Investigating the Biostimulating Effects of ESO Addition to a TCE Contaminated Site

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Abstract

Remediation of chlorinated ethene contaminated sites presents a problem for the environmental industry. Many innovative technologies exist to remove these chemicals from the subsurface; however, most of these technologies require extensive time and incur significant cost. A technology called bioremediation utilizes microorganisms to break down contaminants such as perchloroethene (PCE), trichloroethene (TCE), dichloroethene (DCE), and vinyl chloride (VC) to non-toxic compounds in a process called reductive dechlorination.

Microorganisms that are capable of dechlorination usually require reducing conditions as well as bioavailable hydrogen and carbon sources. Emulsified vegetable oil has emerged as a cost-effective source of degradable organic matter to facilitate reductive dechlorination in the subsurface. Through β-oxidation, microorganisms can break down the long chain fatty acids in vegetable oil into smaller fatty acids such as acetate, propionate, and butyrate. The fermentation of the oil provides reduced conditions as well as a slow release of hydrogen and carbon into the subsurface.

This study consisted of an evaluation the effectiveness of emulsified vegetable oil in stimulating reductive dechlorination using sixteen laboratory microcosms constructed from soil and groundwater from an aquifer contaminated with TCE located at the Naval Weapons Station in Charleston, South Carolina. Each microcosm was monitored for chloroethenes, volatile fatty acids, long chain fatty acids, and total carbon on a weekly basis. Results show successful fermentation of fatty acids and reduced conditions favorable for dechlorination.

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Introduction

Chlorinated Ethene Bioremediation through Reductive Dechlorination

Trichloroethene (TCE), a chlorinated ethene, is a groundwater contaminant found at an estimated 861 of the nation's 1,428 hazardous waste sites on the National Priorities List (USEPA 1997). Dry cleaning, industrial, and military facilities nation-wide used TCE for spot removal and degreasing. Due to improper handling, storage, and disposal, TCE has become a ubiquitous groundwater contaminant.

TCE can cause acute health problems such as headaches, lung irritation, skin rashes, impaired heart function, unconsciousness, and death (USEPA 1997). Long term exposure to TCE, a suspected human carcinogen, may result in liver, kidney, and nerve damage in addition to impaired immune system function and fetal development in pregnant women (USEPA 1997). Exposure to other chlorinated ethenes, such as dichloroethene (DCE) or vinyl chloride (VC), can cause serious health problems as well. A known human carcinogen, VC exposure can lead to permanent liver damage, immune reactions, nerve damage, and liver cancer (ATSDR 1997).

Sites contaminated with chlorinated ethenes are remediated using technologies that employ several physical, chemical, and biological processes. Chlorinated ethenes were thought to be completely recalcitrant and therefore unable to be broken down by bacteria in the subsurface. Until the late 1980's the most common remediation technique was pump-and-treat, which utilized physical and chemical processes to treat water contaminated with chlorinated ethenes. However, the heterogeneous nature of aquifers, the tendency of chlorinated solvents to adsorb to

soil, and the difficulty in estimating the source mass collectively made pump-and-treat a relatively ineffective and expensive remediation technology at TCE-contaminated site (Mackay and Cherry 1989, Bouwer 1994). Because pump-and-treat methods require intensive operation, maintenance and time, professionals in the environmental remediation industry sought more economical and efficient treatment methods (Saaty et al. 1995). In the late 1980's researchers found that microorganisms could reductively dechlorinate chlorinated ethenes, including TCE (Vogel et al. 1987). Bioremediation emerged as a cost and time effective technique to decontaminant groundwater systems (Saaty et al. 1995). In situ bioremediation is a process in which intrinsic microorganisms break down contaminants such as TCE in the subsurface (Borden 1994). This technology is referred to as monitored natural attenuation (MNA). Enhancements to MNA include the addition of compounds to promote biodegradation (biostimulation), the addition of microorganisms (bioaugmentation), or some combination of both.

Due to the harmful nature of chlorinated ethenes to human health and the frequency of occurrence in aquifers, a concerted effort has been made to investigate how microbial processes affect the fate of these chemicals (Bradley 2000). Many different microbial processes contribute to the degradation of TCE. One microbial process, reductive dechlorination (RD), converts highly oxidized TCE through a series of reactions by using chlorinated ethenes as electron acceptors (Vogel et al. 1987). The electronegative chlorine atoms on TCE make it a favorable electron acceptor (Vogel et al. 1987). During RD, a chlorine atom is removed and replaced with a hydrogen atom (Bradley 2000). Unfortunately TCE degrades into more harmful intermediates,

DCE and VC, during RD until it reaches the final end products, ethene, or ethane (Vogel and McCarty 1985, Freedman and Gossett 1989, Bouwer 1994, McCarty and Semprini 1994). However, the RD process is often incomplete. The less oxidized daughter products of dechlorination, DCE and VC, are less likely to be reductively dechlorinated (Bouwer 1994, McCarty and Semprini 1994). Because these compounds are toxic, the accumulation of DCE and VC at some TCE contaminated sites causes a concern.

A complete understanding of all the environmental conditions required for complete and rapid RD is still unknown. Most bacteria capable of RD require highly-reduced conditions in order to degrade TCE and its daughter products (Vogel et al. 1987, Bouwer 1994, McCarty and Semprini 1994, DiStefano et al. 1992). Hydrogen concentrations can also have a significant impact on dechlorination rates (Cupples 2004).

Hydrogen as Electron Donor to Stimulate Reductive Dechlorination

Studies have shown that microorganisms require hydrogen as an electron donor for complete and efficient dechlorination (DiStefano et al. 1992, Holliger et al. 1993, and Maymo-Gatell et al. 1995). Methanogens and acetogenes tend to out-compete dechlorinators at high hydrogen concentrations, but thermodynamics are more favorable for RD at low hydrogen concentrations (Gibson et al. 1994, Fennell et al. 1995, Fennell and Gossett 1997, He et al. 2002). In particular, Smatlak et al. (1996) found approximate H_2 half-saturation constants (K_s) for dechlorination to be 100nM, whereas the K_s values for methanogensis were ten-fold greater at 1000 nM. A K_s value corresponds to the bulk solution concentration of hydrogen that supports half-maximum uptake rates (Smatlak et al. 1996). DiStefano et al. (1992) found that in hydrogen amended

microcosms, about 54% of the hydrogen went to acetogens, while 45% was utilized by dechlorinators.

A number of different technologies have been developed to deliver hydrogen to subsurface environments at concentrations effective for dechlorination. One such application is the direct injection of hydrogen to stimulate biodegradation in the subsurface. The most effective direct application of hydrogen to date utilizes hollow-fiber membranes to apply known, constant concentrations of hydrogen to stimulate dechlorination (Ma et al. 2003). The hollow-fiber membranes stimulate complete dechlorination; however, because high concentration gradients improve the rate of gas transfer, the system operates with high lumen hydrogen partial pressures (Ma et al. 2003). The high lumen hydrogen partial pressures lead to an inefficient process where methanogens utilized 94% of the reducing equivalents, whereas only 4% went to dechlorination (Ma et al. 2003). Other methods involve the injection of water containing dissolved hydrogen and hydrogen sparging, but the low solubility, combustible nature, and difficulty of uniform delivery of hydrogen makes these technologies problematic (Newell et al. 1997, Fisher et al. 1998, Fisher et al. 1999, and Ma et al. 2003).

Safe, inexpensive organic compounds capable of producing hydrogen through anaerobic fermentive oxidation are an alternative to fueling dechlorination (Gottschalk 1986, Fennell et al. 1995). In some studies that added alcohols to groundwater, RD rates were high at first, but soon ceased without complete dechlorination (Gottschalk 1986, Yang 2002). Methanol and other odd carbon number alcohols (propanol) cannot sustain reductive dechlorination (Gottschalk 1986, Maymo-Gatell et al. 1995), but even carbon number alcohols (ethanol and butanol) supported

complete degradation (Villarante et al. 2001). High concentrations of hydrogen produced by alcohol degradation stimulate methanogens and acetogens instead of dechlorinators. Since dechlorinators out-compete methanogens and acetogens at lower partial pressures of hydrogen, a substrate that releases hydrogen into solution slowly, such as a volatile fatty acid (VFA), is more effective for RD (Smatlak et al. 1996, He et al. 2002).

Fatty Acids as Electron Donors to Stimulate Reductive Dechlorination

Fatty acid oxidizing fermentors form a syntrophic relationship with hydrogentrophic dechlorinators (McInerney et al. 1981, Fennell and Gossett 1997). A syntrophism is a special case of symbiotic cooperation between two metabolically different types of bacteria which depend on each other for degradation of a certain substrate, typically for energetic reasons (Schink 1997). In this process, fatty acids are β-oxidized to produce hydrogen (dehydrogenation) and acetate (acetogenesis) (McCarty and Smith 1986). During β-oxidation, a fatty acid with three or more carbons in a chain generates hydrogen while a two-carbon segment of acetate is clipped off the end of the fatty acid. For instance, McCarty and Smith (1986) described the β-oxidation of propionate as:

$$CH_3CH_2COO^-(aq) + 2H_2O(l) = CH_3COO^-(aq) + 3H_2(g) + CO_2(g)$$

Although most studies focus on hydrogen as the only electron donor for RD (DiStefano et al. 1992), acetotrophic dechlorinators exist (Vogel and McCarty 1985, He et al. 2002, He et al. 2003). As long as hydrogen and acetate concentrations remain low, anaerobic oxidation of fatty acids will continue with dechlorination (McCarty and Smith 1986, Gibson et al. 1990, Schink 1997). Unlike methanogens and acetogens, dechlorinators and fatty acid oxidizers prefer low hydrogen and acetate concentrations (McCarty and Smith 1986, Gibson et al. 1990, Schink 1997). Propionate and butyrate can undergo syntrophic degradation to stimulate complete RD

(Gottschalk 1986, Gibson 1992, Gibson et al. 1994, Fennell and Gossett 1997, He et al. 2002), however; nutrient and vitamin B12 deficiencies can limit the extent of dechlorination (DiStefano et al. 1992, Fennell and Gossett 1997). Villarante et al. (2001) found that even numbered carbon fatty acids promote the degradation of PCE to DCE, but odd number carbon fatty acids could not sustain degradation. Formation of TCE daughter products occurred in a hydrogen amended microcosm, but only after acetate accumulation (He et al. 2002). Dechlorination only after acetate accumulation supports Maymo-Gatell et al.'s (1995) conclusion that an insufficient source of acetate or carbon can limit RD.

Substrate Production of Fatty Acids and Hydrogen

Degradation of many different substrates produce propionate, butyrate, and acetate. Fennell and Gossett (1997) found propionate produced by addition of lactic acid. Valerate and heptanoate degradation results in propionate, acetate, and hydrogen creation (McInerney et al. 1981). Butyrate and caproate can be formed by methanotrophs (Ljungdahl 1983). Nozhevnikova et al. (2000) showed that butyrate production increases as temperature decreases. Isoheptanoate, heptanoate, valerate, caprylate, propionate, butyrate, caproate, and caprylate oxidize through syntrophic association to produce acetate and hydrogen (Boone and Bryant 1980, McInerney et al. 1981, Nozhevnikova et al. 2000). In addition, acetate can be formed from formate, methanol and carbon dioxide (Ljungdahl 1983).

Stimulation of RD by electron donors that produce fatty acids can be accomplished by a plethora of substrates. For example, yeast extract, wastewater, cheese whey permeate, cornsteep liquor, molasses, and tea manure ferment and produce fatty acids that can stimulate dechlorination (Lee et al. 1997). Shetty and Doucette (2002) added molasses to a source area and achieved reduction

in TCE concentrations as well as formation of daughter products. HRC (hydrogen release compound) was developed by a company, Regenesis, to slowly release hydrogen through lactate degradation and create reduced conditions favorable to RD (www.regenesis.com 2003). While some studies show lactate as a quickly consumed, ineffective electron donor (Gottschalk 1986, de Bruin et al. 1992, Fennell and Gossett 1997), deBruin (1992) observed complete dechlorination in lactate amended soils. Vigue and Koenigsberg (2002) applied HRC in a TCE contaminated aquifer at the Rocky Mountain Arsenal and found the HRC produced reduced conditions after 7 months.

Vegetable Oil as Substrate to Stimulate Reductive Dechlorination

Vegetable oils have been applied to contaminated aquifers to produce the same results (Yang 2002). Vegetable oil makes an excellent substrate to promote dechlorination because it is readily biodegradable (Wincele et al. 2004) and produces reduced conditions while inhibiting methanogenesis through slow hydrogen and acetate release (Becker and Markl 2000, Lalman and Bagley 2000, Waddill et al. 2002). The six main long chain fatty acids (LCFAs) found in soybean oil are palmitate, stearate, oleate, linoleate, linolenate, and arachidate (Table 1).

Table 1: Main LCFAs of Soybean Oil

LCFA	Molecular Formula[1]	% in oil by weight
Palmitate	C16:0	6
Stearate	C18:0	3
Oleate	C18:1	35
Linoleate	C18:2	50
Linolenate	C18:3	3
Arachidate	C20:0	3

Notes:

[1]: Number of carbons:Number of double bonds

These LCFAs undergo β-oxidation to form VFAs producing hydrogen and acetate (Lalman and Bagley 2000, Waddill et al. 2002). This slow release of hydrogen and acetate is ideal for use as a biostimulant for RD. During the degradation of linoleic acid, a constituent of soybean and many other vegetable oils, unsaturated C18 and C16 fatty acid by-products are readily consumed in reactions, but the saturated C18 and C16 by-products accumulate (Lalman and Bagley 2000).

The fate of vegetable oil and its degradation products in the subsurface is still unknown. When vegetable oil was used as a biostimulant, it was pumped directly into the subsurface, which can lead to changes in the hydrogeologic and chemical characteristics of the aquifer (Waddill et al. 2002). For instance, vegetable oil can successfully control a source zone through the partitioning of TCE into the oil (Gavaskar et al. 2001). Injection of vegetable oil affects the hydraulic conductivity of the aquifer, because the oil fills the largest, most conductive pore spaces (Waddill et al. 2002). In Waddill et al. (2002) study, a year after oil injection, the oil radiated 9 to 43 feet from the injection well (2002). The oil-binding capacity of clays might also affect the fate of vegetable oil in the subsurface (Wincele et al. 2004).

In order to create a more bioavailable and mobile substrate, vegetable oil can be emulsified and mixed with yeast extract and lactate prior to injection (Borden and Lee 2002a, Borden et al. 2002b, Borden et al. 2002c, Hunter 2002). This microemulsion provides a slow release of hydrogen and acetate to sustain RD for years (Borden and Lee 2002a). Robert C. Borden along with Solutions Industrial and Environmental Services, Inc (Solution-IES) and Terra Systems, Inc (TSI) developed and patented a food grade oil emulsion with nutrients to stimulate RD. Emulsified soybean oil (ESO) can be applied to remediation projects to prevent downgradient migration, treat source zones, and supplement organic carbon through the use of injection barriers, temporary direct push or permanent wells (Gibson 1992, Borden 2002c).

Several pilot studies have shown the effectiveness of this new technology of using ESO. For example, Altus Air Force Base (AFB) in Oklahoma is the site of a 5,000 foot-long chlorinated solvent plume with TCE concentrations up to 78,000 μg/L (Borden et al. 2002b). Eight months after emulsified soybean oil injection, RD had successfully reduced the TCE concentration by 90% in addition to promoting the reduction of sulfate and iron for abiotic reactions with TCE (Borden and Lee 2002a, Lee et al. 2003a). Another example of emulsified soybean oil (ESO) applied in the field is Dover AFB in Delaware. Permeable reactive barriers were used to inject ESO; after 3 years daughter products are still being produced and TOC levels remain high (www.eosremediation.com 2003). At Edwards AFB in California, emulsified soybean oil has decreased the TCE concentrations 82% at the source, increased daughter product concentrations, and created reduced conditions (Lee et al. 2003b, www.eosremediation.com 2003).

Current Understanding of Process

When ESO is added to contaminated sites, LCFA fermentation produces VFAs, which are used by bacteria as electron donors and/or carbon sources. For example, the fermentation of one of the LCFAs in soybean oil, linoleate ($C_{18}H_{32}O_2$), occurs when two-carbon segments of acetate ($C_2H_4O_2$) are clipped from the hydrophilic tail and hydrogen (H_2) is produced in the following equation:

$$16H_2O + C_{18}H_{32}O_2 \longrightarrow 9C_2H_4O_2 + 14H_2$$

Acetate can then be further oxidized to carbon dioxide (CO_2) and hydrogen in the following equation:

$$C_2H_4O_2 + 2H_2O \longrightarrow 2CO_2 + 4H_2$$

These equations show that 1 mole of linoleate will produce 9 moles of acetate and 36 moles of hydrogen. According to the above equations, 1 g of soybean oil would yield 1.92 g of acetate and 0.18 g of hydrogen. The acetate and hydrogen can are considered reducing equivalents since they contribute to the reduction of more oxidized electron acceptors. In aerobic or mildly-reducing anaerobic aquifers, the more energetically favorable electron acceptors such as oxygen (O_2), nitrate (NO_3^-), iron (Fe^{3+}), manganese (MnO_2^{4+}), and sulfate (SO_4^{2-}) will be sequentially reduced by microorganisms in the following equations:

$$2H_2 + O_2 \longrightarrow 2H_2O$$

$$2H_2 + 2NO_3^- + C_2H_4O_2 \longrightarrow N_2 + 2CO_2 + 4H_2O$$

$$2H_2 + 4Fe(OH)_3 + C_2H_4O_2 \longrightarrow 4Fe^{2+} + 2CO_2 + 10H_2O$$

$$2H_2 + 3MnO_2^{4+} + C_2H_4O_2 \longrightarrow 3Mn^{2+} + 2CO_2 + 4H_2O$$

$$H_2 + SO_4^{2-} + C_2H_4O_2 \longrightarrow H_2S^- + 2CO_2 + 2H_2O$$

Once the more oxidized compounds are exhausted in the surrounding aquifer sediments, TCE will become the most energetically favorable electron acceptor available to bacteria if the aqueous hydrogen concentrations remain low enough. Eventually, the fermentation of the fatty acids will produce hydrogen and/or acetate at concentrations that will stimulate reductive dechlorination to convert TCE (C_2HCl_3) to DCE ($C_2H_2Cl_2$) in the following equations:

$$H_2 + C_2HCl_3 \longrightarrow C_2H_2Cl_2 + Cl^- + H^+$$

$$2H_2O + C_2H_4O_2 + C_2HCl_3 \longleftarrow C_2H_2Cl_2 + Cl^- + 2CO_2 + 2H_2$$

As best determined from the literature, the current practice at chlorothene contaminated sites where ESO is employed as a remediation technology is to inject and then monitor redox conditions or TOC concentrations in wells to determine the need for additional treatments and the effectiveness of ESO to create reducing conditions. Presently, prediction of the sustainability of the organic substrate/carbon donor at ESO sites is limited by our understanding of how the degradation products of ESO stimulate fermentors and dechlorinators to contribute to an actively dechlorinating community. This knowledge gap can be stated through the following questions. What is the sustainability of soybean oil and its degradation products in the subsurface? What VFAs are being produced from the oil degradation? Do certain concentrations of particular VFAs lead to dechlorination? Can a relationship be drawn between VFA concentrations and dechlorination for use in future ESO field applications?

Experimental Objectives

The purpose of this thesis was to conduct a laboratory microcosm study to improve our understanding of the nature and sustainability of fatty acids in solution over time in ESO-treated aquifers. This study is specifically concerned with which VFAs are formed through soybean oil

degradation, how long they last, and which VFAs stimulate dechlorination. The results of this study will indicate how the study site aquifer will respond during a pilot study. The hypothesis is that the ESO fermentation will lead to a change in the aqueous concentration of the LCFAs in soybean oil and the VFAs from fermentation (such as acetate, propionate, and butyrate) for a prolonged period of time and promote reductive dechlorination.

Methods and Materials

Sampling Site

The Naval Weapons Station Charleston in South Carolina contains a chlorinated ethene plume in a surficial aquifer located upgradient from a marsh and the Cooper River. The TCE originates from a cluster of drums on a historical dumping site. The area now consists of new forest trees and shrubs. The site was located off a main road on base next to power lines (Figure 1).

Figure 1: Photographs of Sample Site

A plastic tarp was laid down to pile all the soil brought up by the hand auger (Figure 2). The augering began smoothly, but soon became difficult as the auger reached clay. Finally, after augering to a depth of nine feet, the bottom of the sandy aquifer was breached. Sampling began at a depth of 9.5 feet and continued to a depth of 12 feet (Figure 3). For each sample, a split core sample was attached to a rod. The split core sampler was decontaminated by scrubbing with methanol to remove any aquifer sediment and free product residue. After scrubbing, the sampler was rinsed well with distilled water. Metal liners were sterilized by soaking in 10ppm bleach solution for 10 minutes and rinsing with autoclaved distilled water. The liner was then inserted

into the sampler tube and driven down to the appropriate sampling depth. Once the sampler and rod were fed down the hole, a hammer was attached to the top of the rod. The rod was hammered nine times to drive the sampler into the aquifer sediments. The hammer was removed and the rod was quickly pulled from the hole to maximize sample recovery. After the soil core was obtained, the liner was capped as quickly as possible, weighed, labeled, and placed in an autoclaved mason jar filled with nitrogen. After six sleeve recoveries, enough soil was obtained to construct the microcosms. Next, a pump was set up next to the borehole to obtain groundwater samples. First six 40 mL vials were filled with groundwater for chemical analysis. A bleached, sanitized container was used to collect the groundwater for microcosm construction. The samples were then transported back to the Environmental Engineering Lab at Virginia Tech in Blacksburg, Virginia in coolers with ice.

Figure 2: Photograph of Borehole and Sampling Setup

Depth, feet bgs	Soil	Description
0		Clayey loam
1 2		Brown/orange sandy clay
3 4 5	**Water Table**	Grey/orange clay
		Less orange more grey wet clay
6 7		Blue/grey wet clay
8		Sandy wet clay
9		Tan sand with 30% fines
10 11 12		Sample
		End samping

Figure 3: Borelog of Sample Collection

Microcosm Setup

Flasks for microcosm setup were first washed with soap and water. Next they soaked in an acid bath and were rinsed with deionized water. The flasks were then baked at 350° F for one hour in a muffle furnace. Finally the flasks were autoclaved, placed in the glovebag, and purged with nitrogen. This process was conducted to remove any metal, carbon, microbial, and/or oxygen from the glassware.

To begin microcosm construction, the liners were opened in an anaerobic glove bag where the soil was homogenized. One inch from both ends of a sample was discarded to reduce contamination. Soil used for abiotic microcosms was autoclaved and then allowed to regenerate before autoclaving again. The autoclaved soil was left out for a day or two in between autoclaving cycles to reduce populations of spore-forming microorganisms. While soil for abiotic controls was autoclaved, the remainder of the soil was stored in the glove bag to reduce exposure to oxygen. Once the abiotic soil was sterilized, soil was weighed, and placed into a microcosm. Any groundwater used for abiotic microcosms was also autoclaved and placed in a glove bag to reduce oxygen concentrations.

Approximately 1800 g of soil and 2000 mL of water were needed for the experimental matrix. Sodium azide was added at 0.05% by volume to abiotic microcosms to further inhibit the activity of any microbial populations. Appropriate amounts of water and soil were added to the flasks, and the microcosms were left undisturbed for three days to allow for microbial generation. Next, a TCE spike was added to the appropriate microcosms to obtain a concentration of 115 μM. After another three days, the ESO and lactic acid were added to the appropriate microcosms. All

microcosms were capped immediately with Mininert ™ valves with stopcocks and stored in the dark under black plastic in an anaerobic glove bag (Figure 4).

Figure 4: Photograph of Microcosm Setup in Glovebag

ESO Preparation

Deionized water was autoclaved and allowed to cool before preparing ESO mixture. A graduate student, Kappo, working for Dr. Robert C. Borden at North Carolina State University developed a solution of ESO for use in biostimulation of contaminated aquifers that was used in this study. According to Kappo's study of emulsifiers at North Carolina State University, a solution of 56% glycerol monoleate (GMO) (Lambent Technologies Skokie, Illinois), 38% Tween80, and 6% water when added at 5% to a mixture of 33% food grade soybean oil and 62% water and mixed at high speed for 5 minutes in a Warring blender creates an emulsion with uniformly sized micelles. In the field this solution is pumped down wells into aquifers and then chased with 8 pore volumes of water.

Microcosm Matrix

Eight microcosms in duplicate were created to compare ESO amended, lactic acid amended, emulsified linoleic acid (ELA) amended, unamended, and dead control subsurface anaerobic environments (Table 2). Table 2 delineates the composition of each microcosm constructed for this study. The first column (Name) represents the abbreviated label for each microcosm. The second column (Weight) shows the weight in grams of aquifer sediment added to each microcosm. Columns three (Water), four (ESO), and five (ELA), indicate the volume in milliliters of groundwater collected from the study site, ESO, or ELA supplied to each microcosm. The next column (Lactic Acid) represents how many milliliters of lactate were added to each microcosm. The seventh column (TCE Spike) shows whether or not a microcosm was spiked with TCE. The final column (Microbial Active) indicates whether or not sodium azide and autoclaved soil and groundwater were added to each microcosm.

Table 2: Microcosm Matrix

Name	Weight	Volume, mL				TCE Spike[1]	Microbial Active
	Soil, g	Water	ESO	ELA[2]	Lactate[3]		
1	150	100	100	0	0	Yes	No
1 Dup	150	100	100	0	0	Yes	No
2	150	100	100	0	0	Yes	Yes
2 Dup	150	100	100	0	0	Yes	Yes
3	150	100	100	0	0	Yes	Yes
3 Dup	150	100	100	0	0	Yes	Yes
4	150	100	0	100	0	Yes	Yes
4 Dup	150	100	0	100	0	Yes	Yes
5	150	200	0	0	64.4	Yes	Yes
5 Dup	150	200	0	0	64.4	Yes	Yes
Liquid Control	0	200	0	0	0	Yes	No
LC Dup	0	200	0	0	0	Yes	No
Soil Control	60	80	0	0	0	Yes	No
SC Dup	60	80	0	0	0	Yes	No
6	150	100	0	100	0	Yes	No
7	150	200	0	0	0	Yes	Yes

Notes:
ESO: Emulsified Soybean Oil
ELA: Emulsified Linoleic Acid

[1]: Spike Concentration: 115 μM

[2]: Emulsified solution of linoleate with 17.5 mL linoleate instead of 35 mL soybean oil. Linoleate is 50% of soybean oil by weight

[3]: Volume based on weight of H in linoleate added

The dead ESO amended spiked microcosms were constructed to show that in the absence of bacteria, no fermentation or dechlorination takes place (Microcosms 1 and 1Dup). The live ESO amended spiked microcosm represented an example of an ESO injected aerobic aquifer (Microcosms 2 and 2Dup). The live ESO amended half-spiked microcosms contained one-half the bottle concentration (7.5 mg/L) of the spiked microcosms to determine if chlorinated ethenes demonstrated any inhibitory factors on fermenting bacteria (Microcosms 3 and 3Dup). The live ELA amended spike microcosm was set up with the same concentration of linoleic acid present in the other ESO amended microcosms to indicate if fermentation products were specific to the LCFA added to the system (Microcosms 4 and 4Dup). Lactic acid amended microcosms were designed to compare a typical carbon donor to the LCFAs (Microcosms 5 and 5Dup). The dead ELA amended spiked microcosm was constructed to show microorganisms are fermenting ELA (Microcosm 6). The live unamended spiked microcosm was set up to show that microbial dechlorination could be attributed to the amendment addition (Microcosm 7). Finally, liquid and soil controls were designed to account for any sorption or head space losses of chlorinated ethenes (Microcosms LC, LCDup, SC, and SCDup).

Volatile Fatty Acid Analysis

Before the microcosms could be constructed, a method for LCFA and VFA detection needed to be determined. Although many wastewater methods exist for the qualification of VFAs, most detection limits are not low enough for this study. Because this study aimed to examine any relationship between the VFAs produced from LCFA degradation and dechlorination, the VFA method required detection limits as low as 1ppm. After many different instruments and methods

had been tested, a Nukol column documented in experiments at Cornell University by Sin Chit To (2001) proved ideal for the experimental objectives.

Weekly 0.25 mL samples were taken from the clean liquid phase of the microcosms before mixing to monitor VFA production, specifically acetate, propionate, isobutyrate, butyrate, isovalerate, valerate, caproate, hexanoate, and heptanoate. Each sample was placed in a 2 mL amber target vial with a glass 250 μL insert and then analyzed that day on a Hewlett-Packard 5890 gas chromatograph (GC) with flame ionization detector (FID). GC analysis required a flow of 17 mL/min through a Supelco Nukol Fused Silica Capillary Column 15 m x 0.53 mm x 0.5 μm film thickness, a 45 mL/min helium flow, a 450 mL/min air flow, and 13 mL/min nitrogen (makeup gas) flow. The temperature program started at 100º C, ramped up to 154º C over an 11 minute period, and finally ended at 154º C at 12 minutes. The detection limit for the VFAs is 0.016 mM.

Iron (II) Analysis

Groundwater samples collected from the site trip were analyzed for ferrous iron (Fe^{2+}). First, 0.1 mL of sample was diluted with 0.3 mL of nanopure in a test tube. Then 3.6 mL of ferrozine solution was added to the solution and the test tube was shaken. The sample was poured into a couvette and analyzed with a Hach DR 2010 Spectrophotometer with a wavelength of 562.0.

Cation and Anion Analysis

Twice samples were gathered for cation and anion analysis, one initial sample from the site trip and once during the course of the experiments. Cations were analyzed using a Dionex D-120 Ion Chromatograph (IC) (Dionex Corporation, Sunnyvale, California) with CS-12 column and

conductivity detection with self-generating suppression of the eluent. The eluent used was 20 mM methanesulfonic acid with a flow rate of 1 mL/min. Anions were analyzed with the Dionex DX-300 IC on an Ion Pac AS-14 column.

Mixing Procedure

After VFA sampling, each microcosm was shaken vigorously and allowed to settle for approximately fifteen minutes while the supplies for sampling were gathered. Once all the sampling materials were introduce to the glove bag, each microcosm was turned and over-ended twice and then a liquid sample was collected.

Long Chain Fatty Acid Analysis

Unfortunately, the LCFAs could not be as easily analyzed. Due to the low solubility and volatility of LCFAs, they are difficult to quantify without extraction procedures. After looking into different columns, analysis tools, and various articles, fatty acid methyl esters (FAMEs) were concluded to be the best derivation for analysis. The American Oil Chemists Society (AOCS) and American Society for Testing Materials (ATSM) standard method for derivation of LCFAs to FAMEs involves rapid saponification of oil with methanolic sodium hydroxide followed by boiling with boron trifluoride-methanol (BF_3-MeOH). Due to high costs, another method was tested that used hydrochloric acid in methanol as an esterification reagent instead of BF_3-MeOH to reduce costs and analysis time (Jham et al. 1982). Once the proper derivitization technique was established, the Nukol column used for VFA analysis was also found to analyze FAMEs.

Weekly 0.25 mL samples were taken from the shaken microcosms to monitor LCFA degradation over time. The five main components of soybean oil, palmitate, stearate, oleate, linoleate, linolenate, and arachidate were monitored. Each sample was placed in a 13 mm x 8 cm borosilicate glass test tube to extract fatty acid methyl esters (FAMEs). To begin the extraction, 1 mL of 0.5 M potassium hydroxide (KOH) in methanol (MeOH) was added to each sample. Next, the test tubes were placed in a heating block at 100º C. After 5 minutes the test tubes were removed from the heating block and allowed to cool to room temperature. Then, 400 μL of 0.5 N hydrochloric acid (HCl) in MeOH was added to each test tube. The test tubes were placed back in the heating block at 100º C for 15 minutes. After the test tubes cooled to room temperature, each sample was extracted with 3 mL of petroleum ether. The petroleum ether was removed from the test tube with a Pasteur pipette and placed in a 2 mL amber target vial. The target vials were placed in the 4º C room until GC with FID utilizing the Nukol column analysis was run approximately every four weeks. The gas flows through the column were the same as the VFA method. The temperature program started at 80º C, after two minutes the temperature increased 10º C/min, 90º C was held for 3 minutes and then increased 10º C/min, 100º C was held for 6 minutes, then the temperature ramped to 200º C over a 12.5 minute period, and ended at 200º C at 30 minutes. The detection limit for the FAMEs is 5 μM.

Total Carbon Analysis

Weekly 0.2 mL samples were taken from shaken microcosms to monitor total carbon (TC) levels over time. Amber target vials were prepared before sampling with 0.8 mL of acidified nanopure water. During sampling, 0.2 mL of sample was added to 0.8 mL acidified nanopure water and placed in the 4º C room until analysis on a TOC analyzer Dohrman Model DC 80 (Santa Clara,

California). TC analysis was performed approximately every four weeks. The detection limit for the TOC analyzer is 0.5 mg/L.

Chlorinated Ethenes Analysis

Weekly samples were taken from shaken microcosms to monitor the chlorinated ethenes, TCE, cis-DCE, and VC. Depending on the microcosm and time of the experiment between 0.2 and 2 mL of sample was removed from the microcosm and diluted into 5 mL before being injected on a Tekmar 3000 Purge and Trap Concentrator (Tekmar Company, Cincinnati, Ohio) that fed into a Tremetrics 9001 GC (Tremetrics Incorporated, Austin, Texas) with a Tracor 1000 Hall detector (Tracor Instruments, Austin, Texas). To begin each sampling event, each glass borosilicate test tube from the 16 port Tekmar autosampler Model 2016 was washed with soap and water and allowed to dry. Once each clean test tube was installed on the autosampler, 5 mL of sample was injected into each port and purged with helium for 11 minutes. The chlorinated ethenes were concentrated in a Tenex/silica gel/charcoal trap (Tekmar trap number 3). After purging was completed, the trap was heated to 225º C. Once the 10 minute trap bake at 225º C began, helium carried the chlorinated ethenes at 25 mL/min to the GC with a RTX-volatiles megabore capillary column (Resteck, Bellefonte, California). The temperature program for chlorinated ethene separation began by holding 35º C for 5 minutes then continued with two temperature ramps by raising 6º C/min to 95º C and then 25º C/minute to 225º C. The Hall detector operated at 842º C with a hydrogen flow of 25 mL/min. The detection limit for chlorinated ethenes is 0.04 μM.

Methane and Carbon Dioxide Analysis

The headspace gases methane and carbon dioxide were measured with a Shimadzu model Gas Chromatograph-14A GC (Shimadzu Scientific Instruments, Columbia, Maryland) with a thermal

conductivity detector (TCD). The column was a 4m copper tube with 0.25 inch inner diameter packed with HaysepQ media (Supelco, Bellefonte, Pennsylvania) and coiled to fit into the GC-14 oven. Helium was the carrier gas with a flow rate of 17 mL/min.

Complex Emulsion

When the microcosms were first constructed, a milky, white liquid (a mixture of emulsion and groundwater) formed on top of the aquifer sediment. Once the microcosms were shaken vigorously multiple times, the contents of the microcosm changed from two to three phases (Figure 5). A tan murky layer formed in between a layer of clear water and the aquifer sediment. Once microcosms 2, 2D, 3, 3D, 4, and 4D had reached reduced conditions, the aquifer sediments and the murky middle layer turned grey. This complex emulsion complicated sampling and analysis of the microcosms.

