8	12	16	16 Soil
PCE	µg/L	<100	<50	<40	<10	<10	<4.0	<2.0	18
TCE	µg/L	<100	<50	<40	<10	<10	<4.0	<2.0	32
cDCE	µg/L	12200	6690	3710	4030	3280	1830	470	250
tDCE	µg/L	<100	<50	180	<10	19	18	<2.0	<2.0
1TCA	µg/L	1140	190	100	<10	<10	<4.0	<2.0	<2.0
1DCE	µg/L	<100	<50	200	<10	27	19	<2.0	<2.0
1DCA	µg/L	800	190	180	66	82	43	23	<2.0
CA	µg/L	<100	<50	<40	<10	<10	<4.0	<2.0	<2.0
VC	µg/L	1090	580	420	220	220	73	17	<2.0
Methane	µg/L	210	44	<27	14	<6.7	54	8.9	14
Acetylene	µg/L	<100	<50	<40	<10	<10	<4.0	<2.0	5.3
Ethene	µg/L	580	<60	<48	53	60	65	27	11
Ethane	µM	<120	<120	<48	45	39	46	22	22
PCE	µM	<0.60	<0.60	<0.24	<0.060	<0.060	<0.024	<0.012	0.11
TCE	µM	<0.76	<0.76	<0.30	<0.076	<0.076	<0.030	<0.015	0.24
cDCE	µM	125.9	69.0	38.3	41.6	33.8	18.9	4.9	2.6
tDCE	µM	<1.0	<0.51	1.9	<0.10	0.20	0.19	<0.021	<0.021
1TCA	µM	8.5	1.4	0.75	<0.075	<0.075	<0.030	<0.015	<0.015
1DCE	µM	<1.0	<0.51	2.1	<0.10	0.28	0.20	<0.021	<0.021
1DCA	µM	8.1	1.9	1.8	0.67	0.83	0.43	0.23	<0.020
CA	µM	<1.6	<0.78	<0.62	<0.16	<0.16	<0.062	<0.031	<0.031
VC	µM	17.4	9.3	6.7	3.5	3.5	1.2	0.27	<0.033
Acetylene	µM	<3.8	<1.9	<1.9	<0.38	<0.38	<0.15	<0.077	<0.077
Ethene	µM	20.7	<2.1	<2.1	1.9	2.1	2.3	1.0	0.39
Ethane	µM	<4.0	<2.0	<2.0	1.5	1.3	1.5	0.73	0.73
Sum CE	µM	164.1	78.3	46.9	47.0	39.7	22.6	6.1	3.3
Sum CA		16.6	3.3	4.6	2.2	2.4	2.2	1.0	0.7
pH	mV	6.7	6.7	6.7	6.7	6.7	6.5	6.4	
ORP	mg/L CaCO3	-99	-138	-117	-116	-116	-169	-63	
Alkalinity	µM	280	270	195	285	285	145	120	
Sum CE w/o Gases	µM	143.3	78.3	46.9	45.1	37.6	20.2	5.1	
Sum CA w/o Gases		16.6	3.3	4.6	0.7	1.1	0.6	0.2	