

Final Report

Development of a Real-time Monitoring Protocol for Assessing Volatile Organic Compound (VOC) Impacts on Response and Cleanup Workers' Safety During Surface and Subsurface Dispersant Operations

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EXECUTIVE SUMMARY

The *Deepwater Horizon* oil spill released over 200 million gallons of South Louisiana sweet crude oil into the northern Gulf of Mexico raising concerns for human health and ecological damage. The spill represents the first occurrence of a significant oil spill at depths greater than 5,000 feet and the first instance chemical dispersants were applied directly to an undersea spill. The immediate health contaminants of concern in crude oils are the volatile organic compounds (VOCs), especially the light aromatic hydrocarbons, BTEX (benzene, toluene, ethyl benzene, and xylene). In order to evaluate human health risks associated with the spill, Occupational Safety & Health Administration (OSHA) industrial hygienists were deployed to monitor worker exposure and looking for health effects from chemical exposure to oil, weathered oil, oil dispersants, and vessel cleaning agents. The direct reading results at most sites indicated VOCs were non-detect or below method detection limits. Unfortunately, most of the sites examined were associated with beach cleanup or hazardous material removal workers.

In this project, the investigators developed real-time and passive analytical techniques and protocols for assessing VOC impacts to response and cleanup workers during surface and subsurface releases. Laboratory baffled flask and recirculating tank test were designed to determine the quantity of BTEX components detectable in the air and water following exposure to naturally and chemically-dispersed SLC oil at various temperatures (20°C and 4°C) and DORs (1:20, 1:50, and 1:100). An additional laboratory experiment was designed to monitor the effects of pressure (2300, 500, and 50 psi) and temperature (21°C, 13°C, and 4°C) on the dissolution of chemically-dispersed (DOR=1:100) and non-dispersed SLC oil within sea water employing a high-pressure vessel system. A field study was conducted at the Ohmsett wave tank facility in Leonardo, NJ to test the analytical methods and monitoring protocols developed during the

laboratory studies. In addition, National Oceanic and Atmospheric Administration (NOAA) and United States Coast Guard (USCG) Gulf Coast Strike Team personnel reviewed the final document and provided recommendations and countermeasures to optimize dispersant use for VOC control and worker safety.

A side by side comparison of the two analytical methods (direct sampling and passive desorption tube) showed that direct air sampling had 20% higher recoveries over the entire range of BTEX components. A comparison of the temperature treatments (21°C vs. 4°C) showed a 30-32% decrease in BTEX component concentration within the air when the baffled-flask tests were conducted at 4°C. BTEX component concentrations within the water ranged between 10-20 times greater than those found in the air samples. Water analysis results indicated there was a 34% and 132% increase in BTEX component concentrations when dispersant was added to the oil at water temperatures of 21°C and 4 °C, respectively. Air and water results from the larger-scale recirculating tank tests supported the initial findings from the baffled flask tests. Experimental results from the high-pressure vessel study showed there was a 192% increase in overall BTEX concentration with the application of dispersant to oil within the tested pressure and temperature ranges.

The measurements performed at Ohmsett showed surface releases of oil and oil + dispersant create different air and water monitoring challenges to oil spill responders and workers. The highest air reading recorded for the control oil averaged 604 ppb for benzene three minutes after the initial release. The highest detectable air reading for dispersed oil was collected at the 3 minute sampling interval and showed an average concentration of 135 ppb and 186 ppb for benzene and toluene, respectively. The highest detectable water reading for control oil was collected at the 2 minute sampling interval and showed benzene ranging from 25 ppb to

199 ppb. The highest detectable water reading for dispersed oil was collected 7 minutes following the initial release and showed toluene ranging from 2,548 ppb to 44,528 ppb. Results from the Ohmsett wave tank tests show that undispersed oil has the potential to release 4-5 times more BTEX components to the atmosphere than dispersed oil during surface spill response operations. This observation is supported by the results from the BTEX water analysis. Dissolution of BTEX into the water column was 100-200 times higher for dispersed oil when compared to undispersed oil tests, indicating chemical dispersion of oil.