When sampling for VFAs, only the upper clear phase of the groundwater could be collected to allow for the direct injection of the emulsion into the GC. Filtering, acidifying, and storing the samples caused significant losses in VFA concentration. Filtration of the emulsion also proved ineffective. A sample filtered through a 0.25 μm filter produced a milky white filtrate, proving some emulsion clearly passed through the filter. Filtering also caused problems when attempting to analyze for iron, cations, and anions because emulsion would contaminate the filtrate.

The TC analysis had problems similar to the VFA analysis. TC analysis was performed to compare data with a similar study done by Dr. Robert Borden at North Carolina State University. When the 2mL storage vials were mixed prior to injection, the TOC analysis would work for about eight samples and then stop working. The emulsion and clay in the sample contained

complex carbon which caused the TC machine to time out and required over 30 minutes to return to baseline. Since the VFA concentrations were assumed to be the significant source contributing to bioavailable carbon concentrations, the emulsion was allowed to settle before the sample was taken to be injected. The NC State study used sand columns which should have produced clear samples because the sand would filter the emulsion.

Since the VFAs were deemed important to the carbon data, each sample was not purged with oxygen before injection. The oxygen purge in typical TOC measurements releases all the inorganic carbon from the sample, which is why this analysis is TC instead of TOC. Because the VFAs would have volatilized during the oxygen purge, the purge was eliminated from the analysis procedure. The purge also created problems with the emulsion because it created bubbles in the vial and caused sample to escape out the top of the vial.

When sampling for LCFAs, chlorinated ethenes, and TC, each sample was measured in a gas tight glass syringe after vigorous shaking to suspend the DNAPL, emulsion, and sediments. Because the emulsion contained clay from the aquifer sediments, the disposable hypodermic needles attached to the lure-lock syringe would become clogged. This led to small volume losses in each of the microcosms containing emulsion as well as a prolonged settling time prior to sampling. By allowing the microcosms to settle longer the needles clogged less often. Unfortunately this may have caused some chlorinated ethene levels to appear lower then they actually were. In addition to clogging, the emulsion created other problems related to the act of sampling.

Since the emulsion reassembled a soapy mix of oil, water, and soil, getting an accurate volume was difficult. The saponification of the emulsion created tiny bubbles and foam when attempting to read the syringe without head space. In addition, the opaqueness of the emulsion made reading a meniscus difficult. Because the LCFAs, chlorinated ethenes, and TC samples were all eventually diluted, the error in sample volume measurement led to some discrepancy and even larger error in the final data outcome.

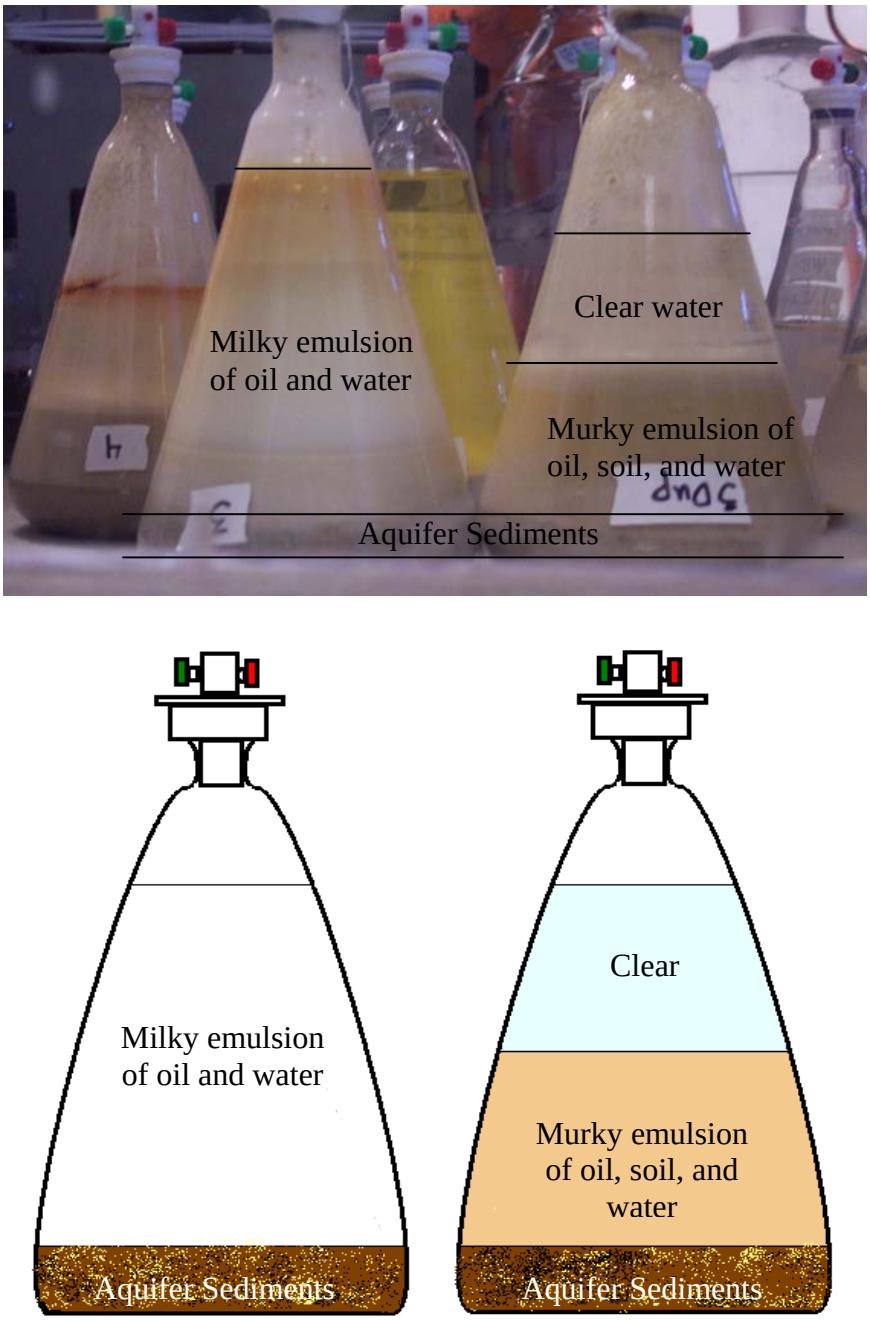

Figure 5: Photograph and Illustration of Two and Three Phase Microcosm

Results and Discussion

The microcosms were monitored over a 250-day period primarily for LCFA, VFA, TC, and chlorinated ethene concentrations. Over the course of the study, chlorinated ethenes, VFAs, LCFAs, and TC concentrations were monitored to better understand the changes in fatty acid, chlorinated ethene, and carbon concentrations in aquifer sediments following ESO injection. The presence of ESO in an aerobic subsurface environment should have created reducing conditions ideal for reductive dechlorination through the fermentation of LCFAs. LCFA concentrations were monitored to show any decrease in concentration to indicate LCFA fermentation. Production of VFAs indicated that fermentation was taking place and the aquifer sediments were becoming reduced. Once the microcosms became reduced, the dechlorinating colonies should begin creating chlorinated ethene daughter products. Cations, anions and iron were analyzed to determine initial groundwater conditions before the experiment began. Cations and anions were analyzed once more during the course of the experiment to determine any changes in groundwater chemistry. TOC was monitored to compare values with a similar study at NC State University. The chlorinated ethene concentrations were monitored to determine if dechlorination was occurring. The decline in TCE concentrations without a corresponding formation of daughter products made the determination difficult.

To determine if the daughter products were being produced, but undetectable with the current method in the microcosm, a spike occurred on day 158 of the study. The microcosms were opened to add additional groundwater to makeup for head space losses during sampling and test for pH to ensure none of the VFA production had lead to acidic conditions. The microcosms were respiked with TCE to bring bottle concentrations back up to 15 mg/L, since the additional

groundwater would dilute the TCE. A cis-DCE spike was added to the duplicate of each microcosm to determine the fate of daughter products in solution.

First-order rates were determined for each microcosm and summarized in Table 3. The first column, Microcosm, contains the ID given to each microcosm in the experimental setup. The next two columns show the first-order utilization rate, k (day^{-1}), for acetate and TCE during the first 100 days of the experiment. Columns 4, 5, and 6 show the k values for acetate, TCE, and cis-DCE after the addition of TCE and cis-DCE to the microcosms on day 158 through the end of the study on day 250. The remaining columns indicate the specific compounds that were added to each microcosm. The graphs depicting the trend lines are located in Appendix A: Supporting Data.

The microcosms presented below in Figures 6-14 represent the best example from each set of duplicates in the order laid out in Table 2 and Table 3. Both microcosms in each set appeared to have similar results, although there was some variation in the VFA produced and concentrations of VFAs and chlorinated ethenes. The duplicate data along with all the tabulated data values are located in Appendix A: Supporting Data.

Table 3: Comparison of Utilization Rates for all Microcosms

Microcosm	First order rates, day^{-1}					Microcosm Additions					
	Acetate[1]	TCE[1]	Acetate[2]	TCE[2]	cDCE[2]	ESO	ELA	Lactic Acid	TCE	cDCE	Live
1	-0.0315	-0.0192	-0.0320	0.0026		X			X		
1D	-0.0416	-0.0106	-0.0150	0.0045	0.0154	X			X	X	
2	-0.0435	-0.0303	0.0077	0.0093		X			X		X
2D	-0.0126	-0.0080	-0.0409	0.0084	0.0092	X			X	X	X
3	-0.0185	-0.0286	-0.0119	0.0079		X			X		X
3D	-0.0846	-0.0110	-0.0068	0.0039	-0.0146	X			X	X	X
4	0.0040	-0.0135	-0.0081	-0.0032			X		X		X
4D	-0.0161	-0.0312	-0.0069	0.0006	-0.0114		X		X	X	X
5	-0.0298	-0.0318	-0.0098	-0.0152				X	X		X
5D	-0.0305	-0.0401	-0.0051	-0.0163	-0.0141			X	X	X	X
6	-0.1208	-0.0282	-0.0200	-0.0076			X		X		
7	-0.0860	-0.0220	-0.0355	-0.0198	-0.0186				X	X	X
LC	0.0063	-0.0084	-0.0398	-0.0083					X		
LCD	-0.0071	-0.0135	-0.0374	-0.0076	-0.0073				X	X	
SC	-0.0114	-0.0091	-0.0284	-0.0138					X		
SCD	-0.0076	0.0013	-0.0186	-0.0128	-0.0070				X	X	

Notes:

[1]: Values from days 0-100

[2]: Values from days 150-250

Dead ESO Amended Spiked Microcosm (Microcosm 1)

The dead ESO amended spiked microcosm (Microcosm 1) was designed to account for any abiotic degradation of LCFAs and chlorinated ethenes. The LCFA concentration data remained relatively constant throughout the course of the experiment (Figure 6). The amended microcosms all experienced some fluctuation in the LCFA data, but this scatter is due to dilution and sampling difficulties. Although some acetate does appear over the course of the study, these trace levels are most likely due to build up on the column. Over the first 100 days, a decline in TCE concentrations occurred at a rate of -0.0192 day^{-1}. This decline in TCE concentrations corresponds to a decline in the trace levels of acetate at a rate of -0.0315 day^{-1}. The rate of TCE decline is lower than live microcosms and most likely represents the rate of TCE partition into the ESO and headspace. The rate of acetate decline is faster than the live microcosms, but represents concentrations an order of magnitude lower than actively fermenting microcosms and most likely represents some contamination from the column during analysis. After the respike of TCE, the TCE concentrations gradually increased over time at a rate of 0.0026 day^{-1} increase that corresponded to a decline in acetate at a rate to similar to the first 100 days of -0.032 day^{-1}. The low concentrations of VFAs in addition to the low decay rates for TCE indicate that this microcosm did not experience any fermentation or dechlorination.

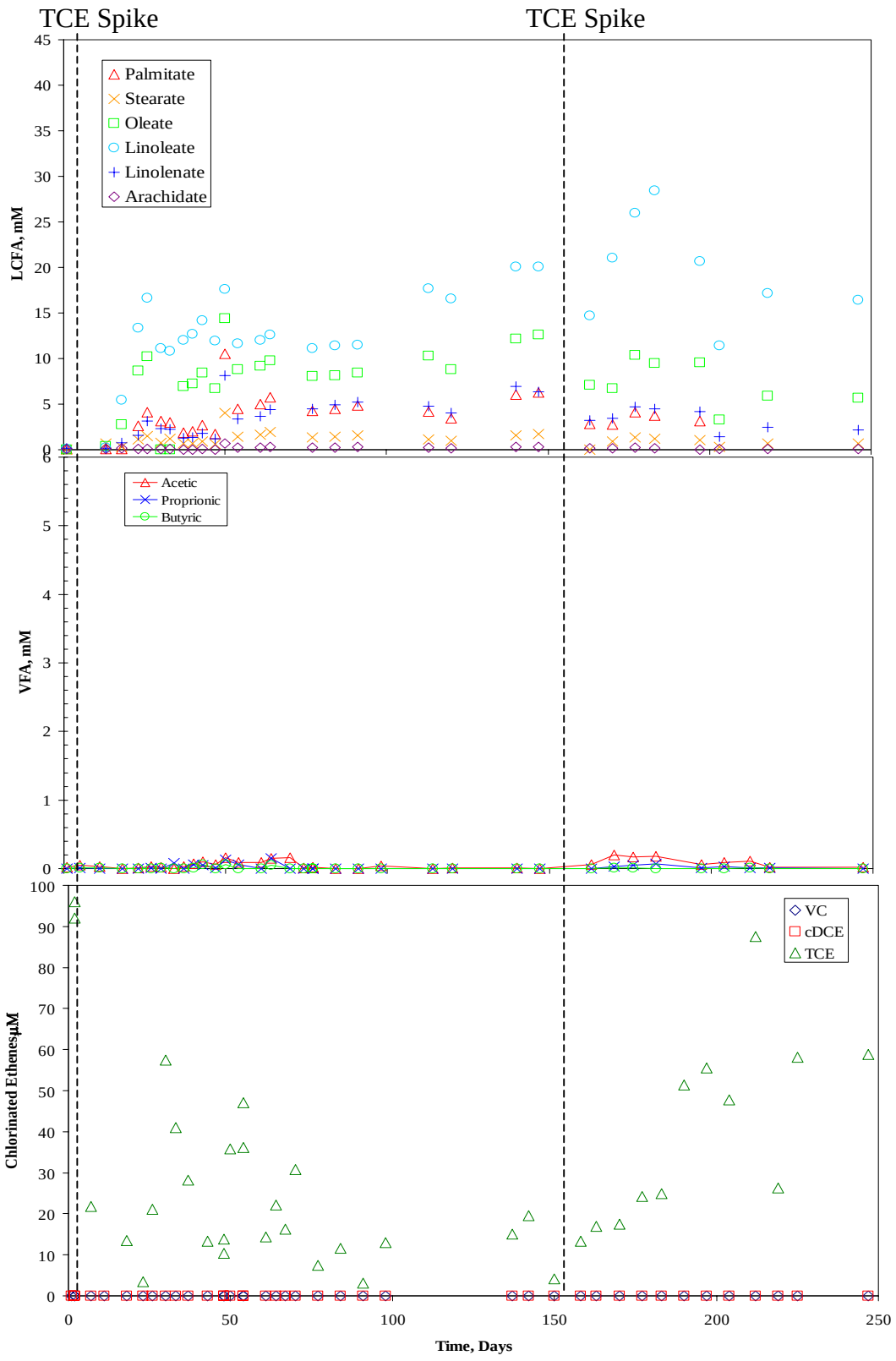

Figure 6: Dead ESO Amended Spiked Concentration Data (Microcosm 1)

Live ESO Amended Spiked Microcosm (Microcosm 2)

The live ESO amended spiked microcosm (Microcosm 2) provides an example of an ESO injected aerobic aquifer. The LCFA concentration data for Microcosm 2 remained fairly constant (Figure 7). Acetate and butyrate production began around day 50. Acetate peaked around day 60 at 2.7 mM and subsequently declined until day 100. Later around day 150, acetate concentrations again began to increase and continued to climb to about 4 mM at the end of the study, day 250. Butyrate peaked close to day 80 at 2 mM and also declined until day 100. Butyrate also recovered from this decline, but at a lower concentration, less than 2 mM, throughout the study period. Around day 140, microcosm 2 began producing isobutyrate and hexanoate. The isobutyrate concentration increased until it surpassed acetate at day 225 at 4.5 mM. The hexanoate concentrations remained steady and low at around 0.3 mM throughout the course of the experiment. TCE peaked after the initial spike and steadily declined without any indication of daughter product formation. Even though no daughter products were detected, a decline in TCE concentrations at a rate of -0.0303 day^{-1} along with the decline in acetate at a rate of -0.0435day^{-1} indicates some acetotrophic dechlorination may have occurred during the first 100 days of the study. After the second addition of TCE no daughter products were observed and TCE appeared to remain constant. This microcosm showed that ESO injection leads to fatty acid fermentation after a 50 day lag period and perhaps dechlorination as well.

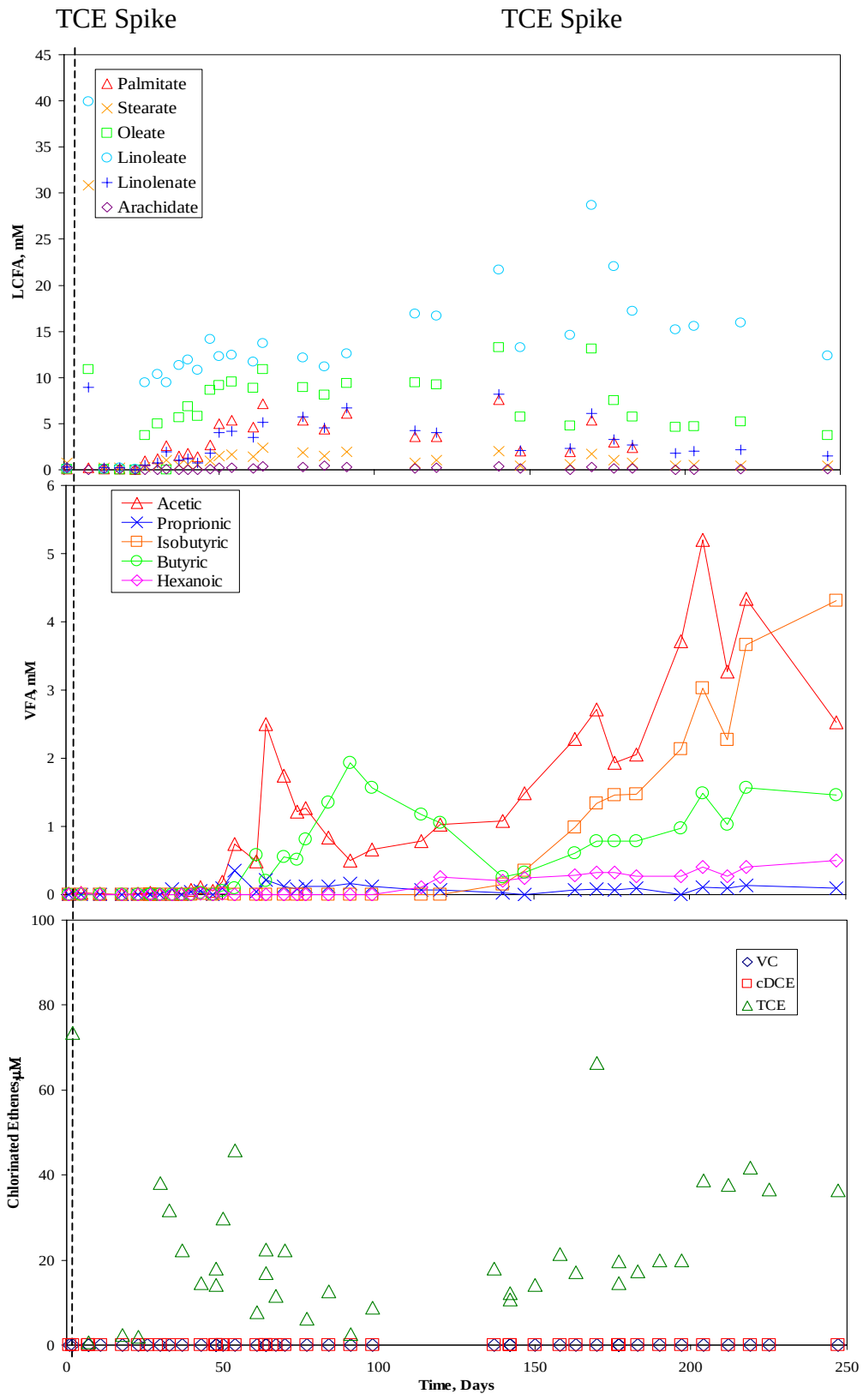

Figure 7: Live ESO Amended Spiked Concentration Data (Microcosm 2)

Live ESO Amended Half-Spiked Microcosm (Microcosm 3)

The live ESO amended half-spiked microcosms were to determine if chlorinated ethenes had an inhibitory effect on fermentation. Microcosm 3 contained half the concentration of TCE added to other spiked microcosms, approximately 57 μM. The LCFA data for Microcosm 3 followed a similar trend to other ESO amended microcosms (Figure 8). Similar to Microcosm 2, Microcosm 3 began producing acetate and butyrate around day 40, but did not peak and subsequently decrease. Instead acetate and butyrate continued to climb to about 5 mM on day 160, after which both fatty acids appeared to decline slightly. Similar to Microcosm 2, hexanoate production began around day 160 and increased to 1.5 mM at day 250. A decline in TCE concentrations at a rate of -0.0286 day^{-1} corresponded to a slight decline in acetate concentrations at a rate of -0.0185 day^{-1}. The loss rate for TCE is greater than the rate calculated for Microcosm 1 indicating that dechlorination may be occurring. However, the TCE concentrations remained fairly constant within error margins after the respike of TCE on day 158 and did not produce any detectable daughter products. The production of VFAs at concentrations similar to Microcosm 2 indicates that high levels of chlorinated ethenes (115 μM) were not more inhibitory to fermentation than concentrations of 60 μM.

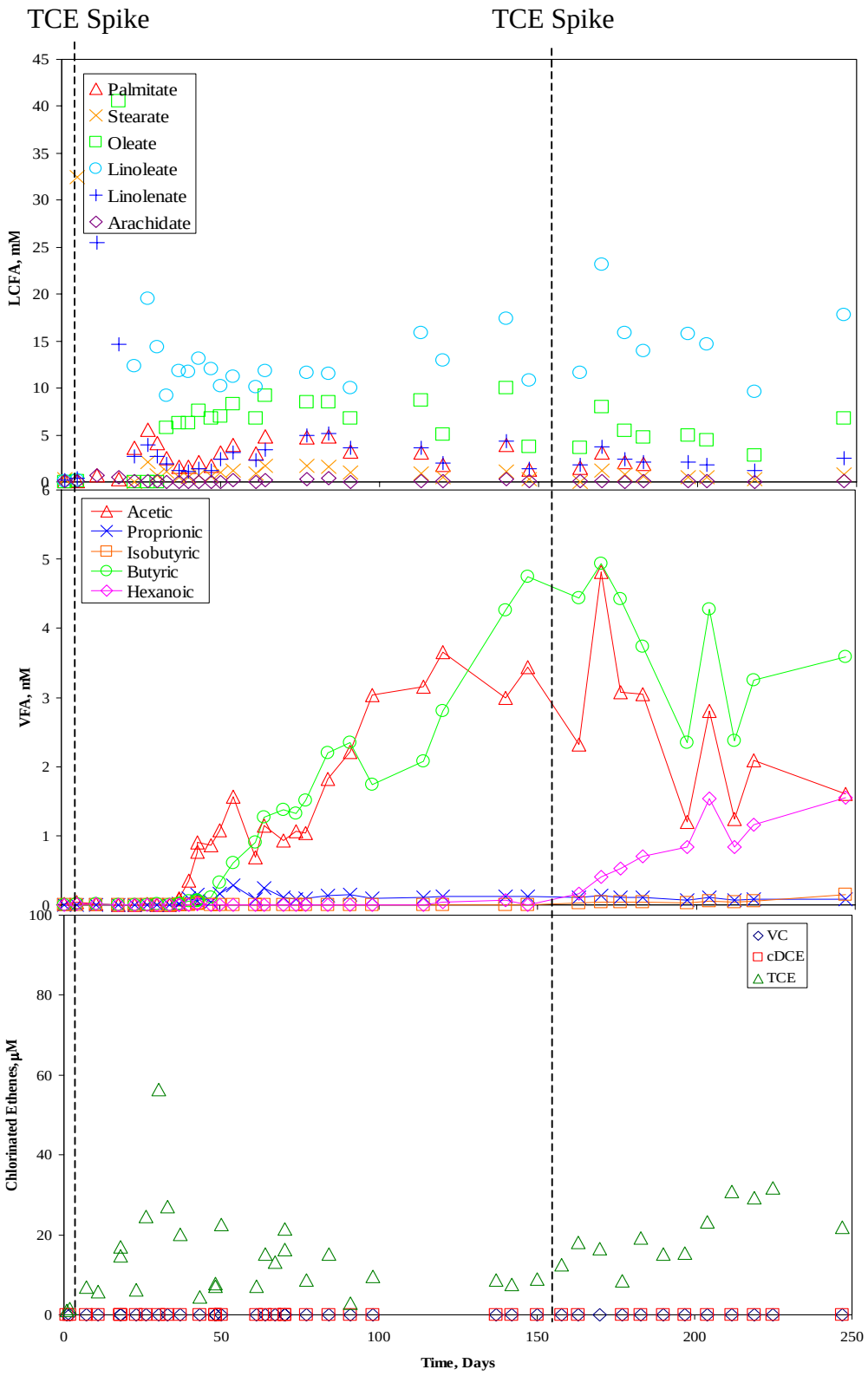

Figure 8: Live ESO Amended Half-Spiked Concentration Data (Microcosm 3)

Live ELA Amended Spiked Microcosm (Microcosm 4Dup)

The live ELA amended spiked microcosms were setup with the same concentration of linoleic acid found in the other ESO amended microcosms to determine if fermentation products were specific to the LCFA added to the system. The LCFA concentrations were similar to the other amended microcosms, except that linoleate was the only the LCFA added (Figure 9). Acetate and butyrate production began around day 40, but butyrate concentrations were much lower than for the ESO amended microcosms. Similar to Microcosm 2, the acetate peaked at day 60 with 1.5 mM in Microcosm 4Dup. This peak and decline in acetate at a rate of -0.0161 day^{-1} corresponded to a noticeable decline in TCE concentrations at a rate of -0.0312 day^{-1}, a rate greater than the corresponding dead Microcosm 6, indicating that dechlorination may have taken place. In addition, small peaks of cDCE appeared on chromatograms during chlorinated ethene analysis. Another peak in acetate concentration occurred on day 160 at 3 mM and declined to 2 mM at day 250 at a rate of -0.0069 day^{-1}. This decline also corresponds to a decline in cis-DCE concentrations at a rate of -0.0114 day^{-1}, similar to the decline noted in TCE earlier in the experiment, except this time, TCE concentrations declined at a low rate of 0.006 day^{-1}. Since the rates of decline were greater than the rates in dead microcosms, this decline in cis-DCE indicates some dechlorination occured. This microcosm showed that the different LCFAs that make up soybean oil ferment to produce VFAs. In this case, linoleic acid produced lower levels of acetate compared to ESO. The concentration of acetate is also approximately half that produced in Microcosm 2. This indicates that by using one-half the composition of soybean oil, only one-half of the VFAs will be produced.

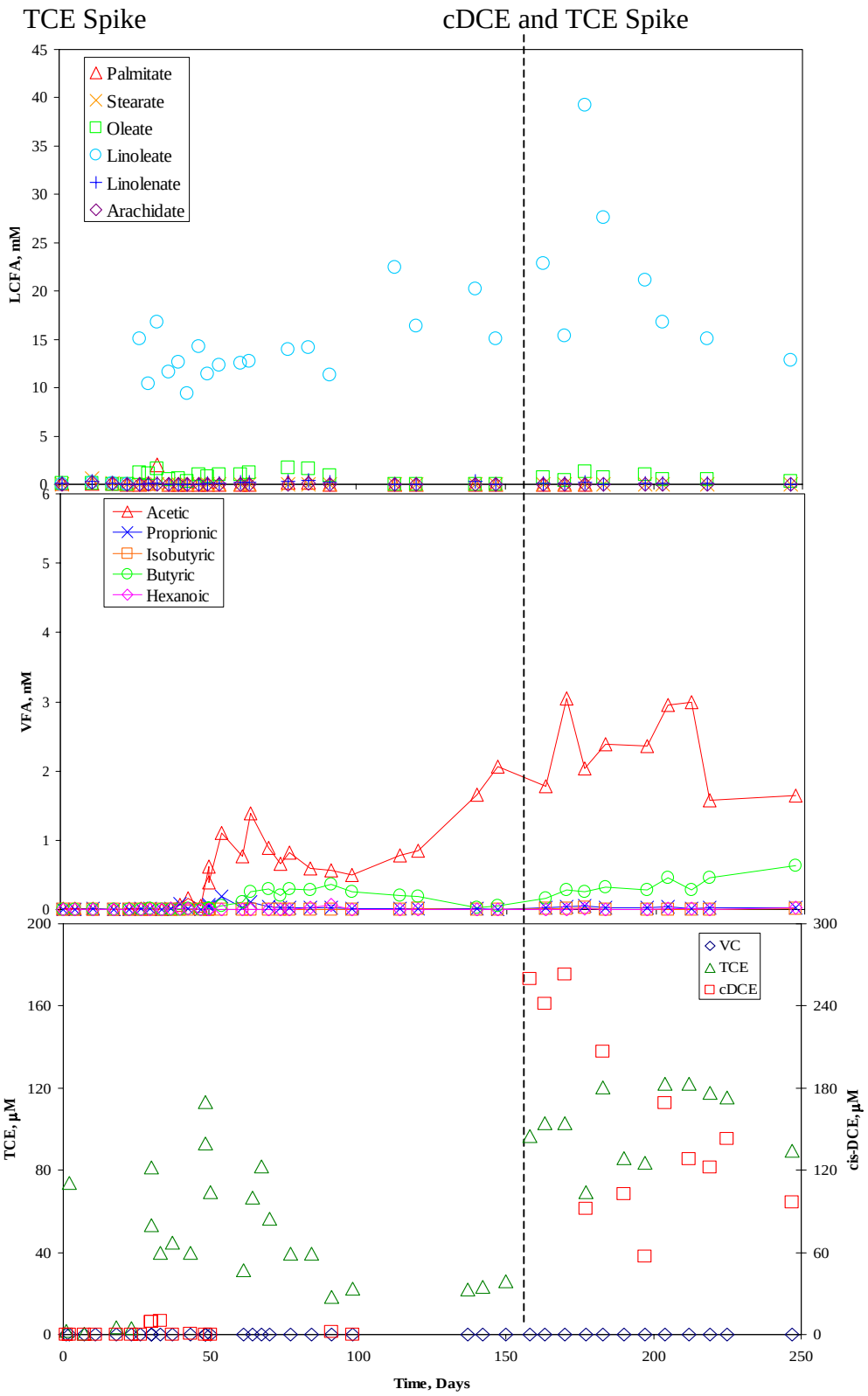

Figure 9: Live ELA Amended Spiked Concentration Data (Microcosm 4Dup)

Live Lactate Amended Spiked Microcosm (Microcosm 5)

The live lactate amended spiked microcosms were designed to compare a typical carbon donor to the ESO. Therefore, lactate was added instead of ESO. No LCFAs were detected in Microcosm 5 (Figure 10). Acetate levels rose immediately (day 2) to 5 mM and remained high throughout the course of the experiment. A decline in acetate at a rate of -0.0298 day^{-1} and beginning around day 50 corresponded to a decline in TCE concentrations at a rate of -0.0318 day^{-1} during the first 100 days of the experiment. This appears to indicate that some acetotrophic dechlorination occurred, because this TCE decline rate is greater than for the control microcosms. Another slight decline in acetate at a rate of -0.0098 day^{-1} corresponded to a decline in TCE concentrations at a rate of -0.0152 day^{-1} after the microcosm was respiked with TCE on day 158; however, the rate of TCE decline is approximately the same as rates calculated for the control microcosms. This microcosm showed that lactate fermented quickly and produced only acetate. This lack of variation in VFA production lead to acidic conditions (pH 2), even though the acetate concentrations are similar to those generated in Microcosm 2.

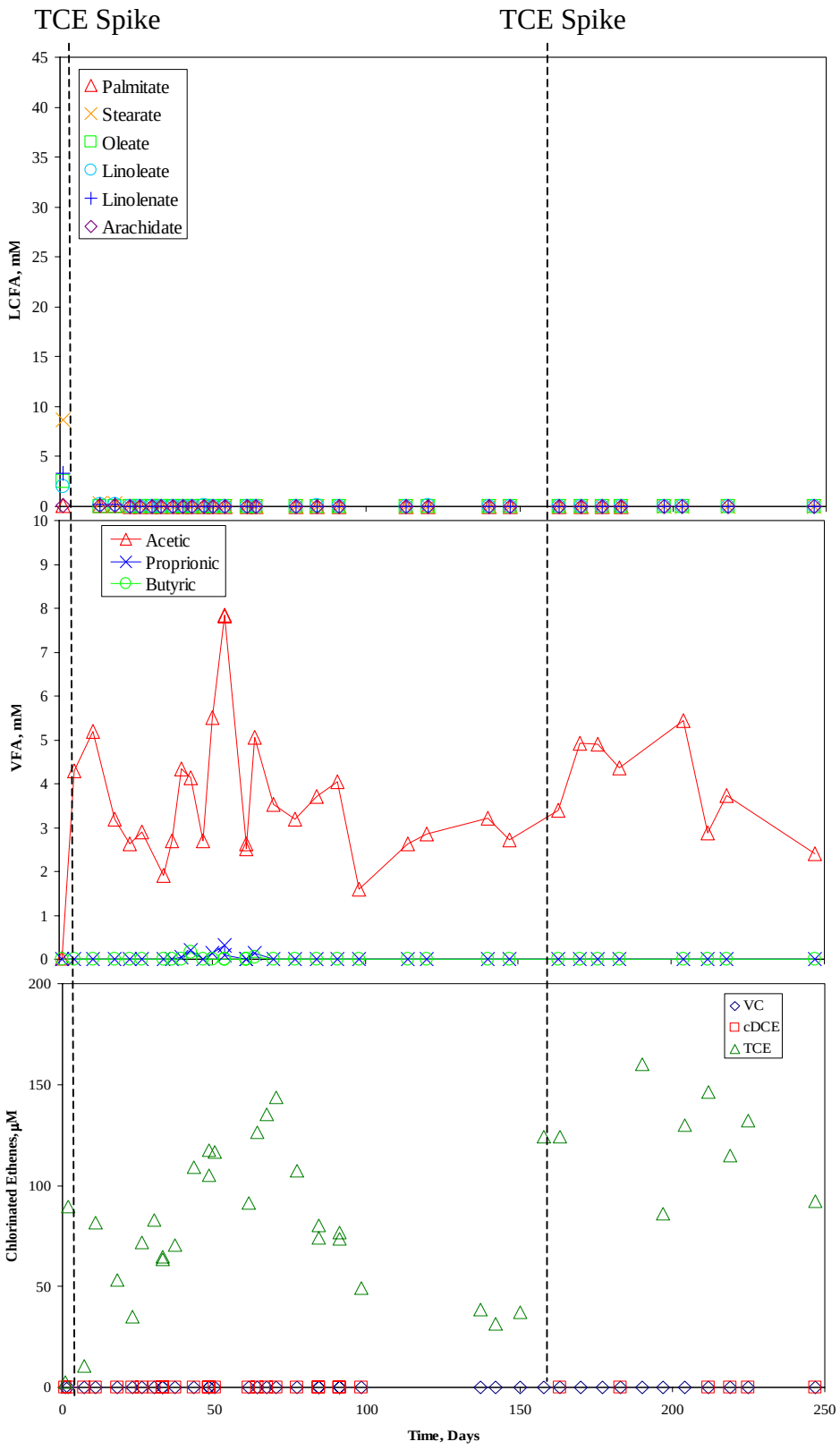

Figure 10: Live Lactate Amended Spiked Concentration Data (Microcosm 5)

Dead ELA Amended Spiked Microcosm (Microcosm 6)

The dead ELA amended spiked microcosm was to show microorganisms are fermenting ELA by comparing the results to Microcosm 4Dup. The linoleate concentrations were similar to other amended microcosms (Figure 11). Some acetate was produced at levels below 1 mM on days 50 and 175 and decline at rates equal to -0.1208 day^{-1} and -0.02 day^{-1}, respectively. The acetate production is most likely due to contamination on the GC column. The first acetate peak before the respike, corresponded to a peak and decline in TCE concentrations at a rate of -0.0282 day^{-1}; however, this rate of decline for TCE is low and closer to control microcosm rates than active microcosm rates. After the respike of TCE on day 158, TCE levels remained constant at a rate of -0.0076 day^{-1}. This shows that no abiotic fermentation and dechlorination took place, indicating that all the fermentation and dechlorination in Microcosm 4Dup are biological processes.

Live Unamended Spiked Microcosm (Microcosm 7)

The live unamended spiked microcosm was setup to show that microbial dechlorination could be attributed to the amendment addition. This microcosm did not contain any amendments; therefore no LCFAs appear throughout the course of the experiment, except for some minor contamination in the GC column at the beginning of the experiment (Figure 12). Similar to Microcosm 6, the acetate in Microcosm 7 peaked at days 50 and 175 and declined at a rate of -0.086 day^{-1} and -0.0355 day^{-1} respectively which is most likely due to GC column contamination because the concentrations are below 1 mM. The decline rates in the chlorinated ethenes before and after the spike of TCE and cDCE are closer to control values than active microcosm rates. This microcosm showed that ESO and ELA amended microcosms created greater rates of decline, in TCE and cis-DCE compared to controls.

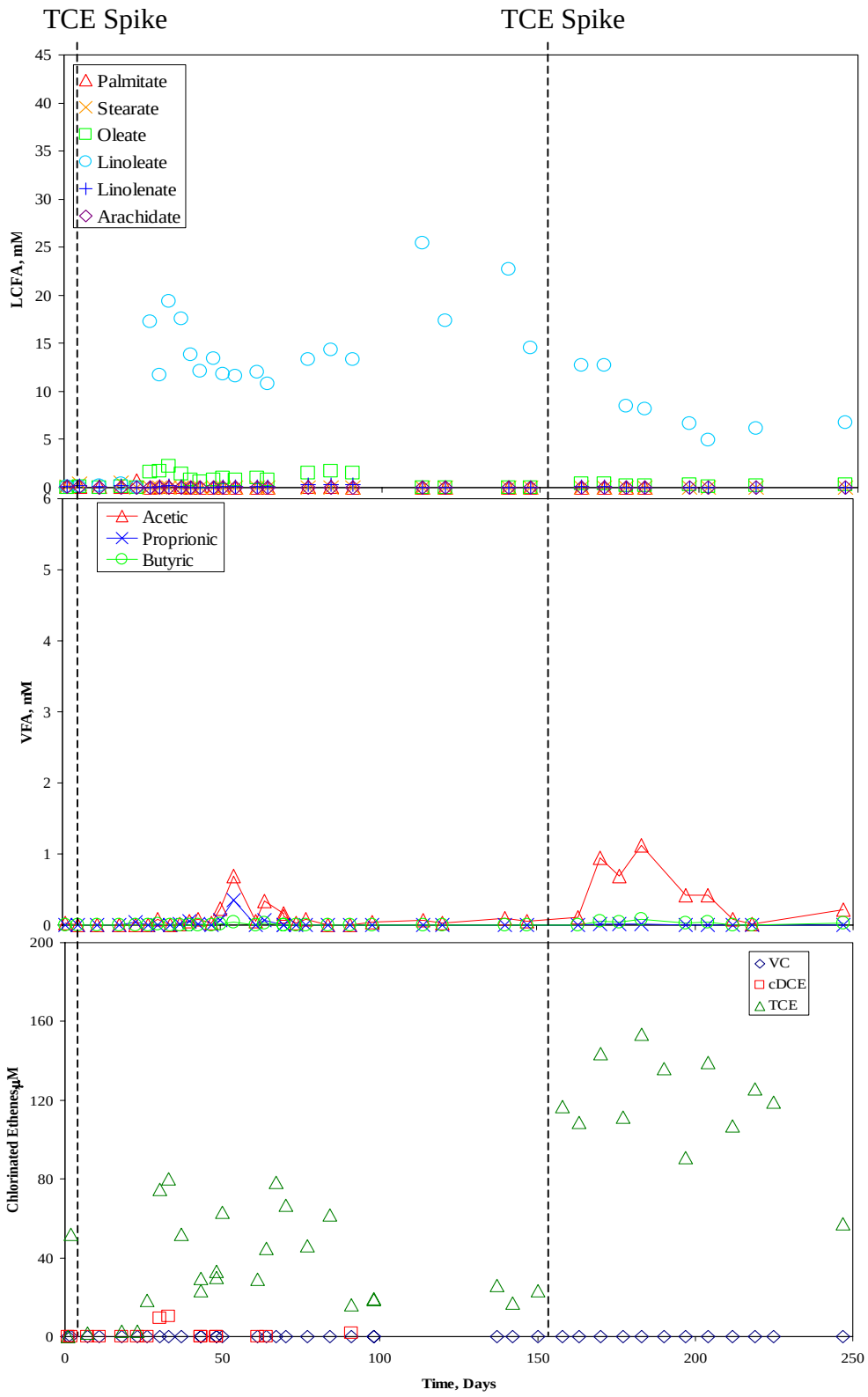

Figure 11: Dead ELA Amended Spiked Concentration Data (Microcosm 6)

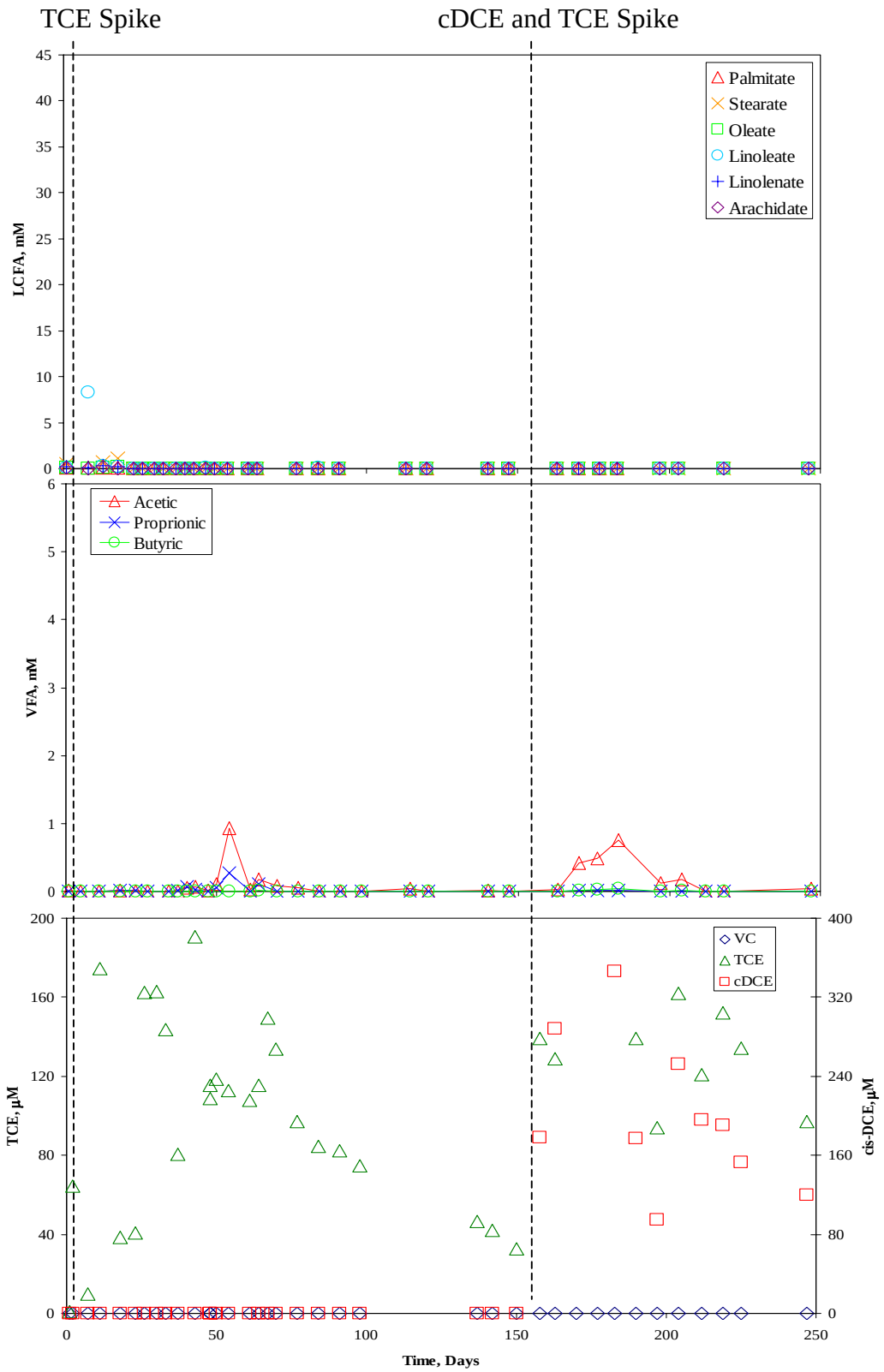

Figure 12: Live Unamended Spiked Concentration Data (Microcosm 7)

Liquid and Soil Control Microcosms (Microcosms LC, LCDup, SC, and SCDup)

The dead unamended spiked microcosms (Microcosms LC, LCDup, SC, and SCDup) were designed to measure sorbtion or head space losses of volatile compounds. The four control microcosms constructed to compare to active microcosms were expected to maintain constant levels of chlorinated ethene, LCFA, and VFA. Although some low concentrations of VFAs appeared in the data, the dead and/or unamended microcosms did not produce any VFAs above general baseline levels (Figures 13 and 14). The program that integrates the data from the GC extrapolates points below the lowest point on a calibration curve. The column used in VFA analysis also required an over-night baking out procedure every couple of months because trace amounts of some VFAs would build up on the column.

In addition to scatter in the data described earlier in the Method Development section, some chlorinated ethene losses can be attributed to head space and sorption losses. The rate of decline in the liquid controls for TCE equaled -0.0135 day^{-1} for days 0-100, and -0.0076 day^{-1} after the respike. The rate of decline for cDCE was -0.0073 day^{-1}. The chlorinated ethene concentrations remained constant in the soil controls with TCE loss rates before and after the respike of 0.0013 day^{-1} and -0.0128 day^{-1} respectively, with a cDCE decay rate of -0.007 day^{-1}. These rates of decay are lower than the active microcosms which indicate that some dechlorination may have occurred in all the biologically active microcosms (Microcosms 2, 3, 4Dup, and 5).

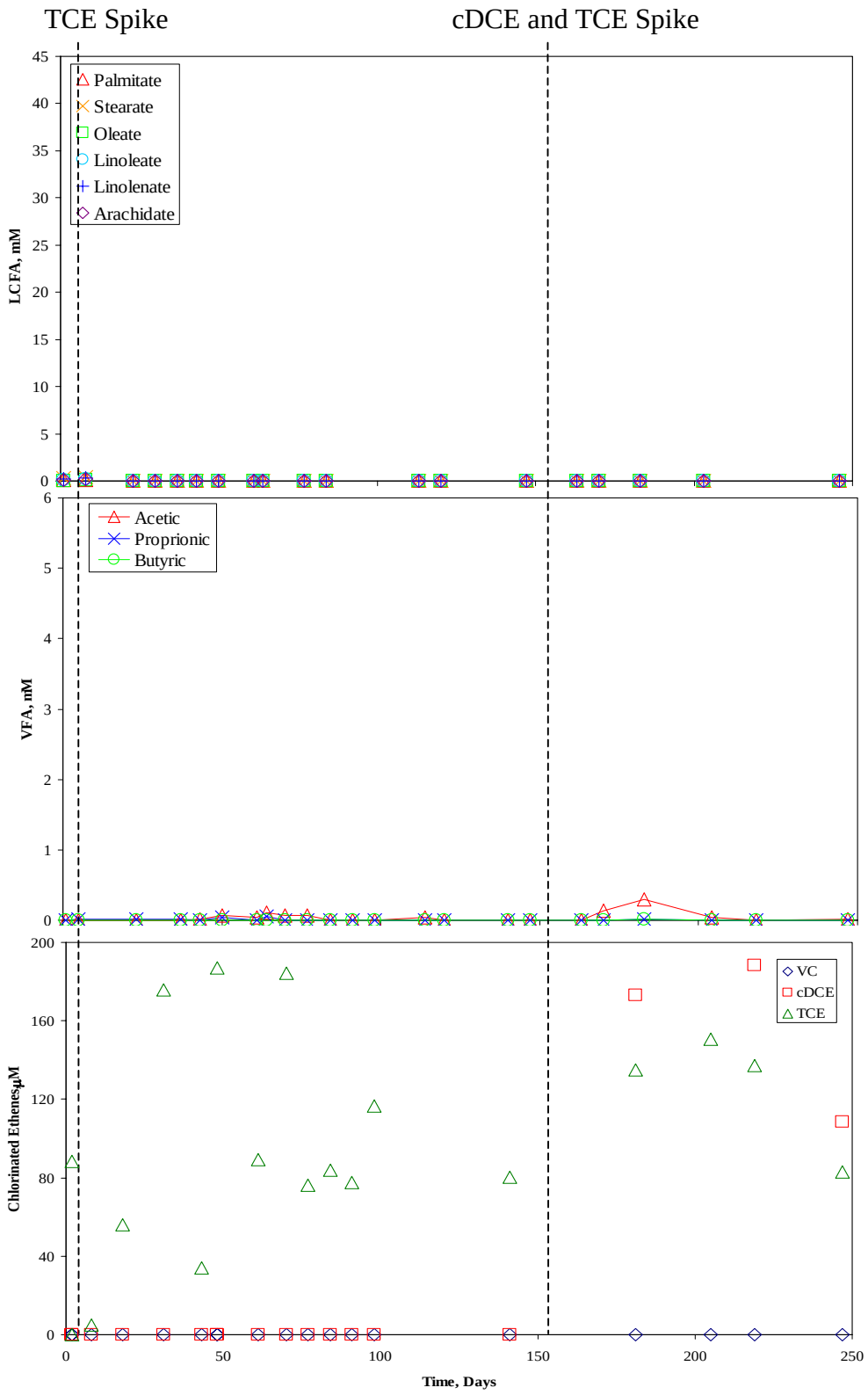

Figure 13: Liquid Control Concentration Data (Microcosm LCDup)

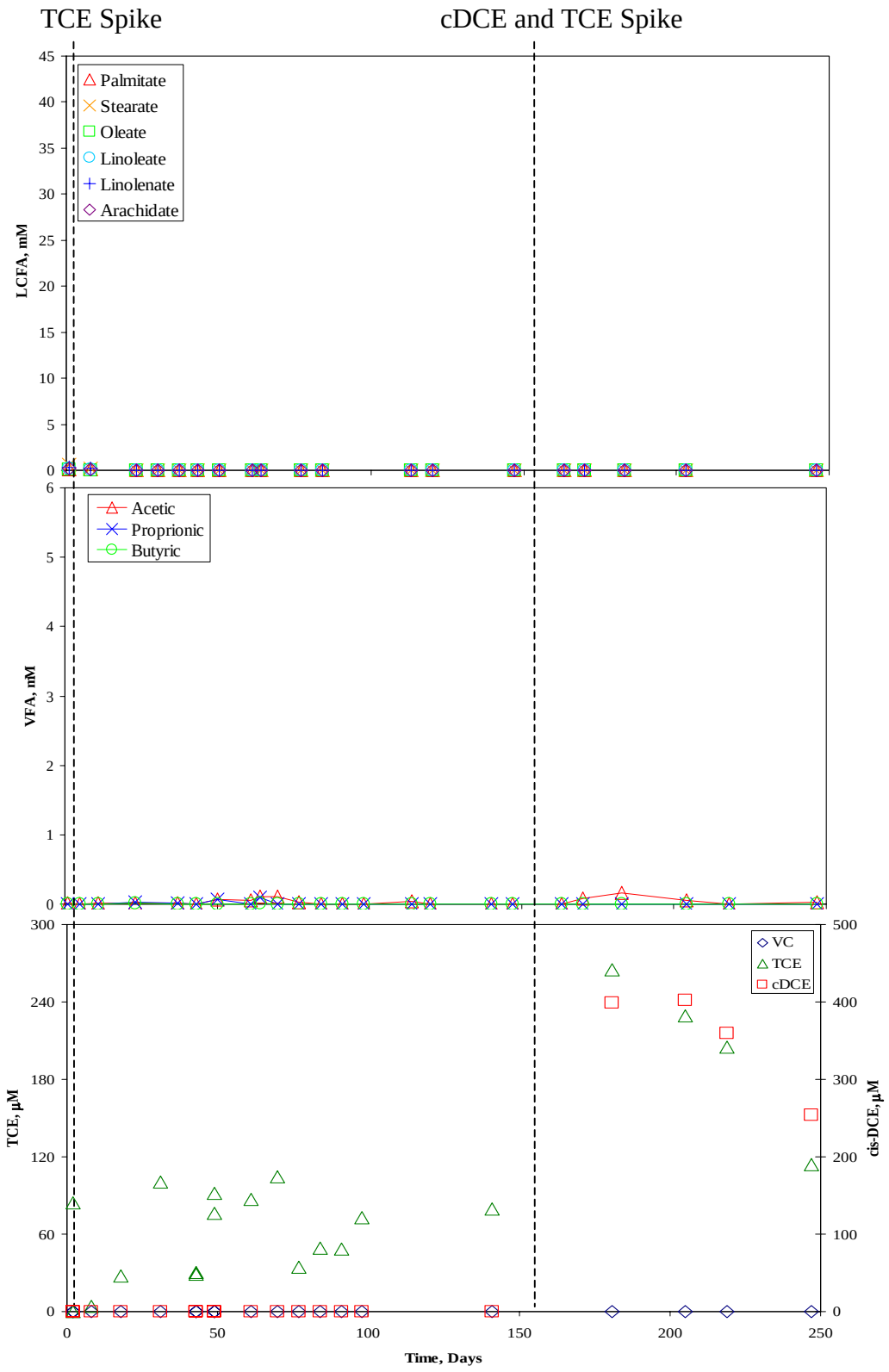

Figure 14: Soil Control Concentration Data (Microcosm SCDup)

Total Carbon Levels

Total carbon (TC) levels were monitored to compare TOC data from this study to TOC data from other studies. The TC levels remained between 500 and 2500 ppm in all the microcosms, except for the controls and lactate amended microcosms (Figure 15). The control microcosms maintained lower TC concentrations at approximately 1000 ppm. The lactate amended microcosms TC levels were much greater than other amended microcosms and reached as high as 25,000 ppm, but declined to 10,000 ppm. A pilot study conducted by Robert Borden at North Carolina State University monitored total organic carbon (TOC) concentrations at a contaminated site utilizing ESO as a biostimulant. Immediately following ESO injection, the TOC concentrations from the pilot site ranged from 39 to 23,500 ppm (Lee et al. 2003a). When the TOC concentrations reached 50ppm after 16 months, the ESO was reinjected (Lee et al. 2003a). The lactate amended microcosms in this study reached concentrations as high as in the Borden studay. The other live amended microcosms in this study maintained concentrations of around 2000 ppm TC. The microcosms in this study do not appear to be loosing any TC over the course of the study; however, this study occurred over only 9 months, half the time the NC State pilot study was conducted. This high and steady level of carbon indicates that ESO is a long-lasting carbon source for subsurface environments.

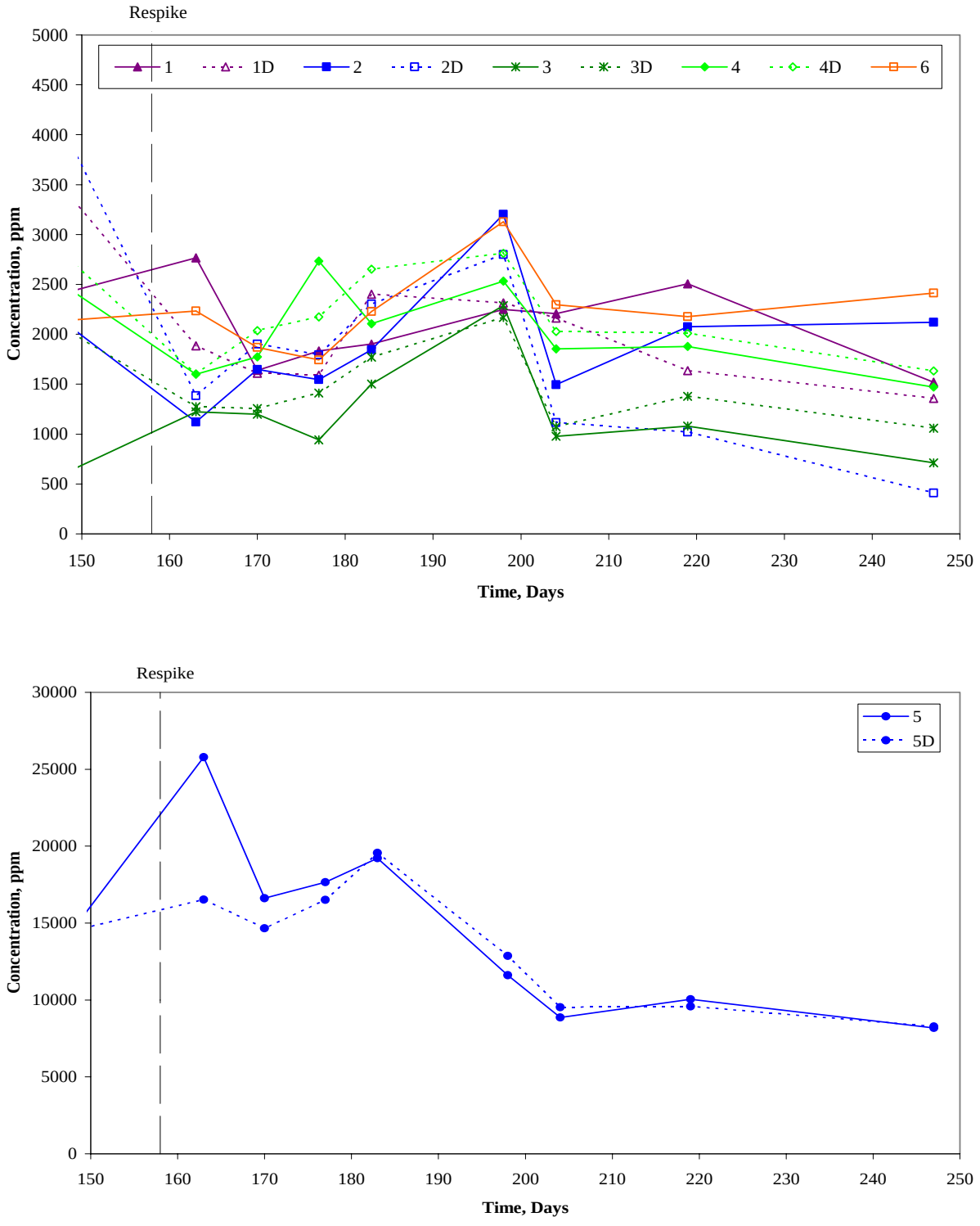

Figure 15: Total Carbon Monitored over Time in all Live Amended Microcosms

Redox Indicators

Cations, anions, and Fe^{2+} were analyzed at the start up of the experiment to determine initial redox conditions in the aquifer. The Fe^{2+} concentration was an average of 400ppm in the groundwater samples collected from onsite. Samples were analyzed twice for cation and anion concentrations, first at the initial start up (Tables 4 and 6) and second, 60 days (Tables 5 and 7) after the start of the experiment, once the microcosms had turned grey and appeared to have reached reduced conditions. Sodium concentrations increased in the microcosms that were treated with sodium azide to kill biological activity (Table 4 and 5). The magnesium, Mg, concentrations remained the same. The decrease in potassium, K, could be due to a dilution effect of adding the ESO to the solution. The emulsifiers used to create the ESO may have contained calcium, Ca, which might explain the increase the concentrations. The ammonium concentrations increased.

The anion concentration data provide more insight into the redox conditions in the groundwater system at 0 and 60 days. The chloride, Cl, concentrations decreased over the 60 day period. An increase in chloride would be another indication of dechlorination taking place, but most of the microcosms did not show any decrease in TCE until after day 60. The decrease in chloride is most likely do to the dilution of ESO addition. The lack of nitrate, nitrite and sulfate in all of the active, grey microcosms (Microcosms 2, 2Dup, 3, 3Dup, 4, and 4Dup) indicate that the ESO and ELA have created reduced conditions in the microcosms. In addition, resazurin was added to the microcosms in the initial setup. Resazurin acts a colorimetric indicator of reduced conditions. Resazurin turns from a pink solution to clear when the microcosms measure below -51 mV. A value of -51 mV is traditionally recognized as reduced conditions in a groundwater system.

Since Microcosms 2, 2Dup, 3, 3Dup, 4, and 4Dup no longer showed a pink hue, and turned grey, they were considered to be reduced by day 60 of the study.

The 30 g of soybean oil added to the ESO provided 5.4 g of H_2 reducing equivalents. Assuming a high Fe(OH)3 content in the soil of 5% by weight of soil, and using the initial concentrations of sulfate (600 ppm), nitrate (4 ppm), TCE spike (15 mg/L) and the equations from the previous section Current Understanding of Process (p. 10-11), the calculated total reduction potential equivalents require 0.036 g of H. Therefore, the ESO provides 5 times the reduction potential to create reduced conditions conducive to reductive dechlorination and dechlorinate TCE to ethene.

Table 4: Initial Cation Concentrations in Groundwater Samples

	Cation Concentration, ppm				
	Ca	**K**	**Mg**	**Na**	**NH_3**
Sample 1	--	915.2	74.7	802.1	--
Sample 2	--	941.3	86.8	791.3	--
Sample 3	--	963.9	85.2	809.5	--

Table 5: Cation Concentrations after 60 days

	Cation Concentration, ppm				
Mic	**Na**	**NH_3**	**Mg**	**Ca**	**K**
1	1432.83	73.176	86.658	158.112	--
1D	781.36	60.222	95.039	180.082	--
2	716.67	62.223	91.534	169.72	--
2D	714.32	64.081	89.81	168.131	--
3	687.12	64.695	89.557	167.817	--
3D	694.54	65.715	81.156	136.809	--
4	727.8	70.768	97.928	192.843	--
4D	720.26	70.199	85.688	151.103	--
5	2153.45	61.606	149.178	344.995	--
5D	1441.7	83.348	188.819	471.574	--
6	834.94	57.228	85.789	153.943	--
7	1070.42	55.068	126.514	309.345	--
LC	1341.09	54.295	129.451	305.478	--
LCD	1198.23	56.349	126.667	303.988	--
SC	1471.25	57.73	123.567	289.316	--
SCD	1419.47	57.614	125.42	295.553	--

Table 6: Initial Anion Concentrations in Groundwater Samples

	Anion Concentration, ppm				
	Cl	**SO_4**	**NO_3**	**NO_2**	**PO_4**
Sample 1	6.9807	592.86	3.0900	80.4600	28.0300
Sample 2	7.0106	613.3	3.0780	12.2100	27.8900
Sample 3	7.0953	--	4.2900	11.1800	28.3500

Table 7: Anion Concentrations after 60 Days

	Anion Concentration, ppm				
Mic	**Cl**	**NO_2**	**NO_3**	**PO_4**	**SO_4**
1	3.68491	2.1376	10.4701	9.2923	0
1D	3.45445	2.1683	10.3939	9.2915	0
2	3.64121	0	0	0	0
2D	3.58647	0	0	0	0
3	3.93589	0	0	0	0
3D	3.57999	0	0	0	0
4	3.48391	0	0	0	12.9336
4D	3.59691	0	0	0	12.3209
5	7.18517	2.1406	10.3939	9.1286	12.7239
5D	6.34769	2.1282	10.3939	9.1259	12.9369
6	3.4286	2.2031	10.3745	9.2443	12.4321
7	5.27597	2.0988	10.2849	9.1643	12.3561
LC	4.19728	2.1742	10.3802	9.3853	12.4859
LCD	4.58174	2.1237	10.3684	9.4834	12.4562
SC	5.24139	2.0878	10.4293	9.4624	12.7063
SCD	4.4239	2.2001	10.4823	9.4781	12.4284

Methane and Carbon Dioxide Production

Another indicator of reduced conditions was the production of gas around day 100 for Microcosm 3. After gas bubbles were observed in Microcosm 3, each microcosm was analyzed on the TCD as described above in Materials and Methods to determine if any methane and/or carbon dioxide were present in the microcosm (Table 8). Microcosm 3 was the only microcosm to show any methane production, but all live amended microcosms contained carbon dioxide. Microcosms 1, 1Dup, 5, and 5Dup contained only trace concentrations of carbon dioxide, at least 2 orders of magnitude less peak area.

Table 8: Observance of Redox and Fermentation Indicator Gases

Microcosm	Methane	Carbon Dioxide
1	--	+
1D	--	+
2	--	++++
2D	--	++++
3	+	++++
3D	--	++++
4	--	++++
4D	--	++++
5	--	++
5D	--	++
6	--	+
7	--	--
LC	--	--
LCD	--	--
SC	--	--
SCD	--	--

Notes:
--: Indicates no detection
+: Indicates peak areas less than 1000
++: Indicates peak areas between 1000-100000
++++: Indicates peak areas greater than 100000

Conclusions

VFA Production

All four live ESO amended microcosms required between 40 and 50 days to generate measurable acetate and to turn gray, indicating that reduced conditions were achieved. Once the acetate concentrations reached between 1.5-3 mM, acetate concentrations decreased. Butyrate production began after day 50 along with the decrease in acetate in most microcosms. The two live ESO amended spiked microcosms appeared to ferment the ESO just as well as the two live ESO amended microcosm that contained only half-spike concentrations of TCE.

Similar, the live ELA amended microcosms took between 40 and 50 days to produce detectable acetate. However, only one of the ELA amended microcosms produced any butyrate within the first 100 days. All six of the emulsion amended microcosms produced trace levels of propionate.

The two lactate amended microcosms began producing acetate almost immediately at extremely high levels, causing the microcosms to become acidic. The acetate concentrations leveled out at around 4 mM and remained at that level throughout the experiments.

After the respike of chlorinated ethenes and addition of groundwater, acetate levels continued to increase in all the live amended microcosms until the concentrations reached around 4 mM when acetate levels dropped to around 2 mM around day 210. The ESO amended microcosms maintained trace levels of propionate and hexanoate, with one exception. One of the ESO amended live unspiked microcosms began producing hexanoate up to 2 mM. Butyrate levels in

the ESO amended microcosms continue to increase to levels between 5-7 mM, with no sign of leveling off. However, one ESO amended spiked microcosm had an almost complete decline in butyrate before a dramatic increases in isobutyrate concentrations. The butyrate levels in this microcosm increased but not as much as other microcosm. The other ESO amended spiked microcosm showed a drop in the acetate concentrations before day 200, coupled with gas production. The other ESO amended microcosms started producing small amounts of gas on day 225. This gas was most likely methane, but no formal analysis was performed. The drop in acetate levels is most likely due to acetotrophic methanogens.

In a similar study at Cornell University, crude and refined soybean oils were used to stimulate reductive dechlorination without any emulsifier (To 2001). The Cornell study did not detect any LCFAs because of their low solubility without an emulsion; the study did, however, detect VFAs similar to this study although in lesser quantities (To 2001). Over a 128 day period, the highest acetate concentration in the study was 1360 μM, whereas in this study, acetate concentrations reached levels as high as 6 mM in most active amended microcosms (To 2001). The Cornell study had successful dechlorination with a lab culture augmentation, and that could have lead to more acetate utilization and lower concentrations. Another reason for lower VFA concentrations could be that the oil is more difficult to biodegrade when it is not emulsified. The Cornell study also showed fermentation products such as propionate, isobutyrate, butyrate, isovalerate, valerate, and hexanoate in steady low quantities, below 50 μM, throughout the course of their study; similar to conditions in many of the active amended microcosms in this study (To 2001).

LCFA Production

Due to the high concentrations of LCFAs in the soybean oil, no degradation was observed in relation to VFA generation. Because the VFAs were small relative to the LCFAs, the loss of LCFA was within the error range of the LCFA measurement.

Chlorinated Ethene Degradation

All live amended microcosms showed a decline in TCE greater than sorption and head space losses, but for the most part, no daughter products were detected to prove dechlorination was occurring. Trace amounts of daughter products were observed in the ELA amended microcosm, but the concentrations did not reach the detection limits. The only indication of dechlorination beyond the loss of TCE and spiked cis-DCE was a corresponding decrease in acetate and TCE concentrations beginning around day 60 in microcosms 2 and 4Dup. This could indicate that acetotrophic dechlorinators were present. Because of the decrease in TCE, but lack of daughter products, cis-DCE was added to the microcosms on day 158 to determine the fate of the daughter products.

After the respike, cis-DCE and TCE levels in most microcosms increased and then gradually decreased greater than the losses attributed to sorption and head space losses. However, no daughter products were observed above detection limits. One microcosm (4Dup) had a corresponding decrease in acetate and cis-DCE after the spike. This could indicate reductive dechlorination, however, no daughter products were observed.

This study showed that ESO readily creates an active, fermenting microbial community and leads to reduced conditions ideal for dechlorination. ESO is a viable low-cost and low-

maintenance alternative to MNA. The slow dechlorination rates and lack of daughter products may be attributed to the fact that achieving an actively dechlorinating community of bacteria may require more time than this study allowed, if the aquifer sediments collected from Charleston Naval Weapons Base did not contain dechlorinators. Biostimulation without bioaugmentation can be a slow process if a small number of dechlorinating organisms are present to degrade chlorinated ethenes in the aquifer (Landvay 2003). Adding a lab-grown dechlorinating culture may have increased the rate of dechlorination in the microcosms, but one of the objectives of this study was to investigate the effect of ESO addition to the aquifer sediment from Charleston Naval Weapons Base and to determine the effectiveness of ESO to reduce an aerobic aquifer. The Navy should be aware that if they elect to run a pilot study and decide against bioaugmentation, a sufficiently large enough dechlorinating microbial community may take some time to develop. Although the dechlorination may take time, ESO quickly created a reduced environment.