PROJECT DESCRIPTION

The *Deepwater Horizon* Oil Spill has sparked much interest in the behavior and fate of South Louisiana crude oil in the marine environment. The spill has also increased interest in the research topics of worker safety and chemical countermeasures associated with oil spills. In order to provide a comprehensive analysis of the possible impacts of spilled crude oil and dispersant usage, Louisiana State University (LSU) and the Bureau of Safety and Environmental Enforcement (BSEE) conducted a collaborative one (1) year project to provide detailed scientific information and data on the flux of volatile organic carbons (VOCs) in the atmosphere and water column during surface and subsurface dispersant operations. The primary objective of this project was to investigate the development of a real-time monitoring protocol for assessing volatile organic compound (VOC) impacts on response and cleanup workers' safety during surface and subsurface dispersant operations. The project was designed to develop monitoring protocols and recommendations to optimize dispersant use for VOC control and worker safety.

The general approach for this project was to evaluate passive and real-time monitoring protocols for detection of benzene, toluene, ethyl benzene, m, p-xylenes, and o-xylene (BTEX)

in air and water matrices during spill incidents; measure volatilization and dissolution of BTEX from crude oil at varying temperatures and dispersant to oil ratios (DORs); and simulate BTEX dissolution in water at varying pressures and DORs. The goals of this project were achieved through a series of laboratory and field-scale studies conducted at research facilities in Baton Rouge, Louisiana (LSU) and Leonardo, New Jersey (Ohmsett), respectively. The Ohmsett facility is the only facility where full-scale oil spill response equipment testing, research, and training can be conducted in a marine environment with oil under controlled environmental conditions (waves, temperature, oil types). The facility provides an environmentally safe place to conduct objective testing and to develop devices and techniques for the control of oil and hazardous material spills. The facility is maintained and operated by the BSEE through a contract with MAR, Incorporated of Rockville, Maryland. The baffled flask, recirculating tank and pressure vessel studies were conducted at LSU's Department of Environmental Sciences facilities, while the South Louisiana crude oil dispersant and VOC monitoring field studies were performed at the Ohmsett research facility. Laboratory and field studies were conducted using South Louisiana crude (SLC) and Corexit 9500 oil supplied by British Petroleum (BP) and Nalco Company, respectively.

PROJECT TIMELINE

A 5-month no-cost extension was approved by BSEE in August 2013. The no-cost extension was requested for two primary reasons: (1) equipment replacement due to stress failure in high-pressure cap, and (2) emergency leave for a critical member of the research team. The modified project timeline is given in Table 1.

Table 1. Modified Project Timeline

Task	Month from Start of Project																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Baffled Flask Study	■	■	■	■	■												
Flow-Through Tank Study			■	■	■												
Pressure Vessel Study					■	■	■				■	■	■	■	■		
Ohmsett Field Study								■	■	■	■			■	■	■	■
Reporting																	
Interim Report				■	■		■	■		■							
Draft Final Report																■	■
Final Report																	■
Preparation of Manuscript(s) for Publication																	■

OIL CHARACTERIZATION AND INSTRUMENTATION METHODOLOGY

The crude oil used in this project was a surrogate MC252 oil provided by BP. The South Louisiana crude (SLC) oil used in the laboratory and Ohmsett field tests is currently being distributed by BP as a surrogate research oil for the MC252 oil released during the DWH incident. The oil was collected from the Marlin Platform of the Dorado field, located approximately 23 miles NE of the Macondo spill site. This oil was chosen because it possesses physical properties and chemical characteristics similar to the Mississippi Canyon lease block 252 (MC252) oil. Initial BTEX oil characterization was performed by an external contract laboratory using EPA method 8260 with a purge and trap system coupled to an Agilent gas chromatograph/quadrupole mass spectrometer. The concentrations of BTEX and physical/chemical characteristics of SLC oil are shown in Table 2.