The ESO readily fermented the LCFAs to VFAs to create a reduced environment favorable for dechlorination and there appeared to be no inhibitory effects of fermentation from the chlorinated ethenes in solution. The heterogeneity of the soil and microbial communities may have contributed to the many different products and concentrations of VFAs as a result of fermentation. While methanogenesis is not completely inhibited, the variety of VFAs aide in keeping methanogenic communities from monopolizing the reducing equivalents. This fermentation of large quantities of carbon donor can lead to large accumulations of biomass.

As the system matures and conditions change, the biomass reaches peak populations and a die-off eventually occurs. The fermentation of this excess dead biomass could be another source of carbon or vitamins for the microbial communities (To 2001). This could be an explanation for the lag time required for the ELA microcosms to begin producing a VFA other than acetate. Since the ELA emulsion was made with a chemically manufactured form of linolenate, it probably did not contain the same vitamins naturally occur in soybean oil. The microcosms needed extra time to build up biomass in order to ferment linoleate and release vitamins.

Another example of ineffective fermentation without biomass build up would be the lactate amended microcosms. The lactate was a chemically manufactured substrate added directly to the microcosm. When acetate levels in the lactate amended microcosms increased, the microorganisms were unable to utilize the acetate quickly enough, thus creating an acidic pH. However, when ESO and ELA amended microcosms reached the same levels of acetate, the bacteria were able to continue to ferment other VFAs. Perhaps if a vitamin solution had been supplemented to the lactate amended microcosms, some dechlorination would have been observed. In addition, the quick utilization of the lactate showed that ESO is a better long-term bio-stimulant because it provides a more natural, all-encompassing substrate for microbial communities.

Aside from the large scale significance of the study, a number of very basic problems were realized to better understand the mechanisms of what occurs in the subsurface when ESO is added. Emulsions create a more complex subsurface environment, especially in clay sediments. Dry clays can be used to clean up vegetable oil spills on water bodies (Wincele, 2004). In

Wincele's (2004) study, dry clay was sprinkled on an oil spill on the surface of a lake where it complexes with vegetable oil and causes oils to sink to bottom sediments where the oils are more easily degraded. The surface chemistry of the interactions between the TCE, oil, sediments, water, and emulsifiers are an integral part to understanding the effect of ESO on the subsurface environment.

Engineering Significance

This study showed that the addition of ESO to aquifer sediments lead to fermentation and production of VFAs, such as acetate, propionate, and butyrate, that can lead to reductive dechlorination. ESO addition may lead to dechlorination, but producing an actively dechlorinating community in an aerobic aquifer will create a lag time. This study showed a correlation between the loss of acetate and TCE, but the lack of daughter products made it difficult to conclude that dechlorination was occurring. The aquifer sediments for this study contained some silt and clay which caused problems with sampling. Adding ESO creates a complex environment that should be studied carefully by studying each component of the system.

Recommendations

The Navy should proceed with the pilot study under certain conditions. A recovery system should be put in place because the emulsion will suspend TCE and carry it further down gradient. At the beginning of the pilot study, a reduction in TCE concentrations will probably occur, but not it will necessarily be related to dechlorination. Some TCE will partition into the oil phase of the ESO. In addition, due to the lack of dechlorination in this laboratory scale study, the Navy may want to run PCR to test for any dechlorinating colonies in the aquifer. If no dechlorinating colonies can be detected, bioaugmention might be a consideration.

A more comprehensive study of each component of ESO biostimulation (fermentation, surface chemistry, sorption, and dechlorination) would lead to a better understanding of this process.

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Appendix A: Supporting Data

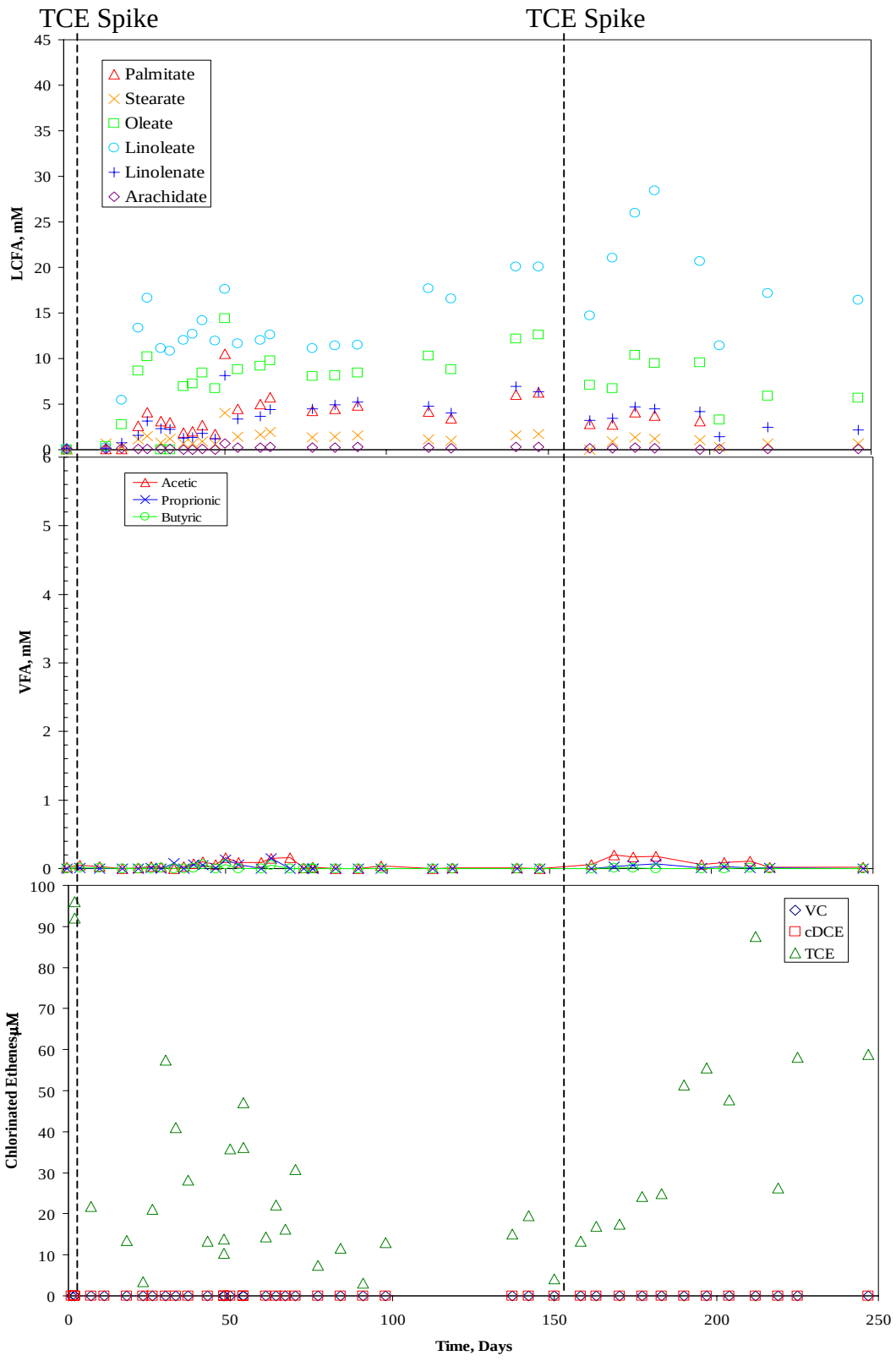

Figure A1: Dead ESO Amended Spiked Concentration Data (Microcosm 1Dup)

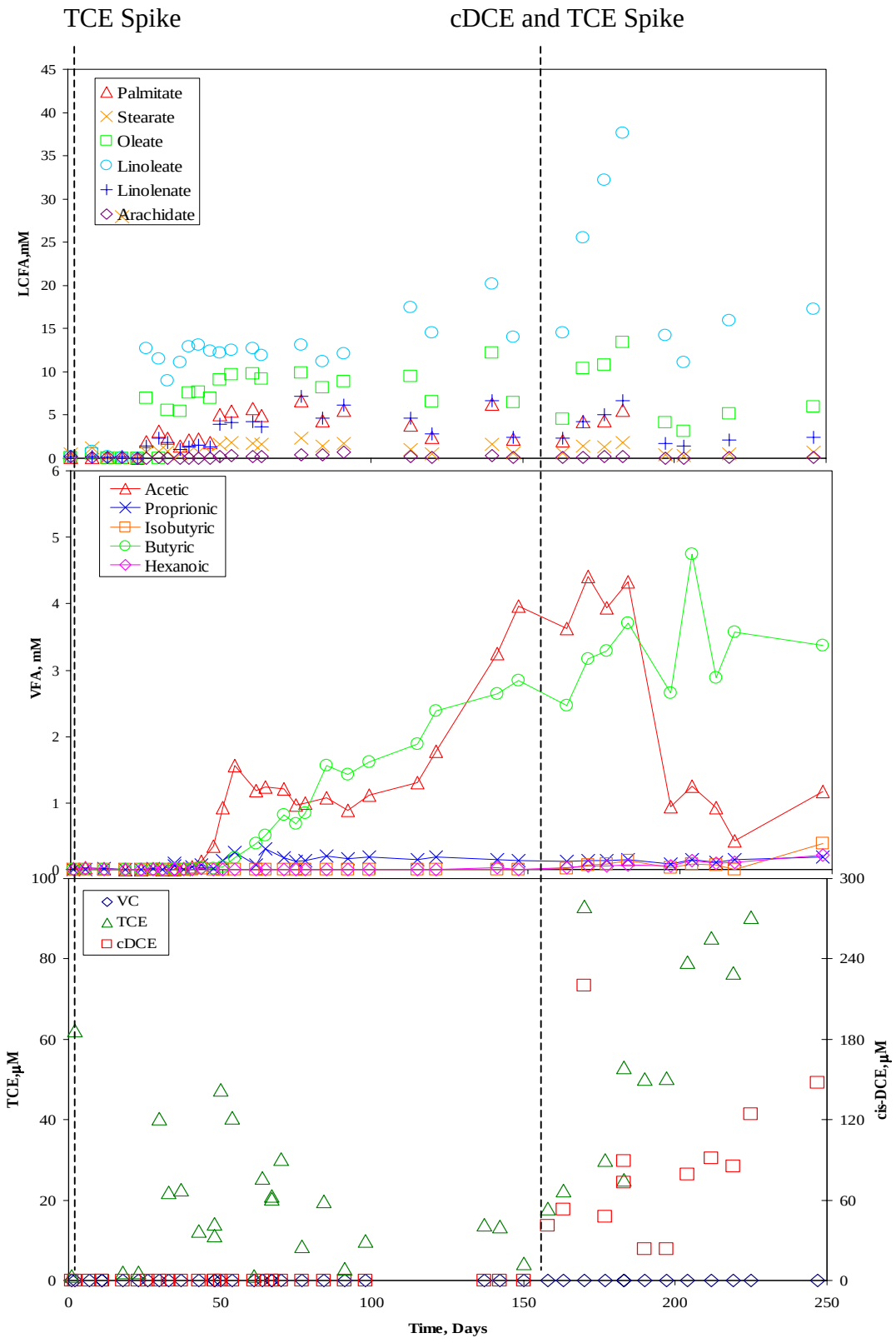

Figure A2: Live ESO Amended Spiked Concentration Data (Microcosm 2Dup)

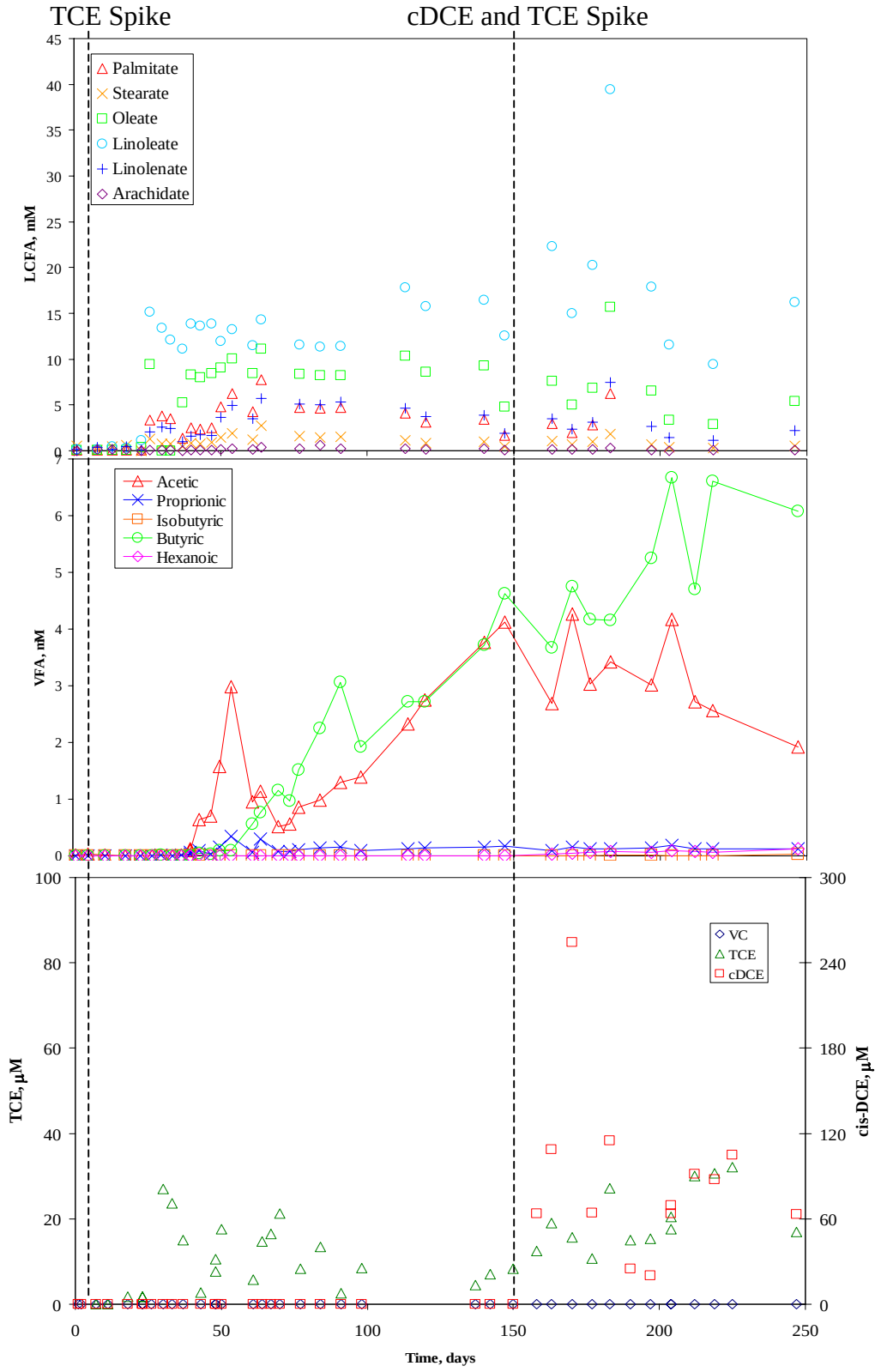

Figure A3: Live ESO Amended Half-Spiked Concentration Data (Microcosm 3Dup)

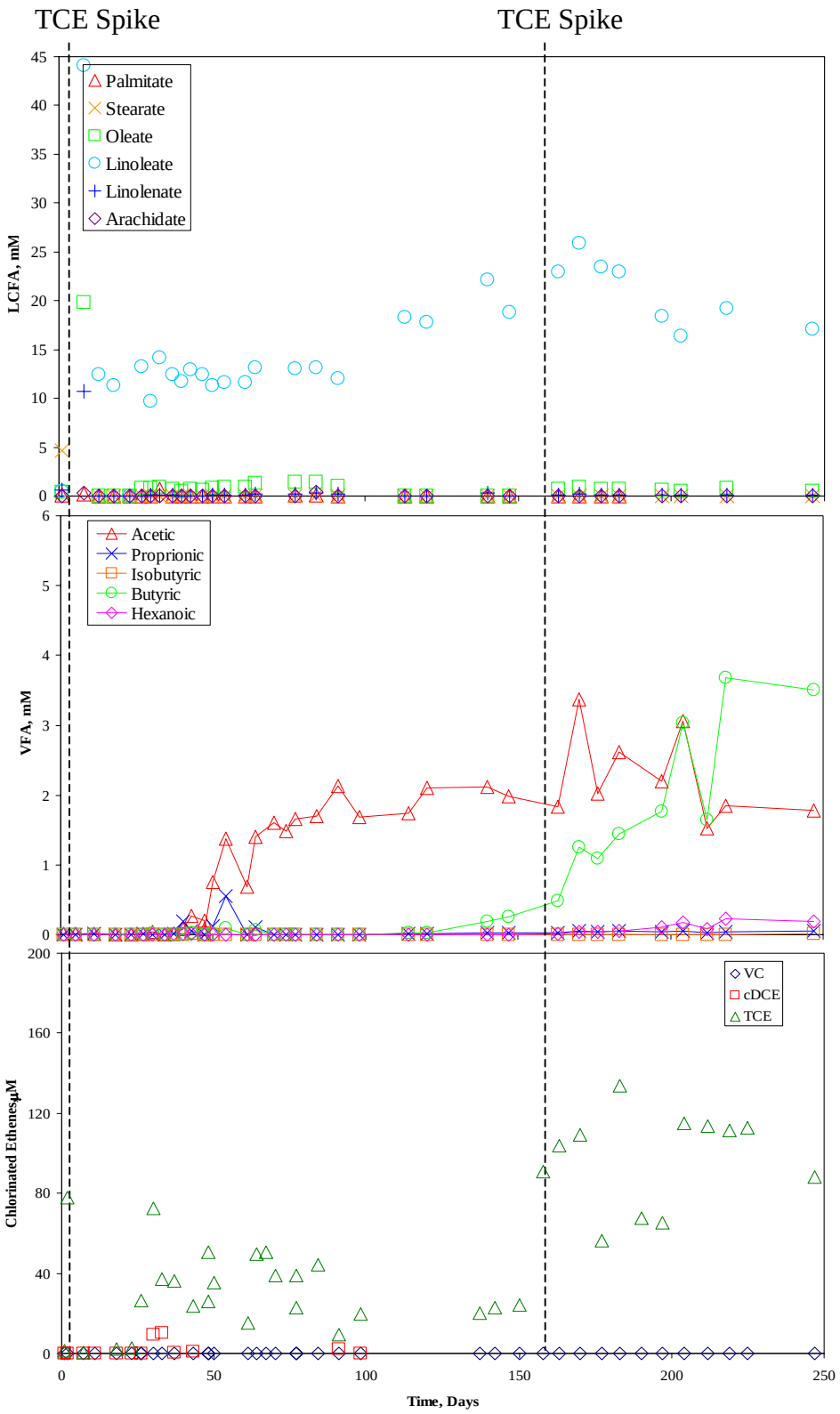

Figure A4: Live ELA Amended Spiked Concentration Data (Microcosm 4)

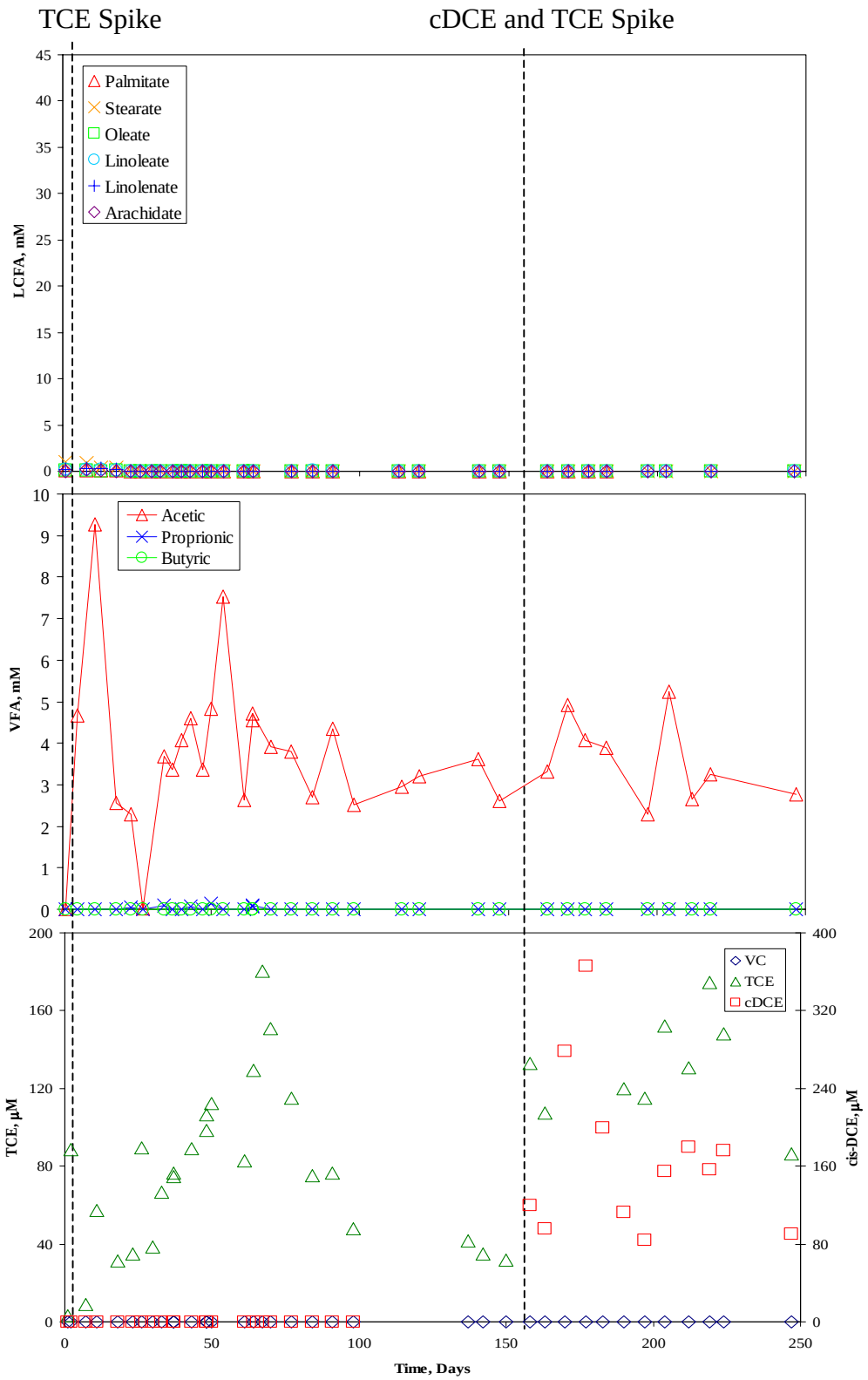

Figure A5: Live Lactate Amended Spiked Concentration Data (Microcosm 5Dup)

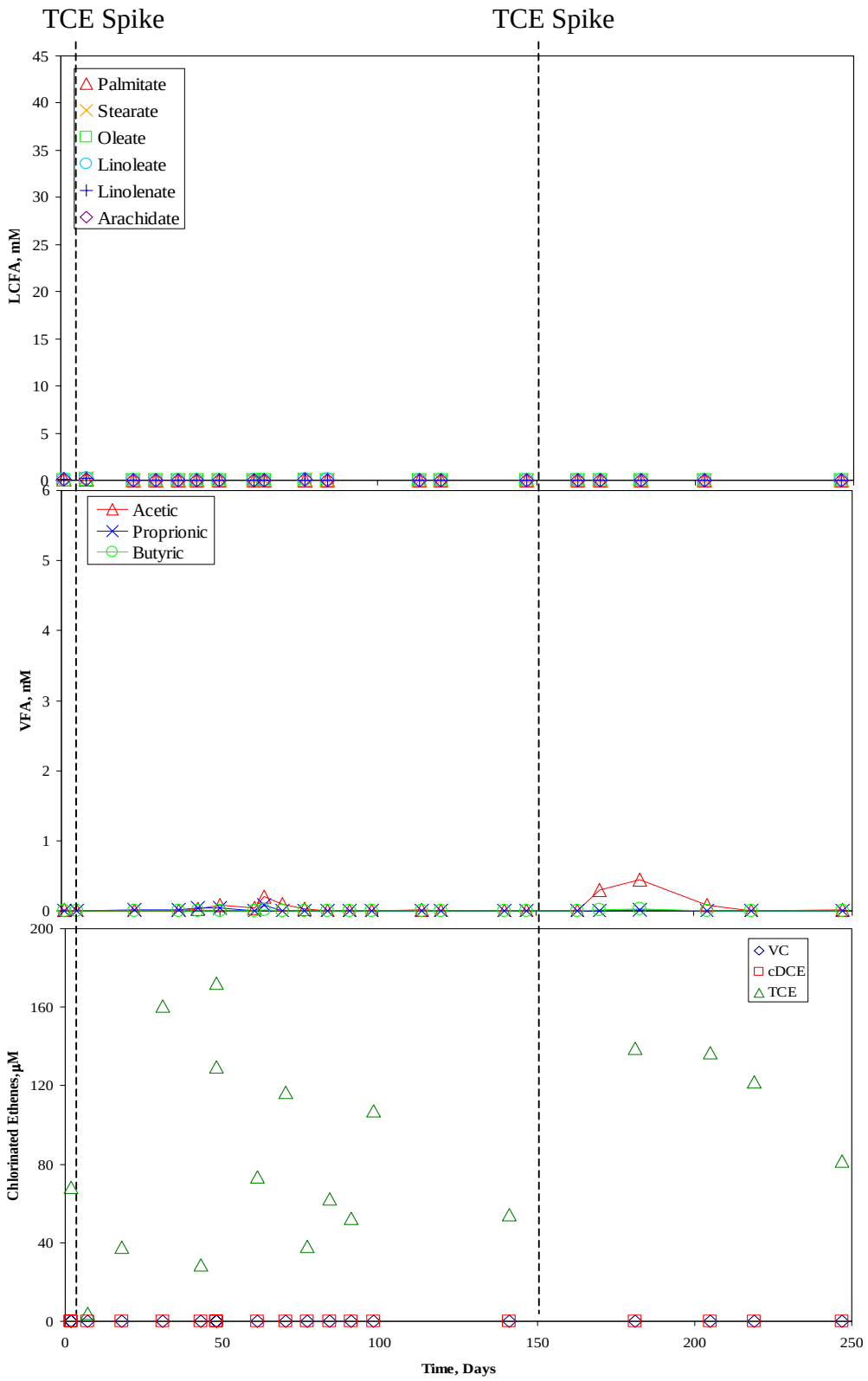

Figure A6: Liquid Control Concentration Data (Microcosm LC)

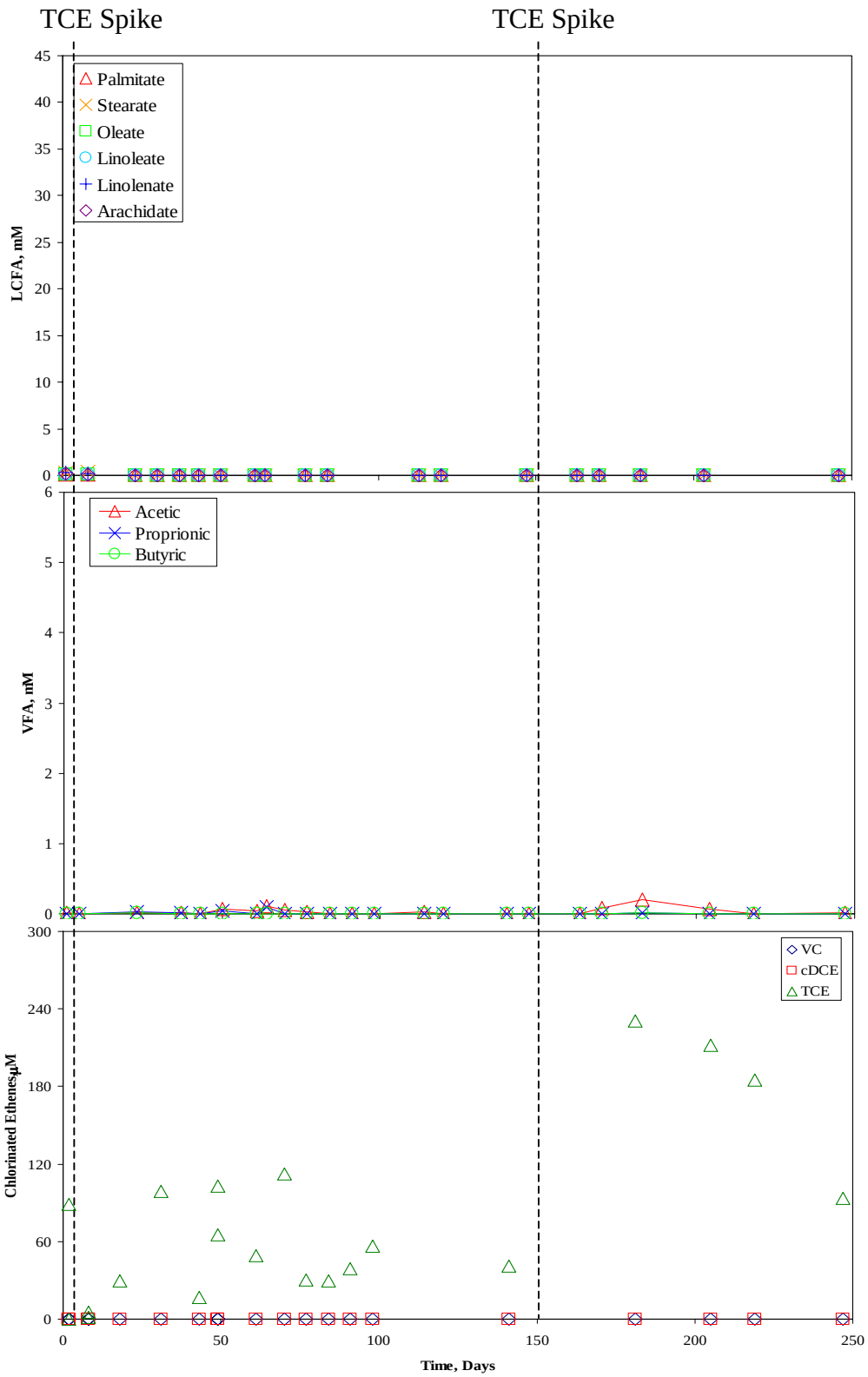

Figure A7: Soil Control Concentration Data (Microcosm SC)

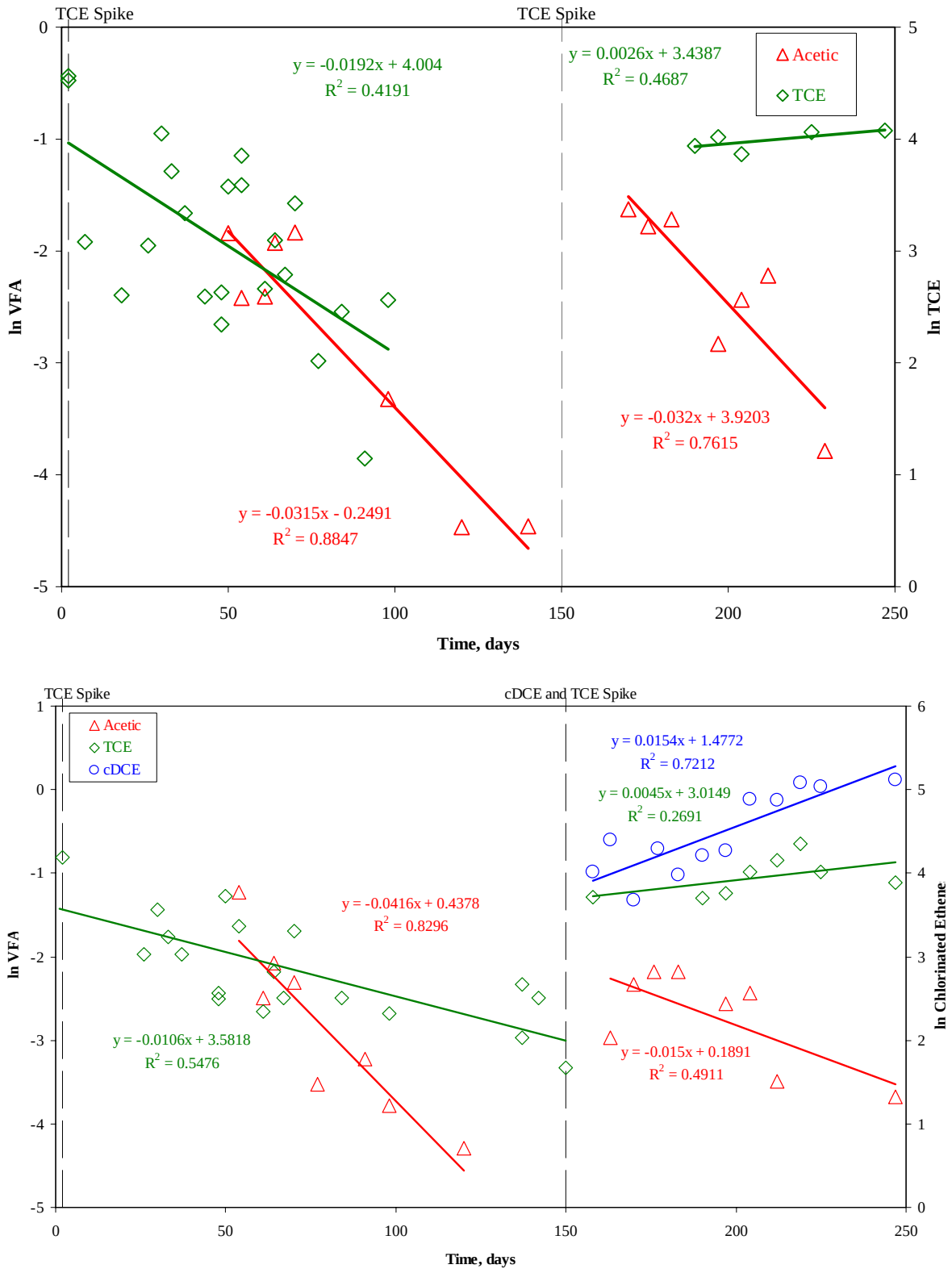

Figure A8: Comparison of Chlorinated Ethene and Acetate Concentration Data and Utilization Rates in Microcosms 1 (top) and 1Dup (bottom)

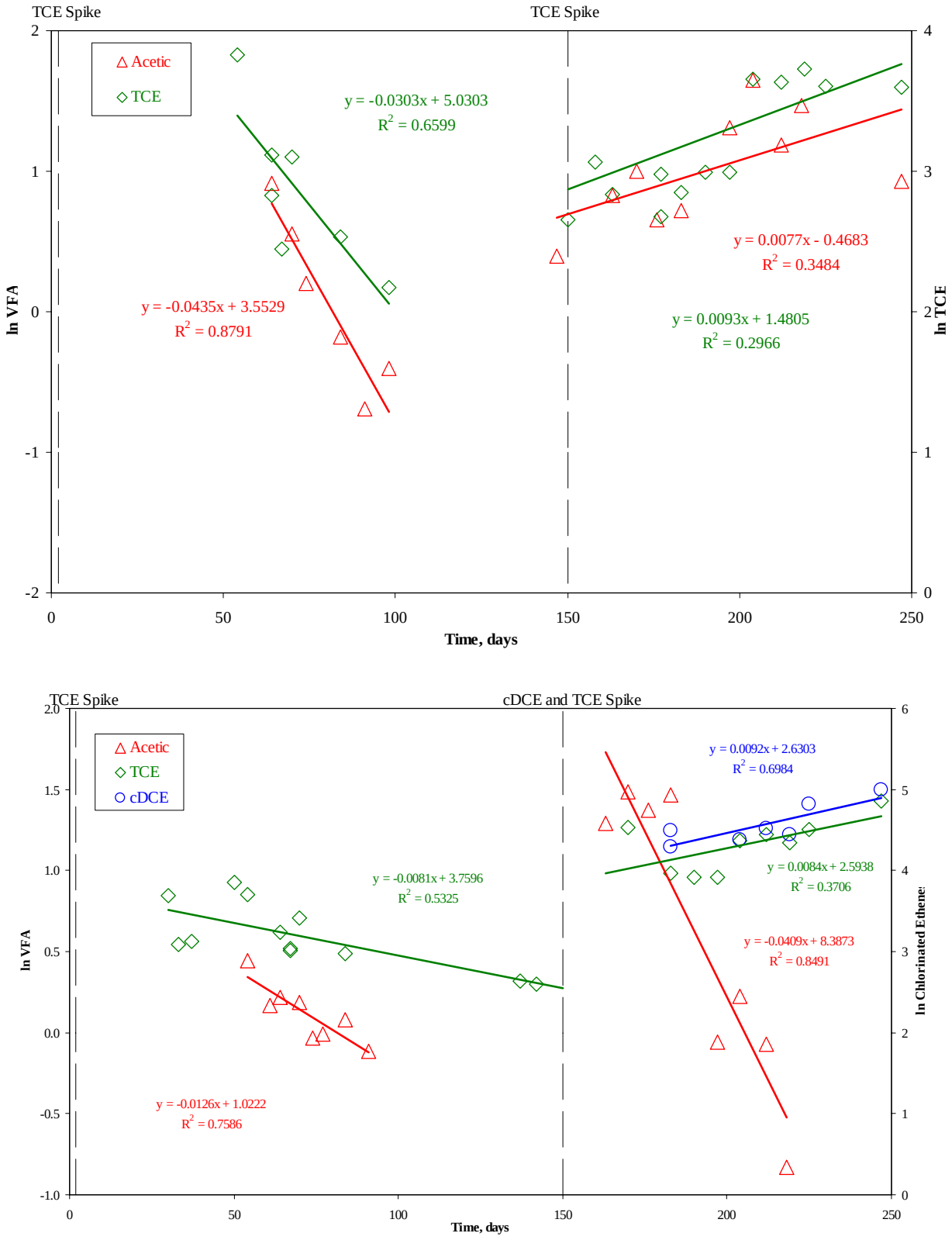

Figure A9: Comparison of Chlorinated Ethene and Acetate Concentration Data and Utilization Rates in Microcosms 2 (top) and 2Dup (bottom)

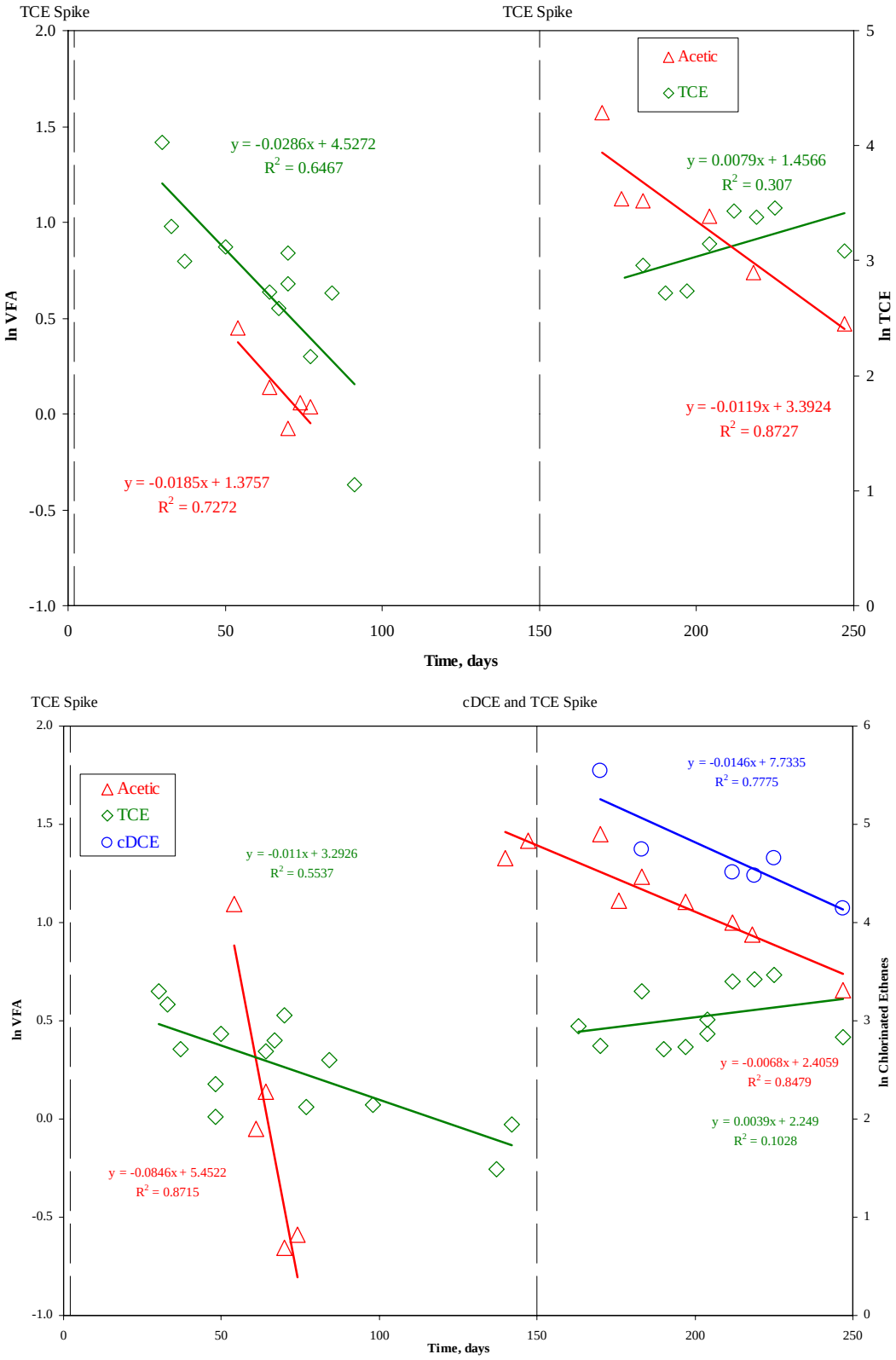

Figure A10: Comparison of Chlorinated Ethene and Acetate Concentration Data and Utilization Rates in Microcosms 3 (top) and 3Dup (bottom)

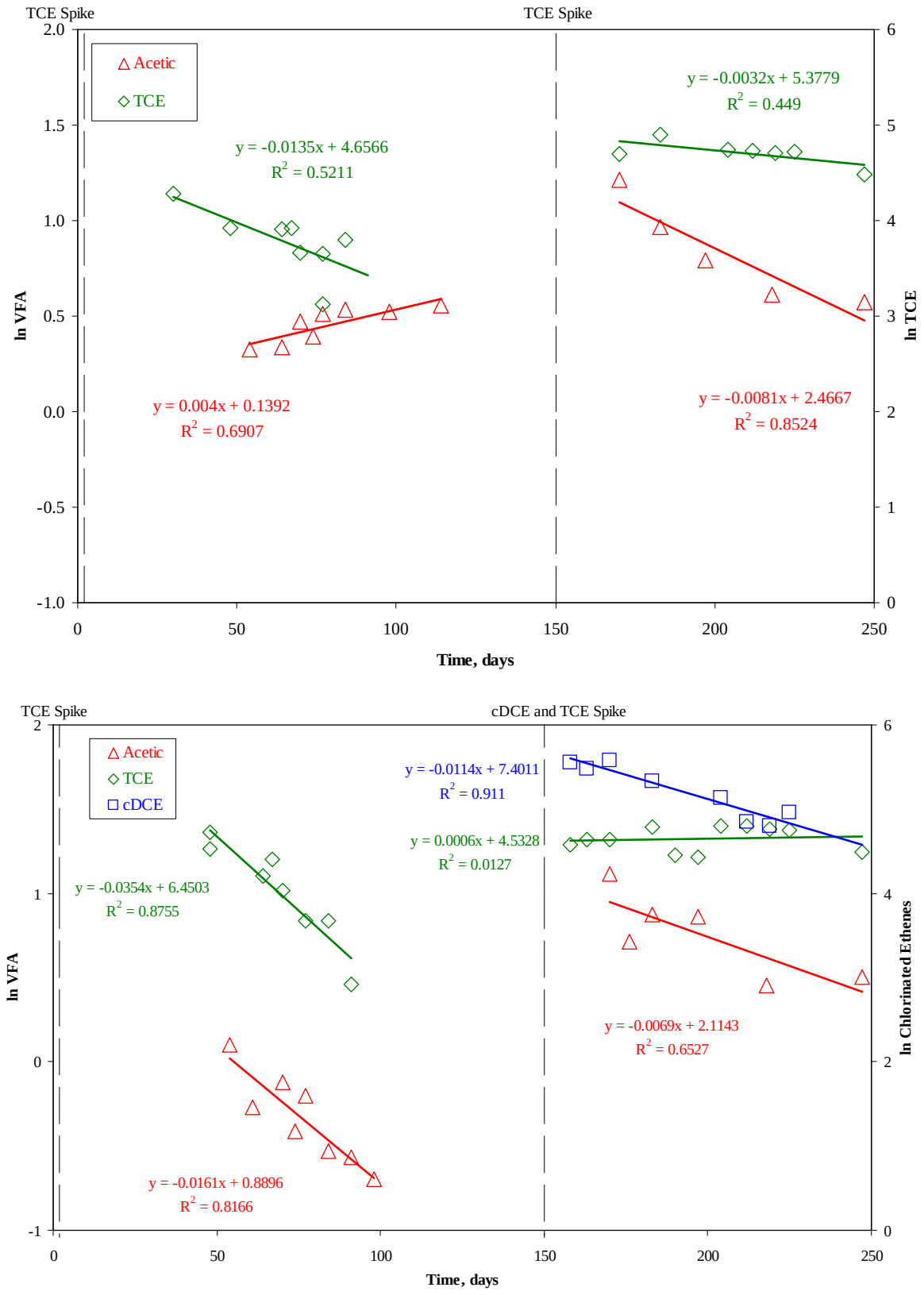

Figure A11: Comparison of Chlorinated Ethene and Acetate Concentration Data and Utilization Rates in Microcosms 4 (top) and 4Dup (bottom)

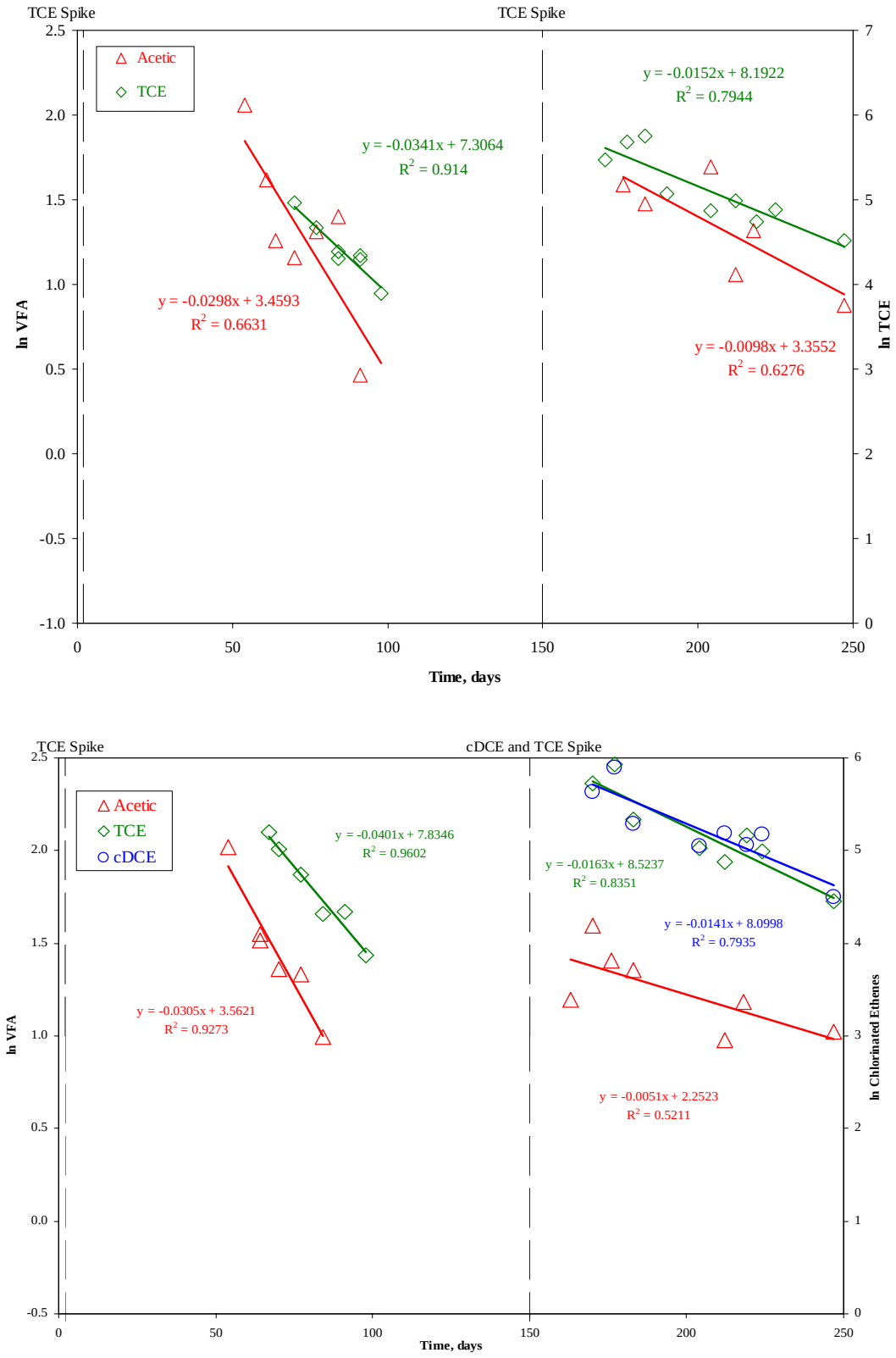

Figure A12: Comparison of Chlorinated Ethene and Acetate Concentration Data and Utilization Rates in Microcosms 5 (top) and 5Dup (bottom)

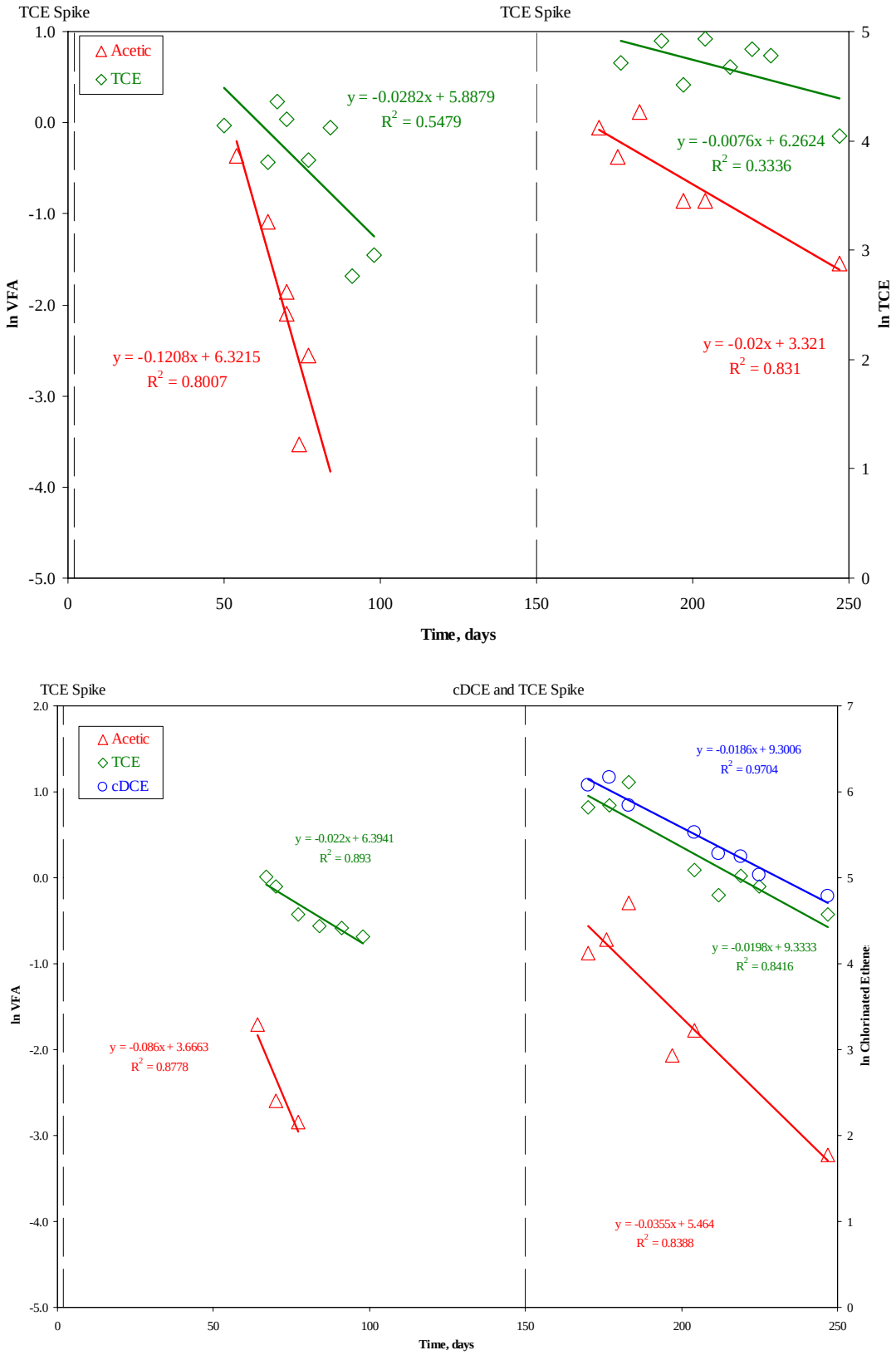

Figure A13: Comparison of Chlorinated Ethene and Acetate Concentration Data and Utilization Rates in Microcosms 6 (top) and 7Dup (bottom)

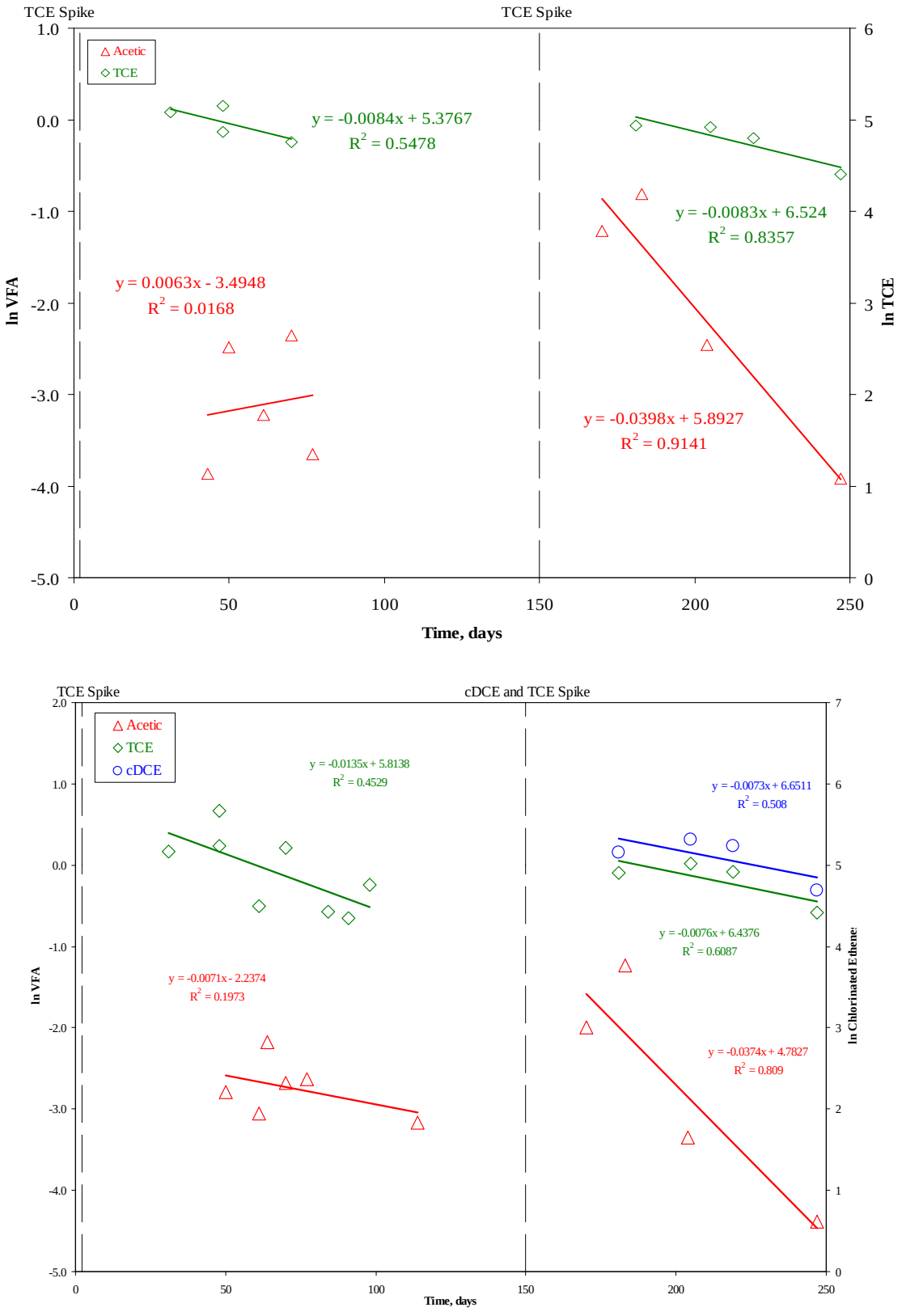

Figure A14: Comparison of Chlorinated Ethene and Acetate Concentration Data and Utilization Rates in Microcosms LC (top) and LCDup (bottom)

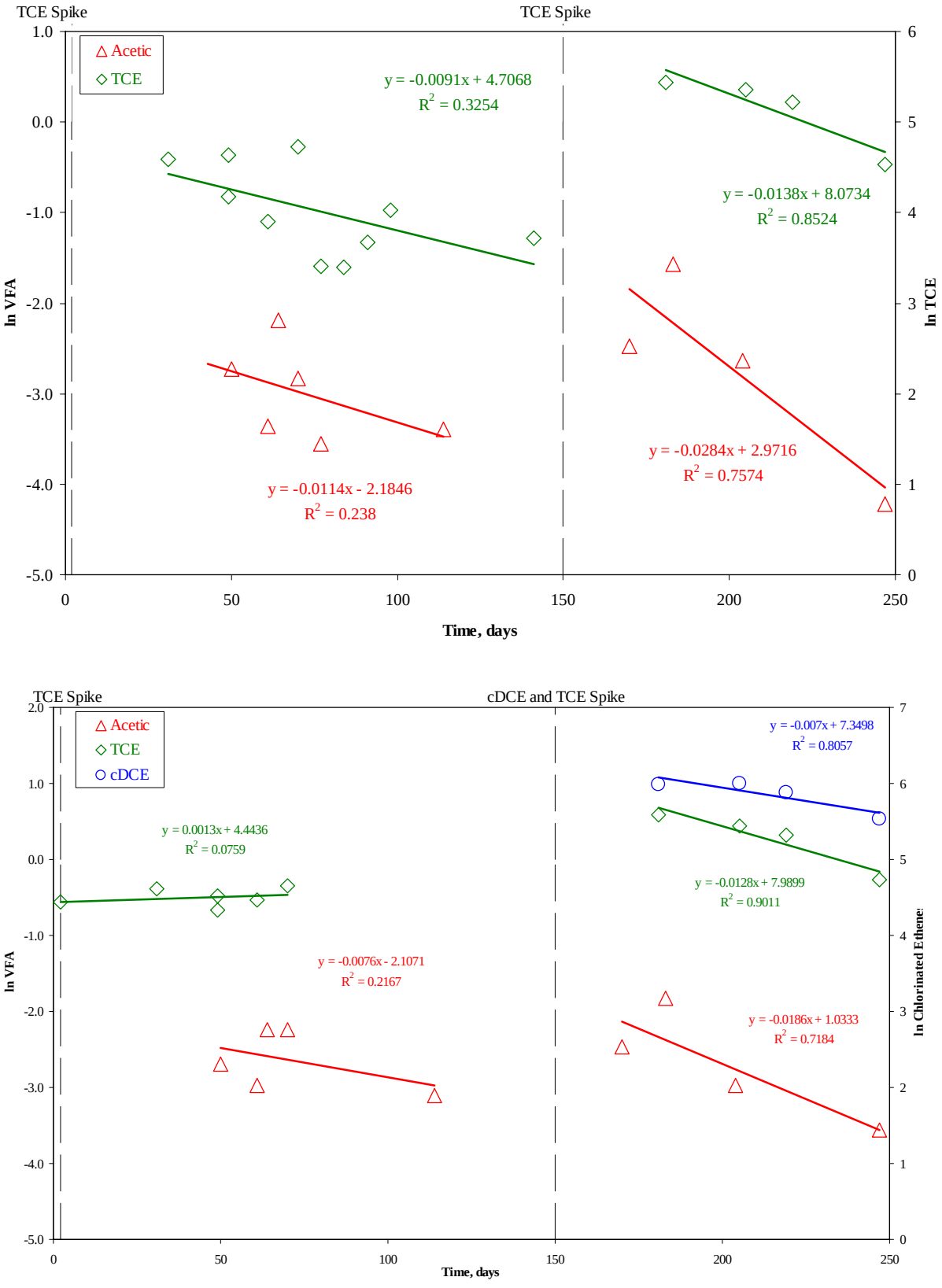

Figure A15: Comparison of Chlorinated Ethene and Acetate Concentration Data and Utilization Rates in Microcosms SC (top) and SCDup (bottom)

Table A1: LCFA Concentration Data Microcosm 1

Date	Day	Concentration					
		Palmitate mM	Stearate mM	Oleate mM	Linoleate mM	Linolenate mM	Arachidate mM
1.21.04	1	0.05	0.03	0.01	0.07	0.13	0.07
2.7.04	13	0.06	0.64	0.41	0.25	0.14	0.11
2.12.04	18	0.07	0.31	2.75	5.44	0.75	0.13
2.17.04	23	2.65	1.10	8.63	13.36	1.59	0.05
2.20.04	26	4.13	1.48	10.20	16.66	3.13	0.07
2.24.04	30	3.11	0.76	0.00	11.13	2.29	0.07
2.27.04	33	2.99	1.22	0.00	10.84	2.24	0.06
3.2.04	37	1.84	0.68	6.90	12.00	1.26	0.03
3.5.04	40	1.99	0.65	7.25	12.72	1.33	0.03
3.8.04	43	2.72	0.91	8.42	14.20	1.80	0.05
3.12.04	47	1.72	0.60	6.70	11.93	1.16	0.04
3.15.04	50	10.53	3.99	14.37	17.63	8.14	0.71
3.19.04	54	4.49	1.42	8.78	11.62	3.34	0.19
3.26.04	61	5.00	1.63	9.21	12.03	3.64	0.20
3.30.04	64	5.77	1.96	9.80	12.59	4.37	0.27
4.12.04	77	4.28	1.35	8.04	11.11	4.51	0.21
4.19.04	84	4.48	1.45	8.13	11.39	4.93	0.24
4.26.04	91	4.87	1.58	8.45	11.52	5.23	0.27
5.17.04	113	4.19	1.10	10.30	17.70	4.78	0.20
5.24.04	120	3.41	0.99	8.78	16.54	4.04	0.15
6.14.04	140	6.02	1.57	12.17	20.10	6.93	0.29
6.21.04	147	6.27	1.74	12.58	20.08	6.36	0.30
7.6.04	163	2.86	0.00	7.10	14.72	3.22	0.13
7.13.04	170	2.76	0.92	6.74	21.01	3.42	0.11
7.20.04	177	4.08	1.32	10.35	25.95	4.67	0.19
7.26.04	183	3.74	1.23	9.48	28.46	4.47	0.17
8.10.04	197	3.13	1.03	9.57	20.71	4.16	0.00
8.16.04	203	1.09	0.30	3.31	11.42	1.44	0.05
8.31.04	218	1.93	0.65	5.91	17.13	2.48	0.08
9.28.04	246	1.81	0.66	5.70	16.41	2.16	0.09

Table A2: LCFA Concentration Data for Microcosm 1D

Date	Day	Concentration					
		Palmitate mM	Stearate mM	Oleate mM	Linoleate mM	Linolenate mM	Arachidate mM
1.21.04	1	0.05	0.07	0.01	0.08	0.15	0.08
1.30.04	5	0.05	-0.22	0.04	0.26	0.50	0.13
2.5.04	11	0.05	0.71	0.06	0.35	0.26	0.19
2.12.04	18	0.17	0.93	12.02	29.95	6.51	0.09
2.17.04	23	0.04	0.02	0.00	0.25	0.01	0.00
2.20.04	26	0.40	0.11	1.49	4.13	0.20	0.00
2.24.04	30	3.94	0.64	0.00	12.89	3.01	0.11
2.27.04	33	3.04	1.13	0.00	10.96	2.29	0.06
3.2.04	37	1.70	0.57	6.56	12.09	1.20	0.02
3.5.04	40	1.26	0.47	5.26	10.49	0.75	0.03
3.8.04	43	2.25	0.80	7.86	13.30	1.47	0.04
3.12.04	47	1.72	0.59	6.74	11.82	1.13	0.04
3.15.04	50	5.11	1.57	9.22	12.26	4.05	0.25
3.19.04	54	5.80	1.81	9.78	12.87	4.63	0.27
3.26.04	61	5.30	1.70	9.50	12.39	4.06	0.25
3.30.04	64	6.58	2.19	10.51	13.25	4.93	0.33
4.12.04	77	4.36	1.50	8.04	11.08	4.45	0.25
4.19.04	84	4.94	1.65	8.58	11.68	5.27	0.31
4.26.04	91	3.71	1.12	7.35	10.56	4.17	0.16
5.17.04	113	4.70	6.56	7.13	32.49	10.80	0.47
5.24.04	120	3.59	0.90	9.22	16.88	4.16	0.16
6.14.04	140	4.30	1.13	10.52	17.89	4.92	0.20
6.21.04	147	1.85	0.45	5.54	12.89	1.94	0.09
7.6.04	163	2.34	0.00	5.86	17.93	2.79	0.00
7.13.04	170	2.16	0.70	5.36	16.31	2.63	0.10
7.20.04	177	3.90	1.24	10.09	28.75	4.36	0.20
7.26.04	183	7.36	2.56	17.98	42.05	8.78	0.34
8.10.04	197	2.63	0.86	8.21	19.39	3.33	0.11
8.16.04	203	1.61	0.54	5.07	15.62	2.06	0.08
8.31.04	218	0.95	0.32	2.89	9.67	1.20	0.00
9.28.04	246	3.56	1.21	11.17	21.16	4.28	0.18

Table A3: LCFA Concentration Data for Microcosm 2

Date	Day	Concentration					
		Palmitate mM	Stearate mM	Oleate mM	Linoleate mM	Linolenate mM	Arachidate mM
1.21.04	1	0.05	0.75	0.11	0.16	0.31	0.20
2.2.04	8	0.23	30.85	10.89	39.93	8.96	0.02
2.7.04	13	0.05	0.20	0.04	0.11	0.22	0.11
2.12.04	18	0.05	0.25	0.03	0.21	0.24	0.11
2.17.04	23	0.00	0.00	0.02	0.04	0.00	0.00
2.20.04	26	0.99	0.26	3.75	9.45	0.54	0.00
2.24.04	30	1.22	0.47	5.02	10.35	0.74	0.02
2.27.04	33	2.59	1.03	0.00	9.49	1.92	0.05
3.3.04	37	1.49	0.49	5.63	11.29	1.03	0.02
3.5.04	40	1.76	0.61	6.89	11.95	1.20	0.03
3.8.04	43	1.39	0.53	5.82	10.80	0.78	0.03
3.12.04	47	2.71	0.98	8.67	14.19	1.79	0.06
3.15.04	50	5.00	1.48	9.18	12.31	4.02	0.24
3.19.04	54	5.38	1.61	9.55	12.46	4.16	0.22
3.26.04	61	4.59	1.39	8.85	11.71	3.52	0.17
3.30.04	64	7.15	2.40	10.87	13.69	5.16	0.38
4.12.04	77	5.38	1.84	8.93	12.18	5.72	0.31
4.19.04	84	4.38	1.51	8.11	11.17	4.55	0.42
4.26.04	91	6.10	1.97	9.39	12.57	6.71	0.32
5.17.04	113	3.58	0.73	9.48	16.92	4.26	0.17
5.24.04	120	3.58	1.01	9.20	16.66	4.04	0.20
6.14.04	140	7.62	2.04	13.26	21.72	8.17	0.40
6.21.04	147	2.01	0.47	5.71	13.27	2.09	0.12
7.6.04	163	1.97	0.59	4.76	14.60	2.29	0.02
7.13.04	170	5.37	1.70	13.14	28.65	6.12	0.28
7.20.04	177	3.00	1.07	7.54	22.07	3.28	0.14
7.26.04	183	2.36	0.76	5.73	17.24	2.71	0.13
8.10.04	197	1.59	0.48	4.59	15.22	1.82	0.01
8.16.04	203	1.62	0.51	4.71	15.57	2.04	0.03
8.31.04	218	1.72	0.46	5.18	15.92	2.14	0.08
9.28.04	246	1.18	0.41	3.73	12.35	1.50	0.05

Table A4: LCFA Concentration Data for Microcosm 2D

Date	Day	Concentration					
		Palmitate mM	Stearate mM	Oleate mM	Linoleate mM	Linolenate mM	Arachidate mM
1.21.04	1	0.05	0.47	0.08	0.18	0.25	0.15
2.2.04	8	0.06	1.21	0.49	0.77	0.25	0.13
2.7.04	13	0.05	0.13	0.03	0.22	0.12	0.09
2.12.04	18	0.05	27.95	0.02	0.11	0.16	0.08
2.17.04	23	0.00	0.00	0.01	0.02	0.00	0.00
2.20.04	26	1.94	0.67	7.00	12.70	1.45	0.04
2.24.04	30	3.16	0.77	0.00	11.53	2.34	0.07
2.27.04	33	2.36	0.82	5.57	8.95	1.84	0.03
3.3.04	37	1.42	0.49	5.46	11.14	0.96	0.02
3.5.04	40	2.08	0.73	7.54	12.93	1.35	0.04
3.8.04	43	2.21	0.74	7.70	13.15	1.48	0.04
3.12.04	47	1.85	0.66	7.00	12.44	1.28	0.04
3.15.04	50	5.02	1.60	9.09	12.18	3.90	0.21
3.19.04	54	5.45	1.81	9.71	12.51	4.11	0.28
3.26.04	61	5.73	1.69	9.82	12.75	4.27	0.22
3.30.04	64	4.95	1.64	9.17	11.93	3.66	0.23
4.12.04	77	6.63	2.28	9.92	13.16	7.17	0.40
4.19.04	84	4.34	1.38	8.14	11.19	4.65	0.36
4.26.04	91	5.52	1.68	8.88	12.13	6.13	0.69
5.17.04	113	3.83	0.98	9.49	17.42	4.61	0.23
5.24.04	120	2.40	0.54	6.58	14.51	2.78	0.14
6.14.04	140	6.22	1.65	12.23	20.14	6.67	0.31
6.21.04	147	2.27	0.56	6.47	13.99	2.44	0.10
7.6.04	163	1.99	0.59	4.50	14.55	2.30	0.06
7.13.04	170	4.24	1.38	10.35	25.52	4.26	0.11
7.20.04	177	4.32	1.27	10.77	32.17	5.09	0.21
7.26.04	183	5.53	1.86	13.41	37.61	6.65	0.21
8.10.04	197	1.47	0.42	4.19	14.24	1.75	0.02
8.16.04	203	1.12	0.29	3.10	11.07	1.42	0.04
8.31.04	218	1.82	0.52	5.16	15.92	2.08	0.07
9.28.04	246	2.11	0.68	5.99	17.23	2.39	0.05