Table 2. Concentrations of BTEX and Physical/Chemical Characteristics of SLC Oil

Compound	SLC Conc. (mg/Kg)	Henry's Law Constant (dimensionless)	Mole weight (g/mole)	Density (g/ml)	Boiling point (°C)	Water solubility (mg/L)	Vapor pressure (mmHg)	Log K _{ow}
Benzene	2300	0.228	78	0.88	80.1	1780	76	2.13
Toluene	6540	0.272	92	0.87	110.8	535	22	2.69
Ethylbenzene	950	0.323	106	0.87	136.2	152	7	3.15
m-Xylene	5100*	0.301	106	0.86	139	135	6	3.2
p-Xylene		0.314	106	0.86	138.4	198	6.5	3.15
o-Xylene	1880	0.213	106	0.88	144.4	175	5	2.77

* m-xylene & p-xylene coelute during analysis

As part of this project, our research team developed and validated analytical methods and protocols designed for passive and real-time analysis of BTEX following surface and deep sea spill incidents. BTEX concentrations in air samples were monitored using both a portable real-time gas chromatography/flame ionization detector (GC/FID) system and a laboratory-based GC/FID system equipped with a thermal desorption unit. Both systems are shown in Figure 1. The instrumentation and general air and water sample preparation are discussed below.

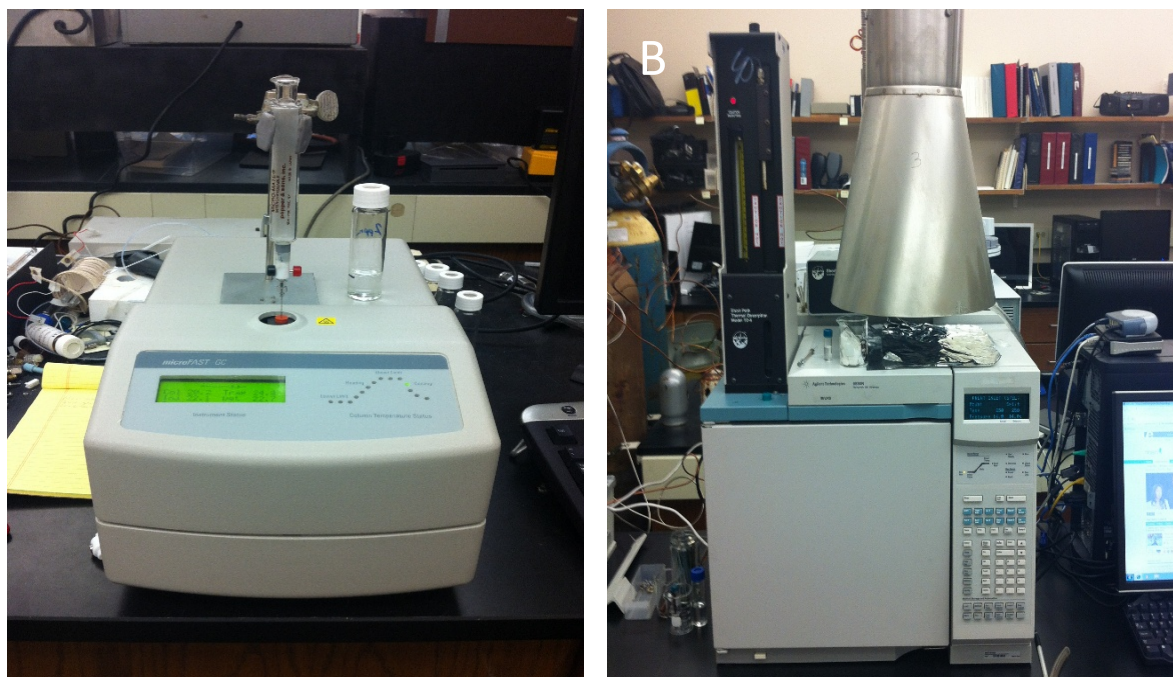


Figure 1. Photograph of (A) microFast GC and (B) thermal desorption systems used for BTEX analysis of air and water samples during this project.

Preparation of VOC Standards

The BTEX gas standard used for this project was purchased from Sigma Aldrich (Scotty Part# 501883). The composition of the standard was 10 ppm by mole BTEX (benzene, toluene, ethyl benzene, and *o*, *p*, *m*-xylenes). All stock gas standards were prepared in 3-L Tedlar bags (SKC part# 23103). Prior to use, each Tedlar bag was cleaned twice by filling with purified helium (99.9995% purity) and then evacuate contents using an air pump. A liter of helium gas was used to prepare lower concentrations of gas standards. The volume of helium gas was indirectly determined using a helium flow rate meter (J&W Scientific ADM3000 part number 220-1172) as a function of time (VWR timer and stopwatch). A known volume (2 mL, 5mL, 10 mL, 15 mL or 20 mL) of standard gas was taken from a standard stock gas bag and injected into

a liter of helium Tedlar bag and allowed to equilibrate for approximately one (1) hour prior to analysis.