Table A5: LCFA Concentration Data for Microcosm 3

Date	Day	Concentration					
		Palmitate mM	Stearate mM	Oleate mM	Linoleate mM	Linolenate mM	Arachidate mM
1.21.04	1	0.05	0.31	0.03	0.14	0.20	0.13
1.30.04	5	0.05	32.48	0.05	0.23	0.38	0.14
2.5.04	11	0.73	96.68	118.65	65.95	25.47	0.67
2.12.04	18	0.34	74.89	40.51	49.98	14.68	0.48
2.17.04	23	3.59	0.00	0.00	12.35	2.75	0.09
2.20.04	27	5.57	2.10	0.00	19.55	3.95	0.10
2.24.04	30	4.12	0.75	0.00	14.41	2.70	0.10
2.27.04	33	2.50	1.07	5.77	9.15	1.88	0.04
3.3.04	37	1.65	0.54	6.31	11.82	1.17	0.02
3.5.04	40	1.59	0.52	6.29	11.68	1.13	0.03
3.8.04	43	2.09	0.69	7.54	13.14	1.43	0.04
3.12.04	47	1.71	0.59	6.73	12.01	1.19	0.04
3.15.04	50	3.10	0.97	6.96	10.18	2.39	0.04
3.19.04	54	3.99	1.20	8.27	11.20	3.10	0.17
3.26.04	61	3.00	0.87	6.76	10.14	2.36	0.00
3.30.04	64	4.84	1.70	9.19	11.80	3.44	0.25
4.12.04	77	4.79	1.67	8.51	11.61	4.94	0.29
4.19.04	84	4.88	1.65	8.47	11.55	5.14	0.45
4.26.04	91	3.20	1.00	6.75	9.99	3.59	0.00
5.17.04	113	3.14	0.89	8.67	15.85	3.67	0.13
5.24.04	120	1.79	0.50	5.06	12.93	2.00	0.11
6.14.04	140	3.91	1.12	10.00	17.37	4.35	0.28
6.21.04	147	1.27	0.34	3.75	10.79	1.41	0.07
7.6.04	163	1.55	0.00	3.68	11.60	1.79	0.07
7.13.04	170	3.17	1.19	8.02	23.20	3.74	0.11
7.20.04	177	2.15	0.78	5.43	15.83	2.43	0.01
7.26.04	183	1.88	0.58	4.71	13.96	2.16	0.09
8.10.04	197	1.63	0.49	4.94	15.76	2.07	0.06
8.16.04	203	1.48	0.49	4.50	14.62	1.83	0.07
8.31.04	218	0.93	0.32	2.83	9.59	1.19	0.04
9.28.04	246	2.17	0.81	6.78	17.77	2.54	0.10

Table A6: LCFA Concentration Data for Microcosm 3D

Date	Day	Concentration					
		Palmitate mM	Stearate mM	Oleate mM	Linoleate mM	Linolenate mM	Arachidate mM
1.21.04	1	0.05	0.56	0.04	0.11	0.18	0.02
2.2.04	8	0.05	0.09	0.06	0.18	0.35	0.15
2.7.04	13	0.05	0.47	0.05	0.43	0.18	0.12
2.12.04	18	0.05	0.58	0.06	0.27	0.45	0.14
2.17.04	23	0.10	0.03	0.39	1.16	0.06	0.00
2.20.04	26	3.39	1.30	9.41	15.18	2.08	0.05
2.24.04	30	3.77	0.76	0.00	13.43	2.58	0.10
2.27.04	33	3.52	0.77	0.00	12.12	2.47	0.09
3.2.04	37	1.40	0.46	5.26	11.14	0.96	0.02
3.5.04	40	2.50	0.84	8.30	13.83	1.61	0.05
3.8.04	43	2.40	0.74	7.96	13.66	1.73	0.04
3.12.04	47	2.53	0.94	8.42	13.87	1.67	0.05
3.15.04	50	4.80	1.48	9.07	11.95	3.68	0.18
3.19.04	54	6.25	1.90	10.04	13.26	4.96	0.20
3.26.04	61	4.27	1.18	8.43	11.53	3.48	0.16
3.30.04	64	7.78	2.74	11.09	14.30	5.73	0.40
4.12.04	77	4.73	1.60	8.38	11.61	5.09	0.21
4.19.04	84	4.61	1.48	8.25	11.37	5.03	0.60
4.26.04	91	4.70	1.50	8.21	11.40	5.33	0.20
5.17.04	113	4.15	1.14	10.38	17.85	4.62	0.25
5.24.04	120	3.14	0.83	8.58	15.78	3.70	0.14
6.14.04	140	3.44	1.00	9.26	16.46	3.86	0.21
6.21.04	147	1.68	0.46	4.76	12.56	1.93	0.10
7.6.04	163	2.97	1.03	7.62	22.31	3.47	0.13
7.13.04	170	2.01	0.66	5.00	14.99	2.37	0.13
7.20.04	177	2.81	0.98	6.89	20.24	3.12	0.17
7.26.04	183	6.22	1.81	15.68	39.46	7.44	0.34
8.10.04	197	2.13	0.67	6.52	17.86	2.65	0.10
8.16.04	203	1.11	0.36	3.38	11.57	1.45	0.00
8.31.04	218	0.89	0.29	2.90	9.47	1.15	0.05
9.28.04	246	1.74	0.56	5.38	16.18	2.17	0.06

Table A7: LCFA Concentration Data for Microcosm 4

Date	Day	Concentration					
		Palmitate mM	Stearate mM	Oleate mM	Linoleate mM	Linolenate mM	Arachidate mM
1.21.04	1	0.06	4.63	0.40	0.47	0.61	0.02
2.2.04	8	0.25	91.41	19.85	44.10	10.72	0.30
2.7.04	13	0.00	0.00	0.00	12.48	0.00	0.00
2.12.04	18	0.00	0.00	0.00	11.34	0.00	0.00
2.17.04	23	0.00	0.00	0.00	0.00	0.00	0.00
2.20.04	27	0.00	0.00	0.82	13.26	0.00	0.00
2.24.04	30	0.05	0.00	0.85	9.72	0.09	0.00
2.27.04	33	0.68	0.00	0.87	14.13	0.08	0.00
3.3.04	37	0.03	0.00	0.67	12.42	0.05	0.00
3.5.04	40	0.00	0.00	0.54	11.78	0.00	0.01
3.8.04	43	0.00	0.00	0.68	12.91	0.00	0.01
3.12.04	47	0.00	0.00	0.61	12.47	0.00	0.01
3.15.04	50	0.00	0.00	0.81	11.29	0.09	0.00
3.19.04	54	0.00	0.00	0.89	11.66	0.10	0.00
3.26.04	61	0.00	0.00	0.87	11.60	0.11	0.00
3.30.04	64	0.00	0.00	1.30	13.10	0.16	0.00
4.12.04	77	0.14	0.00	1.39	13.09	0.25	0.00
4.19.04	84	0.13	0.00	1.42	13.15	0.29	0.38
4.26.04	91	0.00	0.00	1.03	12.06	0.20	0.00
5.17.04	113	0.00	0.00	0.00	18.26	0.00	0.00
5.24.04	120	0.00	0.00	0.00	17.77	0.00	0.00
6.14.04	140	0.00	0.00	0.00	22.16	0.33	0.00
6.21.04	147	0.00	0.00	0.00	18.78	0.00	0.00
7.6.04	163	0.00	0.00	0.69	22.95	0.13	0.00
7.13.04	170	0.00	0.00	0.91	25.87	0.16	0.00
7.20.04	177	0.00	0.00	0.67	23.42	0.12	0.00
7.26.04	183	0.00	0.00	0.67	22.98	0.11	0.00
8.10.04	197	0.03	0.00	0.63	18.38	0.10	0.02
8.16.04	203	0.00	0.00	0.49	16.39	0.07	0.00
8.31.04	218	0.00	0.00	0.83	19.22	0.09	0.00
9.28.04	246	0.00	0.00	0.52	17.13	0.09	0.00

Table A8: LCFA Concentration Data for Microcosm 4D

Date	Day	Palmitate mM	Stearate mM	Oleate mM	Linoleate mM	Linolenate mM	Arachidate mM
1.21.04	1	0.05	0.00	0.07	0.04	0.07	0.02
2.5.04	11	0.05	0.64	0.06	0.22	0.32	0.16
2.12.04	18	0.05	0.08	0.01	0.13	0.12	0.07
2.17.04	23	0.00	0.00	0.00	0.01	0.00	0.00
2.20.04	27	0.00	0.00	1.19	15.11	0.00	0.00
2.24.04	30	0.06	0.00	1.12	10.43	0.08	0.00
2.27.04	33	2.03	0.00	1.57	16.74	0.12	0.00
3.3.04	37	0.02	0.00	0.51	11.62	0.04	0.00
3.5.04	40	0.00	0.00	0.64	12.64	0.00	0.01
3.8.04	43	0.00	0.00	0.35	9.43	0.00	0.00
3.12.04	47	0.00	0.00	0.97	14.29	0.00	0.01
3.15.04	50	0.00	0.00	0.79	11.44	0.10	0.00
3.19.04	54	0.00	0.00	1.04	12.29	0.14	0.00
3.26.04	61	0.00	0.00	1.03	12.59	0.16	0.00
3.30.04	64	0.00	0.00	1.22	12.78	0.16	0.00
4.12.04	77	0.16	0.00	1.67	13.92	0.27	0.00
4.19.04	84	0.16	0.00	1.66	14.12	0.45	0.06
4.26.04	91	0.00	0.00	0.93	11.35	0.18	0.00
5.17.04	113	0.00	0.00	0.00	22.41	0.00	0.00
5.24.04	120	0.00	0.00	0.00	16.43	0.00	0.00
6.14.04	140	0.00	0.00	0.00	20.23	0.26	0.00
6.21.04	147	0.00	0.00	0.00	15.07	0.00	0.00
7.6.04	163	0.00	0.00	0.67	22.80	0.12	0.00
7.13.04	170	0.00	0.00	0.45	15.38	0.07	0.00
7.20.04	177	0.00	0.00	1.27	39.20	0.23	0.00
7.26.04	183	0.00	0.00	0.76	27.65	0.00	0.00
8.10.04	197	0.03	0.00	0.98	21.09	0.14	0.00
8.16.04	203	0.00	0.00	0.53	16.82	0.07	0.00
8.31.04	218	0.00	0.00	0.46	15.06	0.05	0.00
9.28.04	246	0.00	0.00	0.32	12.88	0.05	0.00

Table A9: LCFA Concentration Data for Microcosm 5

Date	Day	Concentration					
		Palmitate mM	Stearate mM	Oleate mM	Linoleate mM	Linolenate mM	Arachidate mM
1.21.04	1	0.05	8.66	2.56	2.01	3.33	0.09
2.7.04	13	0.05	0.29	0.04	0.24	0.22	0.11
2.12.04	18	0.05	0.27	0.04	0.24	0.23	0.11
2.17.04	23	0.00	0.00	0.00	0.01	0.00	0.00
2.20.04	26	0.00	0.00	0.00	0.00	0.00	0.00
2.24.04	30	0.00	0.00	0.00	0.00	0.00	0.00
2.27.04	33	0.00	0.00	0.00	0.00	0.00	0.00
3.3.04	37	0.00	0.00	0.00	0.00	0.00	0.00
3.5.04	40	0.00	0.00	0.01	0.03	0.00	0.00
3.8.04	43	0.00	0.00	0.01	0.03	0.00	0.00
3.12.04	47	0.00	0.00	0.01	0.05	0.00	0.00
3.15.04	50	0.00	0.00	0.01	0.02	0.00	0.00
3.19.04	54	0.00	0.00	0.00	0.03	0.00	0.00
3.26.04	61	0.00	0.00	0.00	0.03	0.00	0.00
3.30.04	64	0.00	0.00	0.01	0.03	0.00	0.00
4.12.04	77	0.01	0.00	0.02	0.04	0.00	0.00
4.19.04	84	0.01	0.00	0.02	0.11	0.01	0.02
4.26.04	91	0.01	0.00	0.01	0.02	0.00	0.00
5.17.04	113	0.00	0.00	0.00	0.03	0.00	0.00
5.24.04	120	0.00	0.00	0.00	0.13	0.00	0.00
6.14.04	140	0.00	0.00	0.00	0.04	0.00	0.00
6.21.04	147	0.00	0.00	0.00	0.02	0.00	0.00
7.6.04	163	0.00	0.00	0.00	0.00	0.00	0.00
7.13.04	170	0.00	0.00	0.00	0.00	0.00	0.00
7.20.04	177	0.00	0.00	0.00	0.00	0.00	0.00
7.26.04	183	0.00	0.00	0.00	0.00	0.00	0.00
8.10.04	197	0.00	0.00	0.00	0.00	0.00	0.00
8.16.04	203	0.00	0.00	0.00	0.00	0.00	0.00
8.31.04	218	0.00	0.00	0.00	0.00	0.00	0.00
9.28.04	246	0.00	0.00	0.00	0.00	0.00	0.00

Table A10: LCFA Concentration Data for Microcosm 5D

Date	Day	Concentration					
		Palmitate mM	Stearate mM	Oleate mM	Linoleate mM	Linolenate mM	Arachidate mM
1.21.04	1	0.05	0.99	0.06	0.15	0.23	0.02
2.2.04	8	0.05	0.92	0.12	0.21	0.32	0.21
2.7.04	13	0.05	0.38	0.05	0.25	0.25	0.12
2.12.04	18	0.05	0.44	0.09	0.09	0.16	0.02
2.17.04	23	0.00	0.00	0.01	0.01	0.00	0.00
2.20.04	26	0.00	0.00	0.00	0.00	0.00	0.00
2.24.04	30	0.00	0.00	0.00	0.00	0.00	0.00
2.27.04	33	0.00	0.00	0.00	0.00	0.00	0.00
3.2.04	37	0.00	0.00	0.00	0.00	0.00	0.00
3.5.04	40	0.00	0.00	0.01	0.02	0.00	0.00
3.8.04	43	0.00	0.00	0.01	0.02	0.00	0.00
3.12.04	47	0.01	0.00	0.01	0.05	0.00	0.00
3.15.04	50	0.00	0.00	0.01	0.02	0.00	0.00
3.19.04	54	0.00	0.00	0.00	0.02	0.00	0.00
3.26.04	61	0.00	0.00	0.00	0.02	0.00	0.00
3.30.04	64	0.00	0.00	0.01	0.03	0.00	0.00
4.12.04	77	0.01	0.00	0.03	0.05	0.01	0.01
4.19.04	84	0.02	0.01	0.04	0.08	0.01	0.01
4.26.04	91	0.04	0.02	0.04	0.02	0.00	0.01
5.17.04	113	0.00	0.00	0.00	0.01	0.00	0.00
5.24.04	120	0.00	0.00	0.00	0.04	0.00	0.00
6.14.04	140	0.00	0.00	0.00	0.03	0.00	0.00
6.21.04	147	0.00	0.00	0.00	0.01	0.00	0.00
7.6.04	163	0.00	0.00	0.00	0.00	0.00	0.00
7.13.04	170	0.00	0.00	0.00	0.00	0.00	0.00
7.20.04	177	0.00	0.00	0.00	0.00	0.00	0.00
7.26.04	183	0.00	0.00	0.00	0.00	0.00	0.00
8.10.04	197	0.00	0.00	0.00	0.00	0.00	0.00
8.16.04	203	0.00	0.00	0.00	0.00	0.00	0.00
8.31.04	218	0.00	0.00	0.00	0.00	0.00	0.00
9.28.04	246	0.00	0.00	0.00	0.00	0.00	0.00

Table A11: LCFA Concentration Data for Microcosm 6

Date	Day	Concentration					
		Palmitate mM	Stearate mM	Oleate mM	Linoleate mM	Linolenate mM	Arachidate mM
1.21.04	1	0.05	0.10	0.01	0.09	0.15	0.09
1.30.04	5	0.05	0.45	0.06	0.14	0.22	0.15
2.5.04	11	0.05	-0.27	-0.03	0.17	0.07	0.02
2.12.04	18	0.05	0.49	0.10	0.36	0.16	0.02
2.17.04	23	0.74	0.00	0.00	0.00	0.00	0.00
2.20.04	27	0.00	0.00	1.60	17.25	0.00	0.00
2.24.04	30	0.07	0.00	1.70	11.67	0.12	0.00
2.27.04	33	0.09	0.00	2.20	19.41	0.16	0.00
3.2.04	37	0.07	0.00	1.45	17.55	0.10	0.00
3.5.04	40	0.00	0.00	0.76	13.87	0.00	0.01
3.8.04	43	0.00	0.00	0.61	12.15	0.00	0.01
3.12.04	47	0.00	0.00	0.79	13.40	0.00	0.01
3.15.04	50	0.00	0.00	0.97	11.82	0.12	0.00
3.19.04	54	0.00	0.00	0.84	11.59	0.12	0.00
3.26.04	61	0.00	0.00	0.98	12.02	0.12	0.00
3.30.04	64	0.00	0.00	0.76	10.82	0.10	0.00
4.12.04	77	0.11	0.00	1.46	13.36	0.26	0.00
4.19.04	84	0.08	0.00	1.75	14.32	0.34	0.00
4.26.04	91	0.00	0.00	1.52	13.30	0.30	0.00
5.17.04	113	0.00	0.00	0.00	25.44	0.00	0.00
5.24.04	120	0.00	0.00	0.00	17.35	0.00	0.00
6.14.04	140	0.00	0.00	0.00	22.67	0.00	0.00
6.21.04	147	0.00	0.00	0.00	14.55	0.00	0.00
7.6.04	163	0.00	0.00	0.41	12.68	0.08	0.00
7.13.04	170	0.00	0.00	0.40	12.75	0.08	0.00
7.20.04	177	0.00	0.00	0.24	8.44	0.04	0.00
7.26.04	183	0.00	0.00	0.24	8.13	0.04	0.00
8.10.04	197	0.02	0.00	0.27	6.71	0.04	0.00
8.16.04	203	0.00	0.00	0.13	4.93	0.02	0.00
8.31.04	218	0.00	0.00	0.23	6.20	0.03	0.00
9.28.04	246	0.02	0.00	0.28	6.74	0.05	0.01

Table A12: LCFA Concentration Data for Microcosm 7

Date	Day	Concentration					
		Palmitate mM	Stearate mM	Oleate mM	Linoleate mM	Linolenate mM	Arachidate mM
1.21.04	1	0.05	0.47	0.06	0.08	0.23	0.14
2.2.04	8	0.05	-0.27	-0.03	8.24	0.07	0.02
2.7.04	13	0.05	0.68	0.08	0.33	0.30	0.16
2.12.04	18	0.05	1.14	0.19	0.18	0.24	0.02
2.17.04	23	0.00	0.00	0.00	0.01	0.00	0.00
2.20.04	26	0.00	0.00	0.00	0.00	0.00	0.00
2.24.04	30	0.00	0.00	0.00	0.00	0.00	0.00
2.27.04	33	0.00	0.00	0.00	0.00	0.00	0.00
3.2.04	37	0.00	0.00	0.00	0.00	0.00	0.00
3.5.04	40	0.00	0.00	0.00	0.05	0.00	0.00
3.8.04	43	0.00	0.00	0.00	0.03	0.00	0.00
3.12.04	47	0.00	0.00	0.01	0.14	0.00	0.00
3.15.04	50	0.00	0.00	0.01	0.02	0.00	0.00
3.19.04	54	0.00	0.00	0.01	0.02	0.00	0.00
3.26.04	61	0.00	0.00	0.00	0.02	0.00	0.00
3.30.04	64	0.00	0.00	0.01	0.03	0.00	0.00
4.12.04	77	0.00	0.00	0.01	0.04	0.00	0.00
4.19.04	84	0.01	0.00	0.03	0.06	0.01	0.00
4.26.04	91	0.01	0.01	0.01	0.01	0.00	0.00
5.17.04	113	0.00	0.00	0.00	0.04	0.00	0.00
5.24.04	120	0.00	0.00	0.00	0.02	0.00	0.00
6.14.04	140	0.00	0.00	0.00	0.04	0.00	0.00
6.21.04	147	0.00	0.00	0.00	0.01	0.00	0.00
7.6.04	163	0.00	0.00	0.00	0.00	0.00	0.00
7.13.04	170	0.00	0.00	0.00	0.00	0.00	0.00
7.20.04	177	0.00	0.00	0.00	0.00	0.00	0.00
7.26.04	183	0.00	0.00	0.00	0.00	0.00	0.00
8.10.04	197	0.00	0.00	0.00	0.00	0.00	0.00
8.16.04	203	0.00	0.00	0.00	0.00	0.00	0.00
8.31.04	218	0.00	0.00	0.00	0.00	0.00	0.00
9.28.04	246	0.00	0.00	0.00	0.00	0.00	0.00

Table A13: LCFA Concentration Data for Microcosm LC

Date	Day	Concentration					
		Palmitate mM	Stearate mM	Oleate mM	Linoleate mM	Linolenate mM	Arachidate mM
1.21.04	1	0.05	-0.06	0.00	0.06	0.14	0.06
2.2.04	8	0.05	0.25	0.07	0.20	0.22	0.11
2.17.04	23	0.00	0.00	0.01	0.01	0.00	0.00
2.24.04	30	0.00	0.00	0.00	0.00	0.00	0.00
3.2.04	37	0.00	0.00	0.00	0.00	0.00	0.00
3.8.04	43	0.00	0.00	0.00	0.02	0.00	0.00
3.15.04	50	0.00	0.00	0.01	0.02	0.00	0.00
3.26.04	61	0.00	0.00	0.00	0.01	0.00	0.00
3.30.04	64	0.00	0.00	0.00	0.02	0.00	0.00
4.12.04	77	0.04	0.09	0.00	0.06	0.00	0.06
4.19.04	84	0.02	0.01	0.03	0.08	0.01	0.00
5.17.04	113	0.00	0.00	0.00	0.01	0.00	0.00
5.24.04	120	0.00	0.00	0.00	0.03	0.00	0.00
6.21.04	147	0.00	0.00	0.00	0.00	0.00	0.00
7.6.04	163	0.00	0.00	0.00	0.00	0.00	0.00
7.13.04	170	0.00	0.00	0.00	0.00	0.00	0.00
7.26.04	183	0.00	0.00	0.00	0.00	0.00	0.00
8.16.04	203	0.00	0.00	0.00	0.00	0.00	0.00
9.28.04	246	0.00	0.00	0.00	0.00	0.00	0.00

Table A14: LCFA Concentration Data for Microcosm LCD

Date	Day	Concentration					
		Palmitate mM	Stearate mM	Oleate mM	Linoleate mM	Linolenate mM	Arachidate mM
1.21.04	1	0.05	0.30	0.03	0.10	0.20	0.11
2.2.04	8	0.05	0.42	0.08	0.17	0.26	0.16
2.17.04	23	0.00	0.00	0.00	0.01	0.00	0.00
2.24.04	30	0.00	0.00	0.00	0.00	0.00	0.00
3.2.04	37	0.00	0.00	0.00	0.00	0.00	0.00
3.8.04	43	0.00	0.00	0.00	0.01	0.00	0.00
3.15.04	50	0.00	0.00	0.01	0.01	0.00	0.00
3.26.04	61	0.00	0.00	0.00	0.01	0.00	0.00
3.30.04	64	0.00	0.00	0.00	0.01	0.00	0.00
4.12.04	77	0.01	0.00	0.01	0.02	0.00	0.00
4.19.04	84	0.01	0.00	0.01	0.03	0.00	0.00
5.17.04	113	0.00	0.00	0.00	0.01	0.00	0.00
5.24.04	120	0.00	0.00	0.00	0.01	0.00	0.00
6.21.04	147	0.00	0.00	0.00	0.01	0.00	0.00
7.6.04	163	0.00	0.00	0.00	0.00	0.00	0.00
7.13.04	170	0.00	0.00	0.00	0.00	0.00	0.00
7.26.04	183	0.00	0.00	0.00	0.00	0.00	0.00
8.16.04	203	0.00	0.00	0.00	0.00	0.00	0.00
9.28.04	246	0.00	0.00	0.00	0.00	0.00	0.00

Table A15: LCFA Concentration Data for Microcosm SC

Date	Day	Concentration					
		Palmitate mM	Stearate mM	Oleate mM	Linoleate mM	Linolenate mM	Arachidate mM
1.21.04	1	0.05	0.29	0.08	0.12	0.26	0.17
2.2.04	8	0.05	0.41	0.06	0.12	0.25	0.14
2.17.04	23	0.00	0.00	0.00	0.01	0.00	0.01
2.24.04	30	0.00	0.00	0.00	0.00	0.00	0.00
3.2.04	37	0.00	0.00	0.00	0.00	0.00	0.00
3.8.04	43	0.00	0.00	0.01	0.01	0.00	0.00
3.15.04	50	0.00	0.00	0.01	0.02	0.00	0.01
3.26.04	61	0.00	0.00	0.00	0.01	0.00	0.00
3.30.04	64	0.00	0.00	0.00	0.02	0.00	0.00
4.12.04	77	0.01	0.00	0.01	0.02	0.00	0.00
4.19.04	84	0.00	0.00	0.01	0.02	0.00	0.00
5.17.04	113	0.00	0.00	0.00	0.02	0.00	0.00
5.24.04	120	0.00	0.00	0.00	0.04	0.00	0.00
6.21.04	147	0.00	0.00	0.00	0.01	0.00	0.00
7.6.04	163	0.00	0.00	0.00	0.00	0.00	0.00
7.13.04	170	0.00	0.00	0.00	0.00	0.00	0.00
7.26.04	183	0.00	0.00	0.00	0.00	0.00	0.00
8.16.04	203	0.00	0.00	0.00	0.00	0.00	0.00
9.28.04	246	0.00	0.00	0.00	0.00	0.00	0.00

Table A16: LCFA Concentration Data for Microcosm SCD

		Concentration					
Date	Day	Palmitate	Stearate	Oleate	Linoleate	Linolenate	Arachidate
		mM	mM	mM	mM	mM	mM
1.21.04	1	0.05	0.60	0.08	0.18	0.27	0.17
2.2.04	8	0.05	0.22	0.04	0.11	0.20	0.11
2.17.04	23	0.00	0.00	0.00	0.00	0.00	0.00
2.24.04	30	0.00	0.00	0.00	0.00	0.00	0.00
3.2.04	37	0.00	0.00	0.01	0.04	0.00	0.00
3.8.04	43	0.00	0.00	0.00	0.01	0.00	0.00
3.15.04	50	0.00	0.00	0.00	0.00	0.00	0.00
3.26.04	61	0.00	0.00	0.00	0.01	0.00	0.00
3.30.04	64	0.00	0.00	0.00	0.02	0.00	0.00
4.12.04	77	0.01	0.00	0.02	0.04	0.00	0.00
4.19.04	84	0.01	0.00	0.02	0.03	0.00	0.00
5.17.04	113	0.00	0.00	0.00	0.01	0.00	0.00
5.24.04	120	0.00	0.00	0.00	0.02	0.00	0.00
6.21.04	147	0.00	0.00	0.00	0.01	0.00	0.00
7.6.04	163	0.00	0.00	0.00	0.00	0.00	0.00
7.13.04	170	0.00	0.00	0.00	0.00	0.00	0.00
7.26.04	183	0.00	0.00	0.00	0.00	0.00	0.00
8.16.04	203	0.00	0.00	0.00	0.00	0.00	0.00
9.28.04	246	0.00	0.00	0.00	0.00	0.00	0.00

Table A17: Chlorinated Ethene Concentration Data for Microcosm 1

Date	Day	Sample Volume,mL	Concentration, µM			
			VC	cDCE	TCE	PCE
1.25.04	1	0.2	0.00	0.00	-1.35	0.00
1.26.04	2	0.2	0.00	0.00	92.04	0.00
1.26.04	2	0.2	0.00	0.00	95.97	0.00
2.1.04	7	0.2	0.00	0.00	21.75	0.00
2.5.04	11	0.4	0.00	0.00	-6.14	0.00
2.12.03	18	1	0.00	0.00	13.51	0.00
2.17.04	23	1	0.00	0.00	3.52	0.00
2.20.04	26	1	0.00	0.00	21.11	0.00
2.24.04	30	1	0.00	0.00	57.39	0.00
2.27.04	33	1	0.00	0.00	40.93	0.00
3.2.04	37	1	0.00	0.00	28.17	0.00
3.8.04	43	1	0.00	0.00	13.36	0.00
3.13.04	48	1	0.00	0.00	10.42	0.00
3.13.04	48	1	0.00	0.00	13.89	0.00
3.15.04	50	1	0.00	0.00	35.76	0.00
3.19.04	54	1	0.00	0.00	36.23	0.00
3.19.04	54	1	0.00	0.00	47.14	0.00
3.26.04	61	1	0.00	0.00	14.31	0.00
3.29.04	64	1	0.00	0.00	22.13	0.00
4.2.04	67	1	0.00	0.00	16.27	0.00
4.5.04	70	1	0.00	0.00	30.72	0.00
4.12.04	77	1	0.00	0.00	7.52	0.00
4.19.04	84	1	0.00	0.00	11.66	0.00
4.26.04	91	2	0.00	0.00	3.14	0.00
5.3.04	98	1	0.00	0.00	12.95	0.00
6.9.04	137	1	0.00	0.00	15.10	0.00
6.14.04	142	1	0.00	0.00	19.62	0.00
6.22.04	150	5	0.00	0.00	4.14	0.00
7.01.04	158	1	0.00	0.00	13.36	0.00
7.6.04	163	1	0.00	0.00	17.01	0.00
7.13.04	170	1	0.00	0.00	17.40	0.00
7.20.04	177	1	0.00	0.00	24.28	0.00
7.26.04	183	1	0.00	0.00	24.84	0.00
8.2.04	190	0.2	0.00	0.00	51.42	0.00
8.9.04	197	0.2	0.00	0.00	55.53	0.00
8.16.04	204	0.2	0.00	0.00	47.75	0.00
8.24.04	212	0.2	0.00	0.00	87.48	0.00
8.31.04	219	0.2	0.00	0.00	26.23	0.00
9.6.04	225	0.2	0.00	0.00	58.18	0.00
9.28.04	247	0.2	0.00	0.00	58.90	0.00

Table A18: Chlorinated Ethene Concentration Data for Microcosm 1D

Date	Day	Sample Volume,mL	Concentration, µM			
			VC	cDCE	TCE	PCE
1.25.04	1	0.2	0.00	0.00	0.00	0.00
1.25.04	1	0.2	0.00	0.00	0.00	0.00
1.26.04	2	0.2	0.00	0.00	66.29	0.00
2.1.03	7	0.2	0.00	0.00	-0.08	0.00
2.5.04	11	0.4	0.00	0.00	-11.15	0.00
2.12.04	18	1	0.00	0.00	9.50	0.00
2.17.04	23	1	0.00	0.00	1.86	0.00
2.20.04	26	1	0.00	0.00	20.63	0.00
2.24.04	30	1	0.00	0.00	35.39	0.00
2.27.04	33	1	0.00	0.00	25.37	0.00
3.2.04	37	1	0.00	0.00	20.72	0.00
3.8.04	43	1	0.00	0.00	6.58	0.00
3.13.04	48	1	0.00	0.00	12.97	0.00
3.13.04	48	1	0.00	0.00	12.08	0.00
3.15.04	50	1	0.00	0.00	41.48	0.00
3.19.04	54	1	0.00	0.00	28.89	0.00
3.26.04	61	1	0.00	0.00	10.46	0.00
3.26.04	61	1	0.00	0.00	7.55	0.00
3.29.04	64	1	0.00	0.00	16.69	0.00
4.2.04	67	1	0.00	0.00	12.32	0.00
4.5.04	70	1	0.00	0.00	27.23	0.00
4.12.04	77	1	0.00	0.00	4.57	0.00
4.19.04	84	1	0.00	0.00	12.22	0.00
4.26.04	91	2	0.00	0.00	2.76	0.00
5.3.04	98	1	0.00	0.00	10.20	0.00
6.9.04	137	1	0.00	0.00	7.63	0.00
6.9.04	137	1	0.00	0.00	14.48	0.00
6.14.04	142	1	0.00	0.00	12.21	0.00
6.22.04	150	5	0.00	0.00	5.31	0.00
7.1.04	158	1	0.00	55.76	41.13	0.00
7.6.04	163	1	0.00	81.54	25.27	0.00
7.13.04	170	1	0.00	39.71	21.69	0.00
7.20.04	177	1	0.00	73.20	17.55	0.00
7.26.04	183	1	0.00	53.32	15.67	0.00
8.2.04	190	0.2	0.00	67.19	40.33	0.00
8.9.04	197	0.2	0.00	71.70	42.79	0.00
8.16.04	204	0.2	0.00	132.34	55.46	0.00
8.24.04	212	0.2	0.00	130.98	63.84	0.00
8.31.04	219	0.2	0.00	161.60	77.66	0.00
9.6.04	225	0.2	0.00	153.19	55.60	0.00
9.29.04	247	0.2	0.00	166.33	48.91	0.00

Table A19: Chlorinated Ethene Concentration Data for Microcosm 2

Date	Day	Sample Volume,mL	Concentration, µM			
			VC	cDCE	TCE	PCE
1.25.04	1	0.2	0.00	0.00	-1.19	0.00
1.26.04	2	0.2	0.00	0.00	73.54	0.00
2.1.04	7	0.2	0.00	0.00	-0.44	0.00
2.1.04	7	0.2	0.00	0.00	0.55	0.00
2.5.04	11	0.4	0.00	0.00	-11.24	0.00
2.12.04	18	1	0.00	0.00	2.39	0.00
2.17.04	23	1	0.00	0.00	1.91	0.00
2.20.04	26	1	0.00	0.00	-11.24	0.00
2.24.04	30	1	0.00	0.00	38.06	0.00
2.27.04	33	1	0.00	0.00	31.71	0.00
3.2.04	37	1	0.00	0.00	22.26	0.00
3.8.04	43	1	0.00	0.00	14.54	0.00
3.13.04	48	1	0.00	0.00	18.07	0.00
3.13.04	48	1	0.00	0.00	14.22	0.00
3.15.04	50	1	0.00	0.00	29.66	0.00
3.19.04	54	1	0.00	0.00	45.85	0.00
3.26.04	61	1	0.00	0.00	7.62	0.00
3.29.04	64	1	0.00	0.00	16.90	0.00
3.29.04	64	1	0.00	0.00	22.59	0.00
4.2.04	67	1	0.00	0.00	11.54	0.00
4.5.04	70	1	0.00	0.00	22.23	0.00
4.12.04	77	1	0.00	0.00	6.31	0.00
4.19.04	84	1	0.00	0.00	12.63	0.00
4.26.04	91	2	0.00	0.00	2.48	0.00
5.3.04	98	1	0.00	0.00	8.76	0.00
6.9.04	137	1	0.00	0.00	18.06	0.00
6.14.04	142	1	0.00	0.00	10.63	0.00
6.14.04	142	1	0.00	0.00	12.19	0.00
6.22.04	150	1	0.00	0.00	14.20	0.00
7.1.04	158	1	0.00	0.00	21.39	0.00
7.6.04	163	1	0.00	0.00	17.06	0.00
7.13.04	170	1	0.00	0.00	66.33	0.00
7.20.04	177	1	0.00	0.00	19.63	0.00
7.20.04	177	1	0.00	0.00	14.49	0.00
7.26.04	183	1	0.00	0.00	17.29	0.00
8.2.04	190	0.2	0.00	0.00	19.94	0.00
8.9.04	197	0.2	0.00	0.00	19.93	0.00
8.16.04	204	0.2	0.00	0.00	38.72	0.00
8.24.04	212	0.2	0.00	0.00	37.76	0.00
8.31.04	219	0.2	0.00	0.00	41.67	0.00
9.6.04	225	0.2	0.00	0.00	36.72	0.00
9.29.04	247	0.2	0.00	0.00	36.37	0.00

Table A20: Chlorinated Ethene Concentration Data for Microcosm 2D

Date	Day	Sample Volume,mL	Concentration, µM			
			VC	cDCE	TCE	PCE
1.25.04	1	0.2	0.00	0.00	1.07	0.00
1.26.04	2	0.2	0.00	0.00	62.17	0.00
2.1.04	7	0.2	0.00	0.00	-0.45	0.00
2.5.04	11	0.4	0.00	0.00	-10.92	0.00
2.5.04	11	0.4	0.00	0.00	-10.37	0.00
2.12.04	18	1	0.00	0.00	2.12	0.00
2.17.04	23	1	0.00	0.00	2.07	0.00
2.20.04	26	1	0.00	0.00	-11.74	0.00
2.24.04	30	1	0.00	0.00	40.26	0.00
2.27.04	33	1	0.00	0.00	21.90	0.00
3.2.04	37	1	0.00	0.00	22.70	0.00
3.8.04	43	1	0.00	0.00	12.33	0.00
3.13.04	48	1	0.00	0.00	11.11	0.00
3.13.04	48	1	0.00	0.00	14.10	0.00
3.15.04	50	1	0.00	0.00	47.45	0.00
3.19.04	54	1	0.00	0.00	40.46	0.00
3.26.04	61	1	0.00	0.00	1.16	0.00
3.29.04	64	1	0.00	0.00	25.52	0.00
4.2.04	67	1	0.00	0.00	20.98	0.00
4.2.04	67	1	0.00	0.00	20.46	0.00
4.5.04	70	1	0.00	0.00	30.24	0.00
4.12.04	77	1	0.00	0.00	8.49	0.00
4.19.04	84	1	0.00	0.00	19.61	0.00
4.26.04	91	2	0.00	0.00	2.98	0.00
5.3.04	98	1	0.00	0.00	9.75	0.00
6.9.04	137	1	0.00	0.00	13.91	0.00
6.14.04	142	1	0.00	0.00	13.42	0.00
6.22.04	150	5	0.00	0.00	4.28	0.00
7.1.04	158	1	0.00	41.00	18.00	0.00
7.6.04	163	1	0.00	53.12	22.32	0.00
7.13.04	170	1	0.00	220.40	93.01	0.00
7.20.04	177	1	0.00	47.86	29.95	0.00
7.26.04	183	0.5	0.00	73.25	52.93	0.00
7.26.04	183	0.5	0.00	89.07	25.13	0.00
8.2.04	190	0.2	0.00	23.52	50.07	0.00
8.9.04	197	0.2	0.00	23.54	50.32	0.00
8.16.04	204	0.2	0.00	79.51	79.14	0.00
8.24.04	212	0.2	0.00	91.23	85.33	0.00
8.31.04	219	0.2	0.00	85.40	76.58	0.00
9.6.04	225	0.2	0.00	124.27	90.30	0.00
9.29.04	247	0.2	0.00	147.73	128.94	0.00

Table A21: Chlorinated Ethene Concentration Data for Microcosm 3

Date	Day	Sample Volume,mL	Concentration, µM			
			VC	cDCE	TCE	PCE
1.25.04	1	0.2	0.00	0.00	1.16	0.00
1.26.04	2	0.2	0.00	0.00	1.67	0.00
2.1.04	7	0.2	0.00	0.00	6.84	0.00
2.5.04	11	0.4	0.00	0.00	5.77	0.00
2.12.04	18	1	0.00	0.00	17.02	0.00
2.12.04	18	1	0.00	0.00	14.72	0.00
2.17.04	23	1	0.00	0.00	6.34	0.00
2.20.04	26	1	0.00	0.00	24.56	0.00
2.24.04	30	1	0.00	0.00	56.29	0.00
2.27.04	33	1	0.00	0.00	27.14	0.00
3.2.04	37	1	0.00	0.00	20.03	0.00
3.8.04	43	1	0.00	0.00	4.55	0.00
3.13.04	48	1	0.00	0.00	7.21	0.00
3.13.04	48	1	0.00	0.00	7.94	0.00
3.15.04	50	1	0.00	0.00	22.57	0.00
3.26.04	61	1	0.00	0.00	7.15	0.00
3.29.04	64	1	0.00	0.00	15.32	0.00
4.2.04	67	1	0.00	0.00	13.21	0.00
4.5.04	70	1	0.00	0.00	16.36	0.00
4.5.04	70	1	0.00	0.00	21.52	0.00
4.12.04	77	1	0.00	0.00	8.76	0.00
4.19.04	84	1	0.00	0.00	15.11	0.00
4.26.04	91	2	0.00	0.00	2.87	0.00
5.3.04	98	1	0.00	0.00	9.66	0.00
6.9.04	137	1	0.00	0.00	8.82	0.00
6.14.04	142	1	0.00	0.00	7.66	0.00
6.22.04	150	5	0.00	0.00	8.93	0.00
7.1.04	158	1	0.00	0.00	12.45	0.00
7.6.04	163	1	0.00	0.00	18.10	0.00
7.13.04	170	1	0.00	-14.49	16.60	0.00
7.20.04	177	1	0.00	0.00	8.43	0.00
7.26.04	183	0.5	0.00	0.00	19.35	0.00
8.2.04	190	0.2	0.00	0.00	15.15	0.00
8.9.04	197	0.2	0.00	0.00	15.40	0.00
8.16.04	204	0.2	0.00	0.00	23.33	0.00
8.24.04	212	0.2	0.00	0.00	30.93	0.00
8.31.04	219	0.2	0.00	0.00	29.31	0.00
9.6.04	225	0.2	0.00	0.00	31.69	0.00
9.29.04	247	0.2	0.00	0.00	21.88	0.00

Table A22: Chlorinated Ethene Concentration Data for Microcosm 3D

Date	Day	Sample Volume,mL	Concentration, µM			
			VC	cDCE	TCE	PCE
1.25.04	1	0.2	0.00	0.00	-0.62	0.00
1.26.04	2	0.2	0.00	0.00	-0.37	0.00
2.1.04	7	0.2	0.00	0.00	0.07	0.00
2.5.04	11	0.4	0.00	0.00	0.00	0.00
2.12.04	18	1	0.00	0.00	1.80	0.00
2.17.04	23	1	0.00	0.00	1.83	0.00
2.17.04	23	1	0.00	0.00	1.78	0.00
2.20.04	26	1	0.00	0.00	-11.92	0.00
2.24.04	30	1	0.00	0.00	27.00	0.00
2.27.04	33	1	0.00	0.00	23.64	0.00
3.2.04	37	1	0.00	0.00	15.05	0.00
3.8.04	43	1	0.00	0.00	2.64	0.00
3.13.04	48	1	0.00	0.00	7.59	0.00
3.13.04	48	0.8	0.00	0.00	10.50	0.00
3.15.04	50	1	0.00	0.00	17.62	0.00
3.26.04	61	1	0.00	0.00	5.79	0.00
3.29.04	64	1	0.00	0.00	14.77	0.00
4.2.04	67	1	0.00	0.00	16.42	0.00
4.5.04	70	1	0.00	0.00	21.23	0.00
4.12.04	77	1	0.00	0.00	8.34	0.00
4.19.04	84	1	0.00	0.00	13.40	0.00
4.26.04	91	2	0.00	0.00	2.56	0.00
5.3.04	98	1	0.00	0.00	8.53	0.00
6.9.04	137	1	0.00	0.00	4.44	0.00
6.14.04	142	1	0.00	0.00	7.02	0.00
6.22.04	150	5	0.00	0.00	8.29	0.00
7.1.04	158	1	0.00	63.94	12.43	0.00
7.6.04	163	1	0.00	108.97	19.06	0.00
7.13.04	170	1	0.00	254.40	15.62	0.00
7.20.04	177	1	0.00	64.40	10.71	0.00
7.26.04	183	0.5	0.00	114.92	27.18	0.00
8.2.04	190	0.2	0.00	24.68	15.06	0.00
8.9.04	197	0.2	0.00	20.17	15.31	0.00
8.16.04	204	0.2	0.00	63.72	20.39	0.00
8.16.04	204	0.2	0.00	69.37	17.51	0.00
8.24.04	212	0.2	0.00	91.49	29.96	0.00
8.31.04	219	0.2	0.00	87.89	30.69	0.00
9.6.04	225	0.2	0.00	104.91	32.15	0.00
9.29.04	247	0.2	0.00	63.14	16.96	0.00

Table A23: Chlorinated Ethene Concentration Data for Microcosm 4

Date	Day	Sample Volume,mL	Concentration, µM			
			VC	cDCE	TCE	PCE
1.25.04	1	0.2	0.00	0.00	1.18	0.00
1.26.04	2	0.2	0.00	0.00	78.05	0.00
2.1.04	7	0.2	0.00	0.00	0.63	0.00
2.5.04	11	0.4	0.00	0.00	-7.55	0.00
2.12.04	18	1	0.00	0.00	2.14	0.00
2.17.04	23	1	0.00	0.00	2.89	0.00
2.20.04	26	1	0.00	0.00	-6.84	0.00
2.20.04	26	1	0.00	-18.06	26.33	0.00
2.24.04	30	1	0.00	9.50	72.60	0.00
2.27.04	33	1	0.00	10.11	37.00	0.00
3.2.04	37	1	0.00	0.28	36.44	0.00
3.8.04	43	1	0.00	0.80	23.68	0.00
3.13.04	48	1	0.00	-0.97	25.89	0.00
3.13.04	48	1	0.00	-1.27	50.57	0.00
3.15.04	50	1	0.00	-1.68	35.31	0.00
3.26.04	61	1	0.00	-5.59	15.38	0.00
3.29.04	64	1	0.00	-5.27	49.64	0.00
4.2.04	67	1	0.00	-5.25	50.53	0.00
4.5.04	70	1	0.00	-5.41	38.86	0.00
4.12.04	77	1	0.00	-2.81	22.82	0.00
4.12.04	77	1	0	-2.3987	38.739	0.00
4.19.04	84	1	0	-1.1514	44.399	0.00
4.26.04	91	2	0	2.2971	9.5982	0.00
5.3.04	98	1	0	-0.039	19.786	0.00
6.9.04	137	1	0	-14.204	20.066	0.00
6.14.04	142	1	0	-14.532	22.898	0.00
6.22.04	150	5	0	-0.5573	24.378	0.00
7.1.04	158	1	0	-12.179	90.707	0.00
7.6.04	163	1	0	-13.38	103.93	0.00
7.13.04	170	1	0	-9.7099	109.05	0.00
7.20.04	177	1	0	-18.562	56.252	0.00
7.26.04	183	0.5	0	-37.766	134	0.00
8.2.02	190	0.2	0	-28.054	67.749	0.00
8.9.04	197	0.2	0	-28.077	65.285	0.00
8.16.04	204	0.2	0	-17.258	115	0.00
8.24.04	212	0.2	0	-18.924	113.8	0.00
8.31.04	219	0.2	0	-17.737	111.23	0.00
9.6.04	225	0.2	0	-19.18	112.54	0.00
9.29.04	247	0.2	0	-3.822	88.031	0.00

Table A24: Chlorinated Ethene Concentration Data for Microcosm 4D

Date	Day	Sample Volume,mL	Concentration, µM			
			VC	cDCE	TCE	PCE
1.25.04	1	0.2	0.00	0.00	1.65	0.00
1.26.04	2	0.2	0.00	0.00	73.73	0.00
2.1.04	7	0.2	0.00	0.00	0.37	0.00
2.5.04	11	0.4	0.00	0.00	-7.13	0.00
2.12.04	18	1	0.00	0.00	3.50	0.00
2.17.04	23	1	0.00	0.00	3.30	0.00
2.20.04	26	1	0.00	0.00	-10.91	0.00
2.24.04	30	1	0.00	9.38	53.05	0.00
2.24.04	30	1	0.00	9.63	81.32	0.00
2.27.04	33	1	0.00	10.06	39.87	0.00
3.2.04	37	1	0.00	0.13	44.58	0.00
3.8.04	43	1	0.00	0.57	39.97	0.00
3.13.04	48	1	0.00	-0.27	113.28	0.00
3.13.04	48	1	0.00	-1.01	93.05	0.00
3.15.04	50	1	0.00	-0.11	69.49	0.00
3.26.04	61	1	0.00	-5.05	31.10	0.00
3.26.04	64	1	0.00	-4.75	66.85	0.00
4.2.04	67	1	0.00	-4.20	82.00	0.00
4.5.04	70	1	0.00	-5.38	56.36	0.00
4.12.04	77	1	0.00	-2.21	39.52	0.00
4.19.04	84	1	0.00	-1.24	39.43	0.00
4.26.04	91	2	0.00	2.23	18.44	0.00
5.3.04	98	1	0.00	0.32	22.30	0.00
6.9.04	137	1	0.00	-14.34	22.05	0.00
6.14.04	142	1	0.00	-15.14	23.43	0.00
6.22.04	150	5	0.00	-1.89	26.04	0.00
7.1.04	158	1	0.00	259.78	96.67	0.00
7.6.04	163	1	0.00	241.40	102.88	0.00
7.13.04	170	1	0.00	263.34	103.09	0.00
7.20.04	177	1	0.00	91.62	69.26	0.00
7.26.04	183	0.5	0.00	206.86	120.26	0.00
8.2.04	190	0.2	0.00	102.40	86.07	0.00
8.9.04	197	0.2	0.00	57.33	83.61	0.00
8.16.04	204	0.2	0.00	169.40	121.97	0.00
8.24.04	212	0.2	0.00	128.38	122.05	0.00
8.31.04	219	0.2	0.00	122.14	117.75	0.00
9.6.04	225	0.2	0.00	142.74	115.39	0.00
9.29.04	247	0.2	0.00	96.56	89.71	0.00

Table A25: Chlorinated Ethene Concentration Data for Microcosm 5

Date	Day	Sample Volume,mL	Concentration, µM			
			VC	cDCE	TCE	PCE
1.25.04	1	0.2	0.00	0.00	2.72	0.00
1.26.04	2	0.2	0.00	0.00	89.51	0.00
2.1.04	7	0.2	0.00	0.00	10.65	0.00
2.5.04	11	0.4	0.00	0.00	81.62	0.00
2.12.04	18	1	0.00	0.00	53.34	0.00
2.17.04	23	1	0.00	0.00	35.22	0.00
2.20.04	26	1	0.00	0.00	71.75	0.00
2.24.04	30	1	0.00	0.00	82.98	0.00
2.27.04	33	1	0.00	0.00	64.70	0.00
2.27.04	33	1	0.00	0.00	63.37	0.00
3.2.04	37	1	0.00	0.00	70.65	0.00
3.8.04	43	1	0.00	0.00	109.22	0.00
3.13.04	48	1	0.00	0.00	117.46	0.00
3.13.04	48	1	0.00	0.00	105.03	0.00
3.15.04	50	1	0.00	0.00	116.66	0.00
3.26.04	61	0.5	0.00	0.00	91.14	0.00
3.29.04	64	1	0.00	0.00	126.30	0.00
4.2.04	67	0.5	0.00	0.00	135.10	0.00
4.5.04	70	0.5	0.00	0.00	143.82	0.00
4.12.04	77	0.5	0.00	0.00	107.16	0.00
4.19.04	84	0.5	0.00	0.00	73.85	0.00
4.19.04	84	0.5	0.00	0.00	80.26	0.00
4.26.04	91	0.5	0.00	0.00	73.43	0.00
4.26.04	91	0.5	0.00	0.00	76.92	0.00
5.3.04	98	0.5	0.00	0.00	49.19	0.00
6.9.04	137	1	0.00	-14.67	38.66	0.00
6.14.04	142	1	0.00	-16.12	31.60	0.00
6.22.04	150	5	0.00	-2.78	37.32	0.00
7.1.04	158	0.5	0.00	-31.66	124.17	0.00
7.6.04	163	0.5	0.00	0.00	124.23	0.00
7.13.04	170	0.2	0.00	-78.72	238.79	0.00
7.20.04	177	0.2	0.00	-107.43	292.33	0.00
7.26.04	183	0.2	0.00	0.00	315.69	0.00
8.2.04	190	0.2	0.00	-30.05	159.98	0.00
8.9.04	197	0.2	0.00	-30.05	86.07	0.00
8.16.04	204	0.2	0.00	-20.94	129.81	0.00
8.24.04	212	0.2	0.00	0.00	146.41	0.00
8.31.04	219	0.2	0.00	0.00	115.00	0.00
9.6.04	225	0.2	0.00	0.00	132.01	0.00
9.29.04	247	0.2	0.00	0.00	92.04	0.00

Table A26: Chlorinated Ethene Concentration Data for Microcosm 5D

Date	Day	Sample Volume,mL	Concentration, µM			
			VC	cDCE	TCE	PCE
1.25.04	1	0.2	0.00	0.00	3.24	0.00
1.26.04	2	0.2	0.00	0.00	88.47	0.00
2.1.04	7	0.2	0.00	0.00	9.06	0.00
2.5.04	11	0.4	0.00	0.00	57.35	0.00
2.12.04	18	1	0.00	0.00	31.41	0.00
2.17.04	23	1	0.00	0.00	34.70	0.00
2.20.04	26	1	0.00	0.00	89.26	0.00
2.24.04	30	1	0.00	0.00	38.39	0.00
2.27.04	33	1	0.00	0.00	66.51	0.00
3.2.04	37	1	0.00	0.00	74.91	0.00
3.2.04	37	1	0.00	0.00	76.69	0.00
3.8.04	43	1	0.00	0.00	88.84	0.00
3.13.04	48	1	0.00	0.00	106.54	0.00
3.13.04	48	1	0.00	0.00	98.57	0.00
3.15.04	50	1	0.00	0.00	112.29	0.00
3.26.04	61	0.5	0.00	0.00	82.64	0.00
3.29.04	64	1	0.00	0.00	129.14	0.00
4.2.04	67	0.5	0.00	0.00	180.32	0.00
4.5.04	70	0.5	0.00	0.00	150.77	0.00
4.12.04	77	0.5	0.00	0.00	114.80	0.00
4.19.04	84	0.5	0.00	0.00	75.03	0.00
4.26.04	91	0.5	0.00	0.00	76.55	0.00
5.3.04	98	0.5	0.00	0.00	48.01	0.00
6.9.04	137	1	0.00	-15.82	41.47	0.00
6.14.04	142	1	0.00	-16.02	35.05	0.00
6.22.04	150	5	0.00	-2.92	31.87	0.00
7.1.04	158	0.5	0.00	120.32	132.91	0.00
7.6.04	163	0.5	0.00	95.79	107.17	0.00
7.13.04	170	0.2	0.00	278.71	305.47	0.00
7.20.04	177	0.2	0.00	365.74	374.71	0.00
7.26.04	183	0.2	0.00	199.38	207.20	0.00
8.2.04	190	0.2	0.00	112.38	119.93	0.00
8.9.04	197	0.2	0.00	83.75	115.00	0.00
8.16.04	204	0.2	0.00	155.15	152.24	0.00
8.24.04	212	0.2	0.00	179.92	130.65	0.00
8.31.04	219	0.2	0.00	156.87	174.71	0.00
9.6.04	224	0.2	0.00	176.25	147.94	0.00
9.29.04	247	0.2	0.00	90.45	86.14	0.00

Table A27: Chlorinated Ethene Concentration Data for Microcosm 6

Date	Day	Sample Volume,mL	Concentration, µM			
			VC	cDCE	TCE	PCE
1.25.04	1	0.2	0.00	0.00	0.00	0.00
1.26.04	2	0.2	0.00	0.00	51.69	0.00
2.1.04	7	0.2	0.00	0.00	1.92	0.00
2.5.04	11	0.4	0.00	0.00	-1.16	0.00
2.12.04	18	1	0.00	0.00	2.78	0.00
2.17.04	23	1	0.00	0.00	2.87	0.00
2.20.04	26	1	0.00	0.00	18.12	0.00
2.24.04	30	1	0.00	9.48	74.73	0.00
2.27.04	33	1	0.00	10.09	79.95	0.00
3.2.04	37	1	0.00	-2.14	51.70	0.00
3.8.04	43	1	0.00	0.00	29.32	0.00
3.8.04	43	1	0.00	0.09	23.25	0.00
3.13.04	48	1	0.00	0.00	30.00	0.00
3.13.04	48	1	0.00	0.00	33.15	0.00
3.15.04	50	1	0.00	-0.59	63.00	0.00
3.26.04	61	1	0.00	0.00	28.90	0.00
3.29.04	64	1	0.00	0.00	44.90	0.00
4.2.04	67	1	0.00	-6.47	78.16	0.00
4.5.04	70	1	0.00	-7.49	66.60	0.00
4.12.04	77	1	0.00	-3.01	45.95	0.00
4.19.04	84	1	0.00	-1.93	61.85	0.00
4.26.04	91	2	0.00	1.63	15.91	0.00
5.3.04	98	1	0.00	-0.40	19.24	0.00
5.3.04	98	1	0.00	-0.50	18.86	0.00
6.9.04	137	1	0.00	-14.69	25.76	0.00
6.14.04	142	1	0.00	-14.02	16.96	0.00
6.22.04	150	5	0.00	-1.93	23.14	0.00
7.1.04	158	1	0.00	-14.02	116.68	0.00
7.6.04	163	1	0.00	-14.41	108.86	0.00
7.13.04	170	1	0.00	-12.92	143.80	0.00
7.20.04	177	1	0.00	-18.78	111.38	0.00
7.26.04	183	0.5	0.00	-39.29	153.67	0.00
8.2.04	190	0.2	0.00	-21.97	135.93	0.00
8.9.04	197	0.2	0.00	-26.47	90.76	0.00
8.16.04	204	0.2	0.00	-17.19	139.10	0.00
8.24.04	212	0.2	0.00	-16.43	106.95	0.00
8.31.04	219	0.2	0.00	-15.62	125.76	0.00
9.6.04	225	0.2	0.00	-15.94	119.11	0.00
9.29.04	247	0.2	0.00	-3.86	57.32	0.00

Table A28: Chlorinated Ethene Concentration Data for Microcosm 7

Date	Day	Sample Volume,mL	Concentration, µM			
			VC	cDCE	TCE	PCE
1.25.04	1	0.2	0.00	0.00	0.82	0.00
1.26.04	2	0.2	0.00	0.00	64.64	0.00
2.1.04	7	0.2	0.00	0.00	9.95	0.00
2.5.04	11	0.4	0.00	0.00	174.67	0.00
2.12.04	18	1	0.00	0.00	38.37	0.00
2.17.04	23	1	0.00	0.00	40.66	0.00
2.20.04	26	1	0.00	0.00	162.31	0.00
2.24.04	30	1	0.00	0.00	163.04	0.00
2.27.04	33	1	0.00	0.00	143.47	0.00
3.2.04	37	1	0.00	0.00	80.70	0.00
3.8.04	43	1	0.00	0.00	190.56	0.00
3.13.04	48	1	0.00	0.00	108.56	0.00
3.13.04	48	1	0.00	0.00	115.47	0.00
3.15.04	50	1	0.00	0.00	118.48	0.00
3.19.04	54	1	0.00	0.00	112.74	0.00
3.26.04	61	0.5	0.00	0.00	107.64	0.00
3.29.04	64	1	0.00	0.00	115.66	0.00
4.2.04	67	0.5	0.00	0.00	149.42	0.00
4.5.04	70	0.5	0.00	0.00	133.76	0.00
4.12.04	77	0.5	0.00	0.00	97.22	0.00
4.19.04	84	0.5	0.00	0.00	84.59	0.00
4.26.04	91	0.5	0.00	0.00	82.30	0.00
5.3.04	98	0.5	0.00	0.00	74.83	0.00
6.9.04	137	1	0.00	0.00	46.44	0.00
6.14.04	142	1	0.00	0.00	42.04	0.00
6.22.04	150	5	0.00	0.00	32.54	0.00
7.1.04	158	0.5	0.00	178.31	139.21	0.00
7.6.04	163	1	0.00	288.05	128.86	0.00
7.13.04	170	0.2	0.00	438.81	338.85	0.00
7.20.04	177	0.2	0.00	477.13	346.34	0.00
7.26.04	183	0.2	0.00	346.63	453.32	0.00
8.2.04	190	0.2	0.00	177.05	138.99	0.00
8.9.04	197	0.2	0.00	94.42	93.82	0.00
8.16.04	204	0.2	0.00	252.34	161.83	0.00
8.24.04	212	0.2	0.00	196.20	120.90	0.00
8.31.04	219	0.2	0.00	190.59	152.35	0.00
9.6.04	225	0.2	0.00	153.33	134.39	0.00
9.29.04	247	0.2	0.00	120.17	97.19	0.00

Table A29: Chlorinated Ethene Concentration Data for Microcosm LC

Date	Day	Sample Volume,mL	Concentration, µM			
			VC	cDCE	TCE	PCE
1.26.04	2	0.2	0.00	0.00	-1.98	0.00
1.26.04	2	0.2	0.00	0.00	67.95	0.00
2.1.04	7	0.2	0.00	0.00	4.19	0.00
2.12.04	18	1	0.00	0.00	37.69	0.00
2.25.04	31	0.5	0.00	0.00	160.42	0.00
3.8.04	43	0.2	0.00	0.00	28.90	0.00
3.13.04	48	0.2	0.00	0.00	129.77	0.00
3.13.04	48	0.2	0.00	0.00	172.22	0.00
3.26.04	61	0.2	0.00	0.00	73.72	0.00
4.5.04	70	0.2	0.00	0.00	116.59	0.00
4.12.04	77	0.2	0.00	0.00	38.19	0.00
4.19.04	84	0.2	0.00	0.00	62.23	0.00
4.26.04	91	0.2	0.00	0.00	52.69	0.00
5.3.04	98	0.2	0.00	0.00	107.35	0.00
6.16.04	141	0.2	0.00	0.00	54.05	0.00
7.26.04	181	0.2	0.00	0.00	139.17	0.00
8.17.04	205	0.2	0.00	0.00	136.55	0.00
8.31.04	219	0.2	0.00	0.00	121.79	0.00
9.29.04	247	0.2	0.00	0.00	81.50	0.00

Table A30: Chlorinated Ethene Concentration Data for Microcosm LCD

Date	Day	Sample Volume,mL	Concentration, µM			
			VC	cDCE	TCE	PCE
1.26.04	2	0.2	0.00	0.00	0.00	0.00
1.26.04	2	0.2	0.00	0.00	88.13	0.00
2.2.04	8	0.2	0.00	0.00	4.84	0.00
2.12.04	18	1	0.00	0.00	56.14	0.00
2.25.04	31	0.5	0.00	0.00	175.80	0.00
3.8.04	43	0.2	0.00	0.00	34.22	0.00
3.13.04	48	0.2	0.00	0.00	187.09	0.00
3.13.04	48	0.2	0.00	0.00	288.55	0.00
3.26.04	61	0.2	0.00	0.00	89.46	0.00
4.5.04	70	0.2	0.00	0.00	184.48	0.00
4.12.04	77	0.2	0.00	0.00	76.07	0.00
4.19.04	84	0.2	0.00	0.00	83.83	0.00
4.26.04	91	0.2	0.00	0.00	77.56	0.00
5.3.04	98	0.2	0.00	0.00	116.52	0.00
6.16.04	141	0.2	0.00	0.00	80.37	0.00
7.26.04	181	0.2	0.00	172.98	135.02	0.00
8.17.04	205	0.2	0.00	203.47	150.84	0.00
8.31.04	219	0.2	0.00	188.32	137.06	0.00
9.29.04	247	0.2	0.00	108.59	82.93	0.00

Table A31: Chlorinated Ethene Concentration Data for Microcosm SC

Date	Day	Sample Volume,mL	Concentration, µM			
			VC	cDCE	TCE	PCE
1.26.04	2	0.2	0.00	0.00	0.00	0.00
1.26.04	2	0.2	0.00	0.00	88.83	0.00
2.2.04	8	0.2	0.00	0.00	1.05	0.00
2.2.04	8	0.2	0.00	0.00	5.60	0.00
2.12.04	18	1	0.00	0.00	29.92	0.00
2.25.04	31	0.5	0.00	0.00	98.71	0.00
3.8.04	43	0.2	0.00	0.00	16.74	0.00
3.14.04	49	0.2	0.00	0.00	65.15	0.00
3.14.04	49	0.2	0.00	0.00	103.14	0.00
3.26.04	61	0.2	0.00	0.00	49.36	0.00
4.5.04	70	0.2	0.00	0.00	112.35	0.00
4.12.04	77	0.2	0.00	0.00	30.27	0.00
4.19.04	84	0.2	0.00	0.00	29.84	0.00
4.26.04	91	0.2	0.00	0.00	39.17	0.00
5.3.04	98	0.2	0.00	0.00	56.17	0.00
6.16.04	141	0.2	0.00	0.00	41.15	0.00
7.26.04	181	0.2	0.00	0.00	230.67	0.00
8.17.04	205	0.2	0.00	0.00	211.56	0.00
8.31.04	219	0.2	0.00	0.00	184.72	0.00
9.29.04	247	0.2	0.00	0.00	93.27	0.00

Table A32: Chlorinated Ethene Concentration Data for Microcosm SCD

Date	Day	Sample Volume,mL	Concentration, µM			
			VC	cDCE	TCE	PCE
1.26.04	2	0.2	0.00	0.00	0.00	0.00
1.26.04	2	0.2	0.00	0.00	84.49	0.00
2.2.04	8	0.2	0.00	0.00	4.38	0.00
2.12.04	18	1	0.00	0.00	27.83	0.00
2.25.04	31	0.5	0.00	0.00	100.18	0.00
3.8.04	43	0.2	0.00	0.00	28.82	0.00
3.8.04	43	0.2	0.00	0.00	30.00	0.00
3.14.04	49	0.2	0.00	0.00	91.54	0.00
3.14.04	49	0.2	0.00	0.00	75.91	0.00
3.26.04	61	0.2	0.00	0.00	87.24	0.00
4.5.04	70	0.2	0.00	0.00	104.79	0.00
4.12.04	77	0.2	0.00	0.00	34.43	0.00
4.19.04	84	0.2	0.00	0.00	49.54	0.00
4.26.04	91	0.2	0.00	0.00	48.69	0.00
5.3.04	98	0.2	0.00	0.00	72.52	0.00
6.16.04	141	0.2	0.00	0.00	79.86	0.00
7.26.04	181	0.2	0.00	398.74	265.09	0.00
8.17.05	205	0.2	0.00	402.34	229.18	0.00
8.31.04	219	0.2	0.00	359.60	205.10	0.00
9.29.04	247	0.2	0.00	253.94	113.77	0.00

Table A33: VFA Concentration Data for Microcosm 1

Date	Day	Acetic mM	Proprionic mM	Isobutyric mM	Butyric mM	Isovaleric mM	Valeric mM	Isocaproic mM	Hexanoic mM	Heptanoic mM
1.21.04	1	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.30.04	5	0.05	0.01	8.30	0.01	0.01	0.02	0.02	0.02	0.02
2.5.04	11	0.03	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.01
2.12.04	18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.17.04	23	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.21.04	27	0.03	0.01	0.54	0.00	0.00	0.00	0.00	0.00	0.00
2.24.04	30	0.02	0.00	11.78	0.01	0.01	0.00	0.06	0.00	0.01
2.28.04	34	0.00	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.2.04	37	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
3.5.04	40	0.07	0.06	2.84	0.01	0.00	0.00	0.00	0.00	0.00
3.8.04	43	0.10	0.05	32.56	0.06	0.02	0.04	0.03	0.03	0.03
3.12.04	47	0.06	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.15.04	50	0.16	0.13	37.95	0.06	0.04	0.05	0.03	0.04	0.04
3.19.04	54	0.09	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.26.04	61	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.30.04	64	0.15	0.15	25.25	0.05	0.06	0.03	0.04	0.03	0.03
4.5.04	70	0.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.9.04	74	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.12.04	77	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.12.04	77	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.19.04	84	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.26.04	91	0.00	0.00	7.66	0.00	0.00	0.00	0.00	0.00	0.00
5.3.04	98	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5.19.04	114	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5.25.04	120	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6.14.04	140	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6.21.04	147	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7.6.04	163	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7.13.04	170	0.20	0.03	3.43	0.01	0.00	0.01	0.00	0.01	0.01
7.19.04	176	0.17	0.05	0.00	0.01	0.01	0.01	0.01	0.01	0.01
7.26.04	183	0.18	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8.9.04	197	0.06	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8.16.04	204	0.09	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8.24.04	212	0.11	0.01	3.00	0.01	0.00	0.01	0.00	0.01	0.01
8.30.04	218	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9.28.04	247	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table A34: VFA Concentration Data for Microcosm 1D

Date	Day	Acetic mM	Proprionic mM	Isobutyric mM	Butyric mM	Isovaleric mM	Valeric mM	Isocaproic mM	Hexanoic mM	Heptanoic mM
1.21.04	1	0.023	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1.30.04	5	0.069	0.009	0.008	0.012	0.012	0.016	0.016	0.021	0.028
2.5.04	11	0.025	0.002	0.000	0.003	0.000	0.000	0.000	0.004	0.005
2.12.04	18	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2.17.04	23	0.014	0.006	0.000	0.000	0.000	0.000	0.000	0.001	0.000
2.17.04	23	0.019	0.004	0.000	0.000	0.000	0.000	0.000	0.001	0.000
2.21.04	27	0.038	0.008	0.000	0.002	0.000	0.000	0.000	0.001	0.001
2.24.04	30	0.035	0.019	0.000	0.004	0.002	0.000	0.061	0.000	0.009
2.28.04	34	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3.2.04	37	0.024	0.005	0.000	0.000	0.000	0.001	0.001	0.002	0.002
3.5.04	40	0.065	0.037	0.002	0.005	0.003	0.003	0.003	0.004	0.002
3.8.04	43	0.101	0.070	0.018	0.031	0.016	0.026	0.020	0.018	0.016
3.12.04	47	0.031	0.004	0.000	0.001	0.000	0.001	0.000	0.003	0.003
3.15.04	50	0.117	0.084	0.012	0.027	0.012	0.014	0.010	0.013	0.013
3.19.04	54	0.293	0.193	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3.26.04	61	0.082	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3.30.04	64	0.126	0.091	0.010	0.022	0.000	0.014	0.000	0.013	0.014
4.5.04	70	0.100	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4.9.04	74	0.012	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4.12.04	77	0.030	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4.19.04	84	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4.26.04	91	0.040	0.000	0.007	0.000	0.000	0.000	0.000	0.000	0.000
5.3.04	98	0.023	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5.19.04	114	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5.25.04	120	0.014	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6.14.04	140	0.021	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6.21.04	147	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
7.6.04	163	0.052	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
7.13.04	170	0.097	0.009	0.001	0.003	0.000	0.002	0.001	0.002	0.004
7.19.04	176	0.113	0.023	0.000	0.000	0.000	0.000	0.000	0.000	0.000
7.26.04	183	0.113	0.035	0.000	0.000	0.000	0.000	0.000	0.000	0.000
8.9.04	197	0.077	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
8.16.04	204	0.087	0.032	0.000	0.000	0.000	0.000	0.000	0.000	0.000
8.24.04	212	0.030	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
8.30.04	218	0.012	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
9.28.04	247	0.025	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table A35: VFA Concentration Data for Microcosm 2