MicroFast GC/FID Analysis of Air and Water Samples

The microFAST GC was used for direct analysis of head space (water) and air samples. The microFAST GC is a small, fast gas chromatographic instrument designed to promote analytical efficiency over a broad spectrum of field and laboratory analytical applications. The instrument uses a solid sorbent trap for automated injection of analytes, or concentration and injection of analytes, with fast temperature programming, to achieve rapid, high resolution chromatographic analyses on dual columns from a single injection. Water samples were analyzed following EPA method 3810 for the determination of volatile compounds using static headspace analysis. An aliquot of air sample was removed from the 40-ml sample vial with a 20-ml Micro-mate gas tight syringe (Cadence Science, Inc.) and inserted into the injection port septum. Upon startup the gas sample is drawn into the microFast trap system by an internal air pump. The trap is loaded at 35°C for approximately 15-30 seconds and heated to 200°C. After heating for 18 seconds a flow valve opens to release the sample onto the chromatography column. The column temperature is initially set 30°C, heated to 150°C at 3°C per second, and then held at 150°C for 10 seconds. The trap is automatically purged for 20 seconds at 200°C to recondition trap prior to next analysis. All air samples were injected directly from the 20-ml gas tight syringe. An initial 5-point calibration curve was setup for air (direct) and water (headspace) samples prior to analysis. A single continuing calibration analysis was performed each day to confirm linearity with the initial 5-point calibration curve (<20 %RSD). The method detection limit for individual BTEX components was 1.0 part per billion volume (ppbv).

Thermal Desorption Analysis of Air Samples

The thermal desorption (TD) system (Figure 1-B) used for the project was purchased from Scientific Instrument Services, Inc. (SIS), Ringoes, NJ. It consists of a thermal desorption unit, cryo-trap unit, and electronics control unit. The thermal desorption unit sits directly above the GC injection port, where it introduces thermally extracted volatile directly into the GC injection port and column. It uses a direct short path of sample flow, which eliminates transfer lines that become contaminated, thereby giving maximum sensitivity of samples to the GC injector. The cryo-trap unit is installed inside the GC oven just below the GC injector unit. A length of column is inserted inside the cryo-trap unit and connected to the GC injected unit. This portion of column is cooled at an appropriate temperature which provides cryo-focusing of compounds. The electronic control unit provides automated operation including automatic injection, timed thermal desorption, temperature ramp of heater blocks, temperature control of cryo-trap fitted at the head of GC column, and remote starting of GC.

The general approach involves loading a desorption tube onto to the SIS injection unit and attaching a threaded injection needle to the lower end of the tube. Once the desorption unit and GC/FID systems have reached preset temperature and pressures the collected gas sample is automatically injected into an Agilent 6890N GC equipped with a 60m, 0.322 mm ID, 0.25 μ m film thickness column (GS GasPro). The GC was set to constant flow/split mode and used UHP Helium (99.9995%) as the carrier gas. The method detection limit for individual BTEX components was 1.0 ppbv. The Agilent 6890N GC/FID and thermal desorption unit parameters are displayed in Table 3.

Table 3. Agilent 6890N GC/FID and thermal desorption unit parameters

GC/FID Unit	Thermal Desorption Unit
Column Type: GS GasPro, 60 m, 0.322 mm ID	Purge Time: 0.50 min.
Column Flow Rate: 2.0 mL/min	Injection Time: 0.50 min.
Split Ratio: 10	Temperature Program: 300°C for 3.00 min.
Split Flow: 20 mL/min	
Total Flow: 21 mL/min	
Injector Temperature: 250°C	
Temperature Programming: Initial (50°C for 3 minutes)	
Ramp_1 (10°C/min. to 250°C)	
Ramp_2 (250°C for 15 min.)	
Detector Temperature: 300°C	
H ₂ Flow: 30 ml/min	
Air Flow: 300 ml/min.	
Makeup Gas: 30 ml/min. He	

Sorbent Tube Preparation and Conditioning

Pre-conditioned single bed Tenax GR sorbent tubes (200 mg) were purchased from Scientific Instrument Services, Inc. (SIS), Ringoes, NJ, USA. Desorption tubes are 4.0” long by ¼” diameter and 4.0 mm inside diameter and uniquely identified by a serial number located at the sampling end of the tube. All tubes underwent a conditioning procedure before use for GC analysis. Conditioning was performed by attaching sorbent tubes to a six-position heating block (300°C) and passing purified Helium carrier gas at a flow rate of 40 mL/min for 30 minutes. The cleaned tubes were sealed with stainless steel caps lined with Teflon o-rings. The tubes were then stored in a closed glass container for later use.

Summary of Oil Characterization and Instrumentation Methodology

The direct air sampling and thermal desorption methodologies developed for the detection of BTEX components are capable of monitoring the target compounds in the low ppb range. The direct sampling coupled with the microFast GC system is capable of analyzing multiple samples within a short time period. The analytical results from both methods exhibited

good peak resolution and results were highly reproducible. Example data from the individual instruments are shown in Figures 2-3.

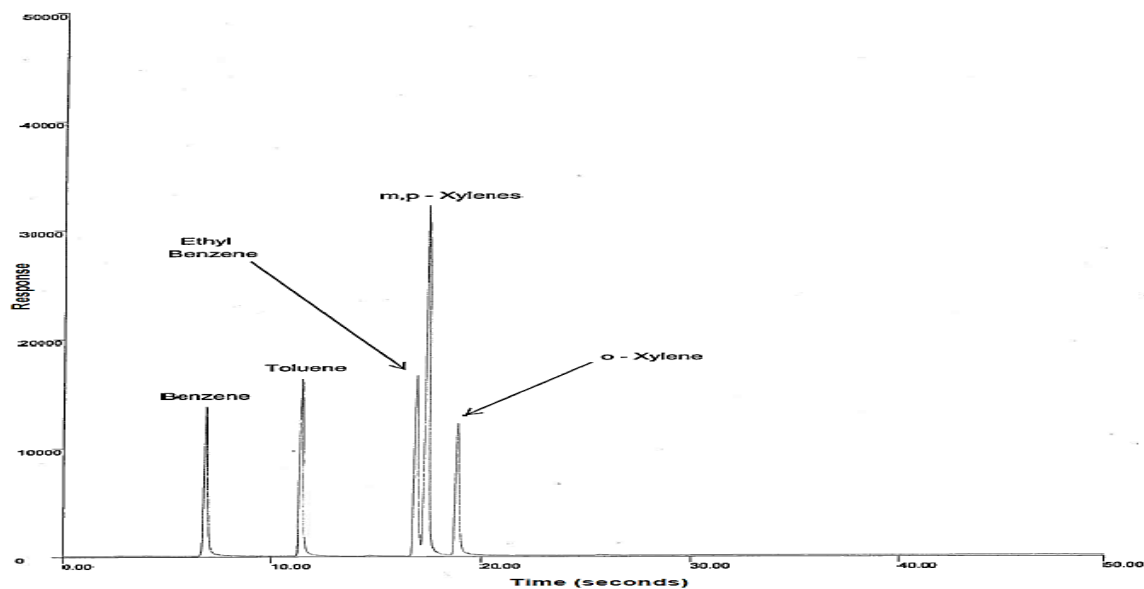


Figure 2. MicroFast GC FID chromatogram of BTEX from calibration standard.