Date	Day	Acetic mM	Proprionic mM	Isobutyric mM	Butyric mM	Isovaleric mM	Valeric mM	Isocaproic mM	Hexanoic mM	Heptanoic mM
1.21.04	1	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.30.04	5	0.02	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01
2.5.04	11	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01
2.12.04	18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.17.04	23	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.21.04	27	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.21.04	27	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.24.04	30	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.00	0.00
2.28.04	34	0.00	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.2.04	37	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.5.04	40	0.06	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.8.04	43	0.11	0.05	0.01	0.02	0.01	0.01	0.01	0.01	0.01
3.12.04	47	0.05	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00
3.15.04	50	0.19	0.09	0.01	0.05	0.01	0.02	0.01	0.01	0.01
3.19.04	54	0.74	0.35	0.00	0.09	0.00	0.00	0.00	0.00	0.00
3.26.04	61	0.48	0.04	0.00	0.59	0.00	0.00	0.00	0.00	0.00
3.30.04	64	2.50	0.21	0.00	0.20	0.00	0.00	0.00	0.00	0.00
4.5.04	70	1.75	0.12	0.00	0.56	0.00	0.00	0.00	0.00	0.00
4.9.04	74	1.22	0.09	0.00	0.51	0.00	0.00	0.00	0.00	0.00
4.12.04	77	1.27	0.12	0.00	0.81	0.00	0.00	0.00	0.00	0.00
4.19.04	84	0.84	0.13	0.00	1.35	0.00	0.00	0.00	0.00	0.00
4.26.04	91	0.50	0.17	0.00	1.94	0.00	0.00	0.00	0.00	0.00
5.3.04	98	0.67	0.12	0.00	1.57	0.00	0.00	0.00	0.00	0.00
5.19.04	114	0.79	0.07	0.00	1.18	0.00	0.03	0.00	0.10	0.00
5.25.04	120	1.03	0.07	0.00	1.05	0.00	0.04	0.00	0.26	0.00
6.14.04	140	1.08	0.03	0.14	0.26	0.00	0.00	0.00	0.20	0.00
6.21.04	147	1.48	0.00	0.36	0.33	0.00	0.00	0.00	0.24	0.00
7.6.04	163	2.29	0.07	0.98	0.61	0.02	0.02	0.00	0.28	0.00
7.13.04	170	2.72	0.08	1.33	0.79	0.02	0.03	0.00	0.32	0.02
7.19.04	176	1.93	0.07	1.46	0.79	0.02	0.03	0.00	0.32	0.02
7.26.04	183	2.06	0.09	1.47	0.79	0.02	0.03	0.00	0.27	0.02
8.9.04	197	3.71	0.00	2.13	0.97	0.02	0.03	0.00	0.27	0.01
8.16.04	204	5.20	0.11	3.03	1.49	0.03	0.04	0.00	0.41	0.02
8.24.04	212	3.27	0.10	2.26	1.03	0.02	0.03	0.00	0.27	0.01
8.30.04	218	4.34	0.14	3.66	1.57	0.00	0.04	0.00	0.41	0.00
9.28.04	247	2.53	0.10	4.31	1.46	0.03	0.04	0.00	0.50	0.00

Table A36: VFA Concentration Data for Microcosm 2D

Date	Day	Acetic mM	Proprionic mM	Isobutyric mM	Butyric mM	Isovaleric mM	Valeric mM	Isocaproic mM	Hexanoic mM	Heptanoic mM
1.21.04	1	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.30.04	5	0.03	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.02
2.5.04	11	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01
2.12.04	18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.17.04	23	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.21.04	27	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.24.04	30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.28.04	34	0.00	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.28.04	34	0.01	0.06	0.00	0.00	0.05	0.00	0.00	0.00	0.00
3.2.04	37	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.5.04	40	0.05	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.8.04	43	0.12	0.07	0.02	0.03	0.01	0.02	0.01	0.01	0.01
3.12.04	47	0.35	0.02	0.00	0.02	0.00	0.00	0.00	0.00	0.00
3.15.04	50	0.93	0.13	0.00	0.04	0.00	0.00	0.00	0.00	0.00
3.19.04	54	1.56	0.26	0.00	0.18	0.00	0.00	0.00	0.00	0.00
3.26.04	61	1.18	0.07	0.00	0.39	0.00	0.00	0.00	0.00	0.00
3.30.04	64	1.24	0.31	0.00	0.52	0.00	0.00	0.00	0.00	0.00
4.5.04	70	1.21	0.18	0.00	0.82	0.00	0.00	0.00	0.00	0.00
4.9.04	74	0.97	0.12	0.00	0.68	0.00	0.00	0.00	0.00	0.00
4.12.04	77	0.99	0.14	0.00	0.85	0.00	0.00	0.00	0.00	0.00
4.19.04	84	1.08	0.20	0.00	1.57	0.00	0.00	0.00	0.00	0.00
4.26.04	91	0.89	0.16	0.00	1.42	0.00	0.00	0.00	0.00	0.00
5.3.04	98	1.12	0.18	0.00	1.61	0.00	0.00	0.00	0.00	0.00
5.19.04	114	1.31	0.14	0.00	1.89	0.00	0.03	0.00	0.00	0.00
5.25.04	120	1.78	0.18	0.00	2.39	0.00	0.05	0.00	0.00	0.00
6.14.04	140	3.25	0.14	0.00	2.64	0.00	0.08	0.00	0.02	0.00
6.21.04	147	3.96	0.13	0.00	2.85	0.00	0.00	0.00	0.00	0.00
7.6.04	163	3.63	0.11	0.01	2.46	0.02	0.06	0.00	0.02	0.00
7.13.04	170	4.40	0.13	0.06	3.17	0.03	0.07	0.00	0.05	0.00
7.19.04	176	3.94	0.14	0.08	3.30	0.03	0.07	0.00	0.06	0.00
7.26.04	183	4.32	0.15	0.14	3.71	0.03	0.07	0.00	0.07	0.00
8.9.04	197	0.94	0.08	0.02	2.65	0.02	0.05	0.00	0.06	0.00
8.16.04	204	1.25	0.14	0.08	4.75	0.04	0.11	0.00	0.13	0.00
8.24.04	212	0.93	0.11	0.06	2.89	0.03	0.08	0.00	0.09	0.00
8.30.04	218	0.43	0.14	0.00	3.58	0.04	0.10	0.00	0.11	0.00
9.28.04	247	1.17	0.18	0.40	3.37	0.07	0.13	0.00	0.21	0.00

Table A37: VFA Concentration Data for Microcosm 3

Date	Day	Acetic mM	Proprionic mM	Isobutyric mM	Butyric mM	Isovaleric mM	Valeric mM	Isocaproic mM	Hexanoic mM	Heptanoic mM
1.21.04	1	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.30.04	5	0.04	0.00	0.01	0.01	0.01	0.01	0.01	0.02	0.02
2.5.04	11	0.02	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.01
2.12.04	18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.17.04	23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.21.04	27	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.24.04	30	0.00	0.00	0.00	0.02	0.01	0.00	0.04	0.00	0.01
2.28.04	34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.2.04	37	0.09	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00
3.2.04	37	0.09	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00
3.5.04	40	0.35	0.09	0.00	0.05	0.00	0.00	0.00	0.00	0.00
3.8.04	43	0.77	0.06	0.01	0.05	0.00	0.01	0.00	0.01	0.00
3.8.04	43	0.90	0.15	0.02	0.06	0.02	0.02	0.02	0.02	0.02
3.12.04	47	0.86	0.05	0.00	0.11	0.00	0.00	0.00	0.00	0.00
3.15.04	50	1.08	0.16	0.00	0.33	0.00	0.00	0.00	0.00	0.00
3.19.04	54	1.57	0.28	0.00	0.61	0.00	0.00	0.00	0.00	0.00
3.26.04	61	0.69	0.08	0.00	0.91	0.00	0.00	0.00	0.00	0.00
3.30.04	64	1.15	0.24	0.00	1.26	0.00	0.00	0.00	0.00	0.00
4.5.04	70	0.93	0.11	0.00	1.38	0.00	0.00	0.00	0.00	0.00
4.9.04	74	1.06	0.09	0.00	1.32	0.00	0.00	0.00	0.00	0.00
4.12.04	77	1.04	0.10	0.00	1.51	0.00	0.00	0.00	0.00	0.00
4.19.04	84	1.83	0.14	0.00	2.19	0.00	0.00	0.00	0.00	0.00
4.26.04	91	2.22	0.14	0.00	2.35	0.00	0.00	0.00	0.00	0.00
5.3.04	98	3.04	0.09	0.00	1.74	0.00	0.00	0.00	0.00	0.00
5.19.04	114	3.15	0.10	0.00	2.08	0.00	0.00	0.00	0.00	0.00
5.25.04	120	3.66	0.13	0.00	2.81	0.00	0.00	0.00	0.04	0.00
6.14.04	140	2.99	0.12	0.00	4.25	0.00	0.00	0.00	0.07	0.00
6.21.04	147	3.44	0.12	0.00	4.75	0.00	0.00	0.00	0.00	0.00
7.6.04	163	2.31	0.10	0.03	4.44	0.02	0.01	0.00	0.16	0.00
7.13.04	170	4.82	0.14	0.04	4.93	0.02	0.02	0.00	0.41	0.00
7.19.04	176	3.07	0.11	0.04	4.42	0.02	0.02	0.00	0.52	0.00
7.26.04	183	3.04	0.10	0.04	3.73	0.02	0.00	0.00	0.70	0.00
8.9.04	197	1.19	0.06	0.03	2.34	0.00	0.00	0.00	0.84	0.00
8.16.04	204	2.81	0.11	0.05	4.27	0.04	0.04	0.00	1.54	0.00
8.24.04	212	1.24	0.07	0.04	2.37	0.02	0.02	0.00	0.84	0.00
8.30.04	218	2.09	0.08	0.05	3.26	0.03	0.03	0.00	1.16	0.00
9.28.04	247	1.60	0.08	0.14	3.59	0.04	0.03	0.00	1.55	0.00

Table A38: VFA Concentration Data for Microcosm 3D

Date	Day	Acetic mM	Proprionic mM	Isobutyric mM	Butyric mM	Isovaleric mM	Valeric mM	Isocaproic mM	Hexanoic mM	Heptanoic mM
1.21.04	1	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.30.04	5	0.03	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01
2.5.04	11	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01
2.12.04	18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.17.04	23	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.21.04	27	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.24.04	30	0.00	0.01	0.00	0.01	0.01	0.00	0.04	0.00	0.00
2.28.04	34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.2.04	37	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.5.04	40	0.12	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.5.04	40	0.09	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.8.04	43	0.64	0.09	0.02	0.04	0.02	0.01	0.00	0.01	0.01
3.12.04	47	0.70	0.02	0.00	0.03	0.00	0.00	0.00	0.00	0.00
3.15.04	50	1.58	0.16	0.00	0.09	0.00	0.00	0.00	0.00	0.00
3.19.04	54	2.99	0.35	0.00	0.10	0.00	0.00	0.00	0.00	0.00
3.26.04	61	0.95	0.06	0.00	0.55	0.00	0.00	0.00	0.00	0.00
3.30.04	64	1.15	0.29	0.00	0.77	0.00	0.00	0.00	0.00	0.00
4.5.04	70	0.52	0.08	0.00	1.16	0.00	0.00	0.00	0.00	0.00
4.9.04	74	0.56	0.07	0.00	0.98	0.00	0.00	0.00	0.00	0.00
4.12.04	77	0.85	0.10	0.00	1.51	0.00	0.00	0.00	0.00	0.00
4.19.04	84	0.98	0.14	0.00	2.25	0.00	0.00	0.00	0.00	0.00
4.26.04	91	1.30	0.16	0.00	3.06	0.00	0.00	0.00	0.00	0.00
5.3.04	98	1.38	0.09	0.00	1.93	0.00	0.00	0.00	0.00	0.00
5.19.04	114	2.33	0.13	0.00	2.72	0.00	0.00	0.00	0.00	0.00
5.25.04	120	2.75	0.14	0.00	2.72	0.00	0.01	0.00	0.00	0.00
6.14.04	140	3.77	0.15	0.00	3.72	0.00	0.00	0.00	0.00	0.00
6.21.04	147	4.13	0.17	0.00	4.63	0.00	0.00	0.00	0.00	0.00
7.6.04	163	2.69	0.09	0.00	3.67	0.00	0.01	0.00	0.02	0.00
7.13.04	170	4.26	0.15	0.00	4.74	0.01	0.01	0.00	0.05	0.00
7.19.04	176	3.04	0.12	0.00	4.16	0.00	0.00	0.00	0.06	0.00
7.26.04	183	3.42	0.12	0.01	4.16	0.00	0.00	0.00	0.08	0.00
8.9.04	197	3.02	0.14	0.02	5.24	0.00	0.01	0.00	0.07	0.00
8.16.04	204	4.18	0.19	0.00	6.67	0.00	0.00	0.00	0.10	0.00
8.24.04	212	2.71	0.12	0.00	4.70	0.00	0.01	0.00	0.08	0.00
8.30.04	218	2.56	0.13	0.00	6.61	0.00	0.02	0.00	0.06	0.00
9.28.04	247	1.93	0.13	0.03	6.08	0.00	0.00	0.00	0.12	0.00

Table A39: VFA Concentration Data for Microcosm 4

Date	Day	Acetic mM	Proprionic mM	Isobutyric mM	Butyric mM	Isovaleric mM	Valeric mM	Isocaproic mM	Hexanoic mM	Heptanoic mM
1.21.04	1	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.30.04	5	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.5.04	11	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.01
2.12.04	18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.17.04	23	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.21.04	27	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.24.04	30	0.04	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
2.28.04	34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.2.04	37	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00
3.5.04	40	0.07	0.19	0.00	0.00	0.00	0.00	0.00	0.01	0.00
3.8.04	43	0.27	0.05	0.01	0.02	0.01	0.01	0.01	0.01	0.01
3.12.04	47	0.21	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.12.04	47	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.15.04	50	0.75	0.12	0.00	0.02	0.00	0.00	0.00	0.00	0.00
3.19.04	54	1.38	0.56	0.00	0.09	0.04	0.00	0.00	0.00	0.00
3.26.04	61	0.69	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.30.04	64	1.40	0.10	0.00	0.06	0.00	0.00	0.00	0.00	0.00
4.5.04	70	1.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.9.04	74	1.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.12.04	77	1.66	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.19.04	84	1.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.26.04	91	2.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5.3.04	98	1.68	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5.19.04	114	1.74	0.01	0.00	0.03	0.00	0.00	0.00	0.00	0.00
5.25.04	120	2.10	0.02	0.00	0.03	0.00	0.00	0.00	0.00	0.00
6.14.04	140	2.11	0.02	0.00	0.19	0.01	0.00	0.00	0.00	0.00
6.21.04	147	1.99	0.02	0.00	0.25	0.00	0.00	0.00	0.00	0.00
7.6.04	163	1.83	0.03	0.00	0.49	0.00	0.00	0.00	0.02	0.00
7.13.04	170	3.37	0.06	0.00	1.25	0.01	0.00	0.00	0.04	0.00
7.19.04	176	2.02	0.05	0.00	1.09	0.01	0.00	0.00	0.04	0.00
7.26.04	183	2.62	0.05	0.00	1.45	0.01	0.00	0.00	0.06	0.00
8.9.04	197	2.20	0.03	0.00	1.76	0.01	0.00	0.00	0.10	0.00
8.16.04	204	3.06	0.05	0.00	3.04	0.00	0.00	0.00	0.17	0.00
8.24.04	212	1.52	0.03	0.00	1.64	0.01	0.00	0.00	0.08	0.00
8.30.04	218	1.85	0.04	0.00	3.68	0.01	0.01	0.00	0.23	0.00
9.28.04	247	1.77	0.05	0.01	3.51	0.02	0.00	0.00	0.19	0.00

Table A40: VFA Concentration Data for Microcosm 4D

Date	Day	Acetic mM	Proprionic mM	Isobutyric mM	Butyric mM	Isovaleric mM	Valeric mM	Isocaproic mM	Hexanoic mM	Heptanoic mM
1.21.04	1	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.30.04	5	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.5.04	11	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.01
2.12.04	18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.17.04	23	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.21.04	27	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.24.04	30	0.02	0.01	0.00	0.01	0.00	0.00	0.04	0.00	0.00
2.28.04	34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.2.04	37	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00
3.5.04	40	0.07	0.08	0.00	0.00	0.00	0.00	0.00	0.01	0.00
3.8.04	43	0.16	0.01	0.01	0.01	0.01	0.00	0.00	0.01	0.01
3.12.04	47	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.15.04	50	0.62	0.07	0.00	0.02	0.00	0.00	0.00	0.00	0.00
3.15.04	50	0.40	0.04	0.00	0.01	0.00	0.00	0.00	0.00	0.00
3.19.04	54	1.11	0.19	0.00	0.06	0.00	0.00	0.00	0.00	0.00
3.26.04	61	0.76	0.02	0.00	0.11	0.00	0.00	0.00	0.00	0.00
3.30.04	64	1.39	0.11	0.00	0.25	0.00	0.00	0.00	0.00	0.00
4.5.04	70	0.88	0.03	0.00	0.29	0.00	0.00	0.00	0.00	0.00
4.9.04	74	0.66	0.02	0.00	0.21	0.00	0.00	0.00	0.00	0.00
4.12.04	77	0.82	0.03	0.00	0.30	0.00	0.00	0.00	0.00	0.00
4.19.04	84	0.59	0.02	0.00	0.29	0.00	0.00	0.00	0.03	0.00
4.26.04	91	0.57	0.03	0.00	0.36	0.00	0.00	0.00	0.06	0.00
5.3.04	98	0.50	0.01	0.00	0.25	0.00	0.00	0.00	0.00	0.00
5.19.04	114	0.78	0.02	0.00	0.21	0.00	0.00	0.00	0.00	0.00
5.25.04	120	0.85	0.02	0.01	0.19	0.00	0.00	0.00	0.00	0.00
6.14.04	140	1.66	0.02	0.00	0.02	0.00	0.00	0.00	0.00	0.00
6.21.04	147	2.07	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.00
7.6.04	163	1.78	0.03	0.01	0.16	0.01	0.00	0.00	0.00	0.00
7.13.04	170	3.04	0.04	0.01	0.28	0.00	0.00	0.00	0.00	0.00
7.19.04	176	2.04	0.05	0.02	0.26	0.01	0.00	0.00	0.01	0.00
7.26.04	183	2.39	0.03	0.01	0.32	0.00	0.00	0.00	0.00	0.00
8.9.04	197	2.36	0.03	0.00	0.29	0.01	0.00	0.00	0.00	0.00
8.16.04	204	2.95	0.04	0.00	0.46	0.00	0.00	0.00	0.02	0.00
8.24.04	212	2.99	0.02	0.00	0.28	0.00	0.00	0.00	0.01	0.00
8.30.04	218	1.58	0.03	0.00	0.46	0.00	0.00	0.00	0.00	0.00
9.28.04	247	1.65	0.03	0.01	0.64	0.01	0.00	0.00	0.03	0.00

Table A41: VFA Concentration Data for Microcosm 5

Date	Day	Acetic mM	Proprionic mM	Isobutyric mM	Butyric mM	Isovaleric mM	Valeric mM	Isocaproic mM	Hexanoic mM	Heptanoic mM
1.21.04	1	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.30.04	5	4.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.5.04	11	5.19	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00
2.12.04	18	3.18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.17.04	23	2.63	0.00	0.00	0.00	0.00	0.00	0.03	0.03	0.00
2.21.04	27	2.91	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.28.04	34	1.91	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.2.04	37	2.70	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00
3.5.04	40	4.34	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.8.04	43	4.15	0.19	0.03	0.16	0.06	0.09	0.07	0.08	0.07
3.12.04	47	2.69	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.15.04	50	5.50	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.19.04	54	7.85	0.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.19.04	54	7.82	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.26.04	61	2.63	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.26.04	61	2.52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.30.04	64	5.05	0.14	0.00	0.05	0.00	0.00	0.00	0.18	0.00
4.5.04	70	3.53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.12.04	77	3.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.19.04	84	3.71	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.26.04	91	4.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5.3.04	98	1.59	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5.19.04	114	2.64	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5.25.04	120	2.86	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6.14.04	140	3.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6.21.04	147	2.71	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7.6.04	163	3.39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7.13.04	170	4.93	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7.19.04	176	4.89	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7.26.04	183	4.37	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8.16.04	204	5.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8.24.04	212	2.88	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8.30.04	218	3.73	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9.28.04	247	2.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table A42: VFA Concentration Data for Microcosm 5D

Date	Day	Acetic mM	Proprionic mM	Isobutyric mM	Butyric mM	Isovaleric mM	Valeric mM	Isocaproic mM	Hexanoic mM	Heptanoic mM
1.21.04	1	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.30.04	5	4.66	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.5.04	11	9.26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.12.04	18	2.56	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.17.04	23	2.29	0.04	0.00	0.00	0.00	0.00	7.06	0.00	0.00
2.21.04	27	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.28.04	34	3.69	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.2.04	37	3.37	0.00	0.00	0.00	0.00	0.00	0.00	32.91	0.00
3.5.04	40	4.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.8.04	43	4.60	0.08	0.00	0.00	0.00	0.00	195.97	0.00	0.00
3.12.04	47	3.37	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.15.04	50	4.84	0.14	0.00	0.00	0.00	0.00	638.94	0.00	0.00
3.19.04	54	7.53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.26.04	61	2.63	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.30.04	64	4.56	0.07	0.00	0.00	0.00	0.00	0.00	160.37	0.00
3.30.04	64	4.71	0.09	0.00	0.00	0.00	0.00	0.00	187.74	0.00
4.5.04	70	3.91	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.12.04	77	3.79	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.19.04	84	2.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.26.04	91	4.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5.3.04	98	2.52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5.19.04	114	2.95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5.25.04	120	3.20	0.00	0.00	0.00	0.00	0.00	0.00	27.80	0.00
6.14.04	140	3.62	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6.21.04	147	2.61	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7.6.04	163	3.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7.13.04	170	4.92	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7.19.04	176	4.08	0.00	0.00	0.00	0.00	0.00	78.58	0.00	0.00
7.26.04	183	3.88	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8.9.04	197	2.28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8.16.04	204	5.24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8.24.04	212	2.65	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8.30.04	218	3.26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9.28.04	247	2.78	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table A43: VFA Concentration Data for Microcosm 6

Date	Day	Acetic mM	Proprionic mM	Isobutyric mM	Butyric mM	Isovaleric mM	Valeric mM	Isocaproic mM	Hexanoic mM	Heptanoic mM
1.21.04	1	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.30.04	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.5.04	11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.12.04	18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.17.04	23	0.01	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.21.04	27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.24.04	30	0.08	0.00	0.00	0.01	1.07	0.00	7.00	0.00	0.00
2.28.04	34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.2.04	37	0.02	0.01	0.00	0.00	0.00	0.00	0.00	11.00	2.77
3.5.04	40	0.06	0.06	0.00	0.00	2.35	1.91	0.00	9.07	0.00
3.8.04	43	0.08	0.02	0.00	0.01	3.36	4.52	2.62	5.20	4.31
3.12.04	47	0.03	0.00	0.00	0.00	0.00	1.03	0.00	13.22	0.00
3.15.04	50	0.23	0.07	0.00	0.01	7.93	0.00	0.00	0.00	0.00
3.19.04	54	0.69	0.35	0.00	0.04	0.00	0.00	0.00	0.00	0.00
3.26.04	61	0.05	0.00	0.00	0.00	0.00	0.00	0.00	12.46	0.00
3.30.04	64	0.34	0.06	0.00	0.02	0.00	0.00	0.00	0.00	0.00
4.5.04	70	0.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.5.04	70	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.9.04	74	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.12.04	77	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.19.04	84	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.12	0.00
4.26.04	91	0.00	0.00	0.00	0.00	0.00	0.00	0.00	30.87	0.00
5.3.04	98	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5.19.04	114	0.06	0.00	0.00	0.00	0.00	0.00	0.00	2.38	0.00
5.25.04	120	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6.14.04	140	0.10	0.00	0.00	0.00	0.00	0.00	0.00	4.54	0.00
6.21.04	147	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7.6.04	163	0.11	0.00	0.00	0.00	0.00	1.87	0.00	12.29	0.00
7.13.04	170	0.94	0.01	0.00	0.05	0.00	0.00	0.00	6.82	0.00
7.19.04	176	0.68	0.01	0.00	0.03	0.00	0.00	0.00	6.32	0.00
7.26.04	183	1.13	0.01	0.00	0.08	0.00	1.96	0.00	15.07	0.00
8.9.04	197	0.42	0.00	0.00	0.02	0.00	0.00	0.00	23.93	0.00
8.16.04	204	0.42	0.00	0.00	0.04	0.00	0.00	0.00	18.43	0.00
8.24.04	212	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8.30.04	218	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9.28.04	247	0.21	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00

Table A44: VFA Concentration Data for Microcosm 7

Date	Day	Acetic mM	Proprionic mM	Isobutyric mM	Butyric mM	Isovaleric mM	Valeric mM	Isocaproic mM	Hexanoic mM	Heptanoic mM
1.21.04	1	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.30.04	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.5.04	11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.12.04	18	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.17.04	23	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.21.04	27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.28.04	34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.2.04	37	0.01	0.01	0.00	0.00	0.00	0.00	0.00	2.29	0.00
3.5.04	40	0.05	0.06	0.00	0.00	2.39	0.00	0.00	0.00	0.00
3.8.04	43	0.06	0.02	0.00	0.01	4.29	3.32	3.17	3.21	0.00
3.12.04	47	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.15.04	50	0.11	0.06	0.00	0.00	3.50	0.00	0.00	0.00	0.00
3.19.04	54	0.93	0.28	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.26.04	61	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.30.04	64	0.18	0.11	0.00	0.02	0.00	0.00	0.00	0.00	0.00
4.5.04	70	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.12.04	77	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.19.04	84	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.26.04	91	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5.3.04	98	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5.19.04	114	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5.25.04	120	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6.14.04	140	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6.21.04	147	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7.6.04	163	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7.13.04	170	0.42	0.01	0.00	0.02	0.00	0.00	0.00	0.00	0.00
7.19.04	176	0.49	0.01	0.00	0.02	0.00	0.00	0.00	0.00	0.00
7.26.04	183	0.75	0.01	0.00	0.04	0.00	0.00	0.00	0.00	0.00
8.9.04	197	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8.16.04	204	0.17	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
8.24.04	212	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8.30.04	218	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9.28.04	247	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table A45: VFA Concentration Data for Microcosm LC

Date	Day	Acetic mM	Proprionic mM	Isobutyric mM	Butyric mM	Isovaleric mM	Valeric mM	Isocaproic mM	Hexanoic mM	Heptanoic mM
1.21.04	1	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.30.04	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.17.04	23	0.00	0.02	0.00	0.00	0.56	0.00	0.00	0.00	0.00
3.2.04	37	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.8.04	43	0.02	0.03	0.00	0.01	4.36	3.14	3.83	2.42	3.72
3.15.04	50	0.08	0.04	0.00	0.00	3.13	0.00	0.00	0.00	0.00
3.26.04	61	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.30.04	64	0.20	0.09	0.00	0.02	0.00	0.00	0.00	0.00	0.00
4.5.04	70	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.12.04	77	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.19.04	84	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.26.04	91	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5.3.04	98	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5.19.04	114	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5.25.04	120	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6.14.04	140	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6.21.04	147	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7.6.04	163	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7.13.04	170	0.30	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
7.26.04	183	0.45	0.01	0.00	0.02	0.00	0.00	0.00	0.00	0.00
8.16.04	204	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8.30.04	218	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9.28.04	247	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table A46: VFA Concentration Data for Microcosm LCD

Date	Day	Acetic mM	Proprionic mM	Isobutyric mM	Butyric mM	Isovaleric mM	Valeric mM	Isocaproic mM	Hexanoic mM	Heptanoic mM
1.21.04	1	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.30.04	5	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	50.81
2.17.04	23	0.01	0.02	0.00	0.01	0.00	0.00	0.00	0.00	0.00
3.2.04	37	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.8.04	43	0.01	0.00	0.00	0.00	2.17	1.17	3.50	0.56	2.87
3.15.04	50	0.06	0.04	0.00	0.00	2.91	0.00	0.00	0.00	0.00
3.26.04	61	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.30.04	64	0.11	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.5.04	70	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.12.04	77	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.19.04	84	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.26.04	91	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5.3.04	98	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5.19.04	114	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5.25.04	120	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6.14.04	140	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6.21.04	147	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7.6.04	163	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7.13.04	170	0.14	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
7.26.04	183	0.29	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00
8.16.04	204	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8.30.04	218	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9.28.04	247	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table A47: VFA Concentration Data for Microcosm SC

Date	Day	Acetic mM	Proprionic mM	Isobutyric mM	Butyric mM	Isovaleric mM	Valeric mM	Isocaproic mM	Hexanoic mM	Heptanoic mM
1.21.04	1	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.30.04	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.17.04	23	0.01	0.03	0.00	0.01	0.00	0.00	0.00	0.00	0.00
3.2.04	37	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.8.04	43	0.00	0.00	0.00	0.00	0.27	0.17	1.84	0.00	2.10
3.15.04	50	0.07	0.04	0.00	0.00	1.45	0.00	0.00	0.00	0.00
3.26.04	61	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.30.04	64	0.11	0.09	0.00	0.01	0.00	0.00	0.00	0.00	0.00
4.5.04	70	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.12.04	77	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.19.04	84	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.26.04	91	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5.3.04	98	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5.19.04	114	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5.25.04	120	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6.14.04	140	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6.21.04	147	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7.6.04	163	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7.13.04	170	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7.26.04	183	0.21	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00
8.16.04	204	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8.30.04	218	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9.28.04	247	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table A48: VFA Concentration Data for Microcosm SCD

Date	Day	Acetic mM	Proprionic mM	Isobutyric mM	Butyric mM	Isovaleric mM	Valeric mM	Isocaproic mM	Hexanoic mM	Heptanoic mM
1.21.04	1	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.30.04	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.5.04	11	0.01	0.00	0.00	0.01	0.00	3.67	0.00	3.59	8.06
2.17.04	23	0.01	0.03	0.00	0.01	0.00	0.00	0.00	0.00	0.00
3.2.04	37	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.8.04	43	0.00	0.00	0.00	0.00	0.00	0.18	0.00	0.00	0.00
3.15.04	50	0.07	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.26.04	61	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.30.04	64	0.11	0.10	0.00	0.01	0.00	0.00	0.00	0.00	0.00
4.5.04	70	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.12.04	77	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.19.04	84	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.26.04	91	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5.3.04	98	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5.19.04	114	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5.25.04	120	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6.14.04	140	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6.21.04	147	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7.6.04	163	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7.13.04	170	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7.26.04	183	0.16	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8.16.04	204	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8.30.04	218	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9.28.04	247	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table A49: Summary of TC Data for all Microcosms

Date	Day	Total Carbon Concentration, ppm															
		1	1D	2	2D	3	3D	4	4D	5	5D	6	7	LC	LCD	SC	SCD
2.2.04	9	3433	3043	805.3	1635	13126.5	1386	3672	3472.2	931.8	44236.5	4564	6505	2876.3	4403.5	2754.5	3230.85
2.12.04	13	3682.5	3526	2722	2087	8711.5	1753	1810.5	2198	27115	32450	2278	1524.5	4764	9355	6025	3574
2.21.04	27	26001.5	8775	3797.5	2687.5	96525	2742.5	2490	2559	34298	34331	3012.5	1797.5				
2.27.04	33	3649	4195	4065	1555	20975	1492	2528.5	3281.5	48460	23954.7	3128	30.03	3389	3343	6275	3893
3.12.04	47	2226	3661	3331	3995.5	2398	2830	4179	3770.5	16780	26200	4247	3951	3679.5	4582.5		
3.19.04	54	7150	9995	8965	7860	8955	9660	11465	17514	37200	43530	7860	7060	5820	6870	3555	4300.5
3.26.04	61	7610	3752.5	4365.5	3754.5	3157	3343.5	4510	5050	12460	38310	5530	5045	3466.5	5045	2678.5	10720
4.12.04	78	786	556	2571.5	664	622	533	943	898.5	11259	11682	909.5	929	1197	1010.5	11700	2845.5
4.19.04	85	7641	822	1381	1722	1518	1279	1568	2465	20690	20460	1805	1405	1891	1739	1925	1890
4.26.04	92	30440	27370	30280	31090	24330	32040	16580	14910	12530	14110	1639	1231	1368.5	11560	1371.5	1923
6.14.04	141	7937	21140	5926	9215	6462	5330	9048	8965	30380	29680	9127	6764	6733	6896	7844	8710
6.21.04	149	2437.5	3349.5	2055	3866.5	645	2003.5	2429	2716.5	15352	14640	2143	1875.5	1855.5	2135	2085	2385.5
7.6.04	163	2767.6	1882.8	1120.4	1384	1224	1273	1600.8	1602.8	25776	16520	2232.8	1482.5	1730	2269	2365	2820.5
7.13.04	170	1639.5	1609.5	1647	1900.5	1199	1254.5	1773	2037	16616	14656	1869.5	2083.5	1935.5	2260	2880	2995.5
7.20.04	177	1834	1590	1547.5	1794.5	942	1411	2734.5	2174.5	17664	16512	1742	1342.5				
7.26.04	183	1903	2402	1846	2302.5	1501	1769	2106	2653	19224	19560	2229	2045.5	2087	2344	2750.5	3888.5
10-Aug	198	2249.6	2313.6	3202	2800.4	2288.4	2166.8	2534	2811.2	11616	12872	3127.6	2578				
16-Aug	204	2206.5	2163.5	1495	1115.5	979	1074.5	1854.5	2029	8864	9528	2295.5	1741	1466.5	1925	2348	2385
31-Aug	219	2506	1635	2075.5	1020	1079	1380	1877	2010.5	10048	9576	2176	2429.5				
28-Sep	247	1519.5	1357.5	2119	408.9	711	1059	1472	1634	8176	8280	2414.5	1813	1500.5	1723.5		2161

Vita

Kelli Mattson was born on February 26, 1980 to Sally T. Mattson and James Mattson. She began attending Virginia Tech in August of 1998 as an undergraduate engineering student. She completed her undergraduate Civil Engineering degree in the spring of 2002 in addition to earning her Fundamentals of Engineering certification. She began working for Mark Widdowson in May of 2002 towards a Master's of Science in Environmental Engineering. She completed her requirements and graduated in Spring 2005.