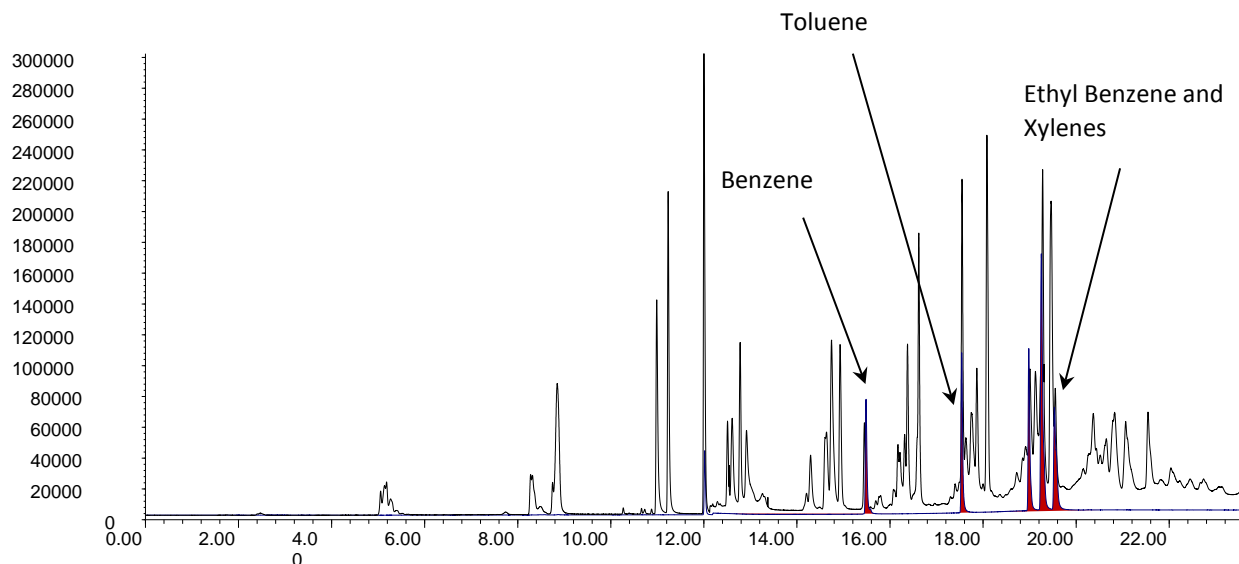


Figure 3. Agilent 6890N GC/FID overlay chromatogram of surrogate MC252 oil and BTEX standard.

BAFFLED-FLASK STUDY

A series of bench-scale baffled-flask studies were performed to compare and assess the feasibility of using two analytical methods, thermal desorption and direct sampling, to monitor BTEX exposure to response personnel during oil spill cleanup operations. In addition, the closed system allowed investigators to determine mass balance (air and water) of BTEX components within the baffled-flask microcosm following the addition of Corexit 9500 to the South Louisiana crude oil. The experimental apparatus (Figure 4) consisted of a modified 250-ml baffled trypsinizing flask with a dual-port cap and a glass side spout near the bottom of the flask. The dual-port cap allowed for attachment of a desorption tube vacuum line and an air intake vent. All vacuum line consisted of ¼" Teflon flex hose (Cole-Parmer). The vacuum pump pulls air into the sealed flask through the intake vent, sweeping above the water surface, and out through the vacuum line. Once the air exits the baffled-flask, it flows approximately 24 inches until encountering an air sampling valve (direct sampling) or a thermal desorption tube. The desorption tubes were packed with an absorbent resin that is specific for removal of BTEX components from the vacuum-side stream. Flow rate is controlled with a multitube flowmeter system (Cole-Parmer) fitted with nine (9) 150-mm direct-reading flowtubes for air. Vacuum was provided by a standard-duty dry vacuum piston pump (Cole-Parmer). The experiments were conducted in a wet laboratory (21°C) and a temperature controlled environmental room (4°C). Synthetic seawater (32 ‰) was used for all experiments. The experimental variables and analysis matrix for the baffled-flask study is displayed in Table 4.



Figure 4. Experimental setup for baffled-flask study.

Table 4. Experimental variables and analysis matrix for the baffled-flask study.

Treatment	# of Samples at Temperature		Total # of Analytical Determinations	
	4°C	20°C	Water-MicroFast	Air-Desorb. Tube
Control				
Time=10 min.	3	3	6	6
Time=30 min.	3	3	6	6
Time=90 min.	3	3	6	6
DOR=20				
Time=10 min.	3	3	6	6
Time=30 min.	3	3	6	6
Time=90 min.	3	3	6	6
DOR=50				
Time=10 min.	3	3	6	6
Time=30 min.	3	3	6	6
Time=90 min.	3	3	6	6
DOR=100				
Time=10 min.	3	3	6	6
Time=30 min.	3	3	6	6
Time=90 min.	3	3	6	6

Salinity=30-32 PPT

DOR=Dispersant to oil ratio

Approximately 125-ml of synthetic seawater was added to the each test flask. A total of nine (9) baffled-flask were placed on the outer edge of the orbital shaker platform. Three (3) flasks were designated for water sampling, three (3) for direct air sampling, and the last three (3) flasks were designated for desorption tube air sampling. Prior to spiking, the oil was mixed with a known volume of dispersant Corexit 9500 to create the desired dispersant to oil ratio (DOR) for each test. A 50- μ l aliquot of oil (340 ppm nominal oil concentration) was dispensed onto the water surface. The cap, along with the vacuum tube, were immediately attached to the baffled-flask. The vacuum pump was activated and air flowed through the flasks and sampling lines at a flow rate of 85 ml/min. The experimental flasks were rotated at 150 ± 10 rpm for the designated time interval (60 minutes). At the designated sampling intervals (15, 30, 45, and 60 minutes) the shaker was shut off. A 10-ml aliquot of water was removed from the designated flasks through the sampling valve with a 20-ml polypropylene (PP) syringe. A 20 μ m PTFE syringe filter and stainless steel needle were attached to the PP syringe and the collected water was forced through the filter into a 40-ml PTFE septum top sampling vial. The water samples were immediately analyzed using the microFAST GC/FID system configured for headspace analyses. The desorption tubes were quickly removed, capped, and replaced with clean, conditioned tubes. The sampling tubes were stored in a 4°C refrigerator and analyzed on the thermal desorption system once the entire experiment was completed. The direct air samples were collected through a PTFE inline three-way valve attached to the vacuum lines originating from the designated direct air sampling flasks. A 20-ml gas-tight glass syringe (Cadence Science, Inc.) equipped with a luer lock fitting was used to collect the direct air sample. The syringes were wrapped in aluminum foil to protect from UV light and immediately analyzed on the microFAST GC/FID system. Analytical method development and instrument calibrations were performed prior to

startup of this experiment. Sample treatments were replicated in triplicate and results interpreted using current statistical analysis techniques.

Summary of Baffled-Flask Experiments

Figures 5-10 contain the averaged results of the air and water analysis from the baffled-flask experiments. The results from the air sampling results showed a 20% decrease over the entire range of BTEX components when comparing the direct sampling method to the thermal desorption method. Sample transfer errors and high humidity may have contributed to the lower BTEX concentrations for the thermal desorption tube method. A comparison of the temperature treatments (21°C vs. 4°C) showed a 30-32% decrease in BTEX component concentration within the air when the baffled-flask tests were conducted at 4°C. This is expected due to the decrease in vapor pressure as a function of temperature decrease. Air monitoring results indicated there was 15% and 4% difference between the oil and oil + dispersant treatments at 21°C and 4°C, respectively. In addition, there was less than a 17% difference in BTEX component air concentrations between the dispersant treatments over the temperature ranges. Although the investigators expected greater differences in BTEX component concentrations in the air samples between the various treatments and temperature ranges, the similarity in air concentration results can be explained by the nature of the experimental system design. The baffled-flasks are designed to increase mixing energy within the system, thus promoting increased volatilization of both dispersed and non-dispersed oil within the system. BTEX component concentrations within the water ranged between 10-20 times greater than those found in the air samples. Water analysis results indicated there was a 34% and 132% increase in BTEX component concentrations when dispersant was added to the oil at water temperatures of 21°C and 4°C, respectively. Both the non-dispersed and dispersed treatments displayed a 25-30% increase in

BTEX concentration within the water when the temperature was decreased from 21°C to 4°C. Again, the lack of difference in BTEX concentrations between the temperature treatments may be due to the mixing phenomenon mentioned earlier. Table 8 contains mass fraction results of BTEX components in air and water removed from SLC oil during the baffled-flask experiments. The initial mass of BTEX components was obtained from analysis of the oil prior to starting the experiment. The mass fraction air results were obtained from the average of the thermal desorption and direct sampling experiments. Mass fraction results from the baffled-flask experiment showed there was less than a 15% difference in the mass of BTEX components loss to air and water between the oil and dispersed oil treatments. Results did indicate a noticeable decrease (15-35%) in mass loss when the oil and dispersed oil were tested at the lower temperature of 4°C. The averaged results for the baffled-flask experiments are displayed in Tables 5-7. Tables A1-A6 contain raw data for the baffled-flask study.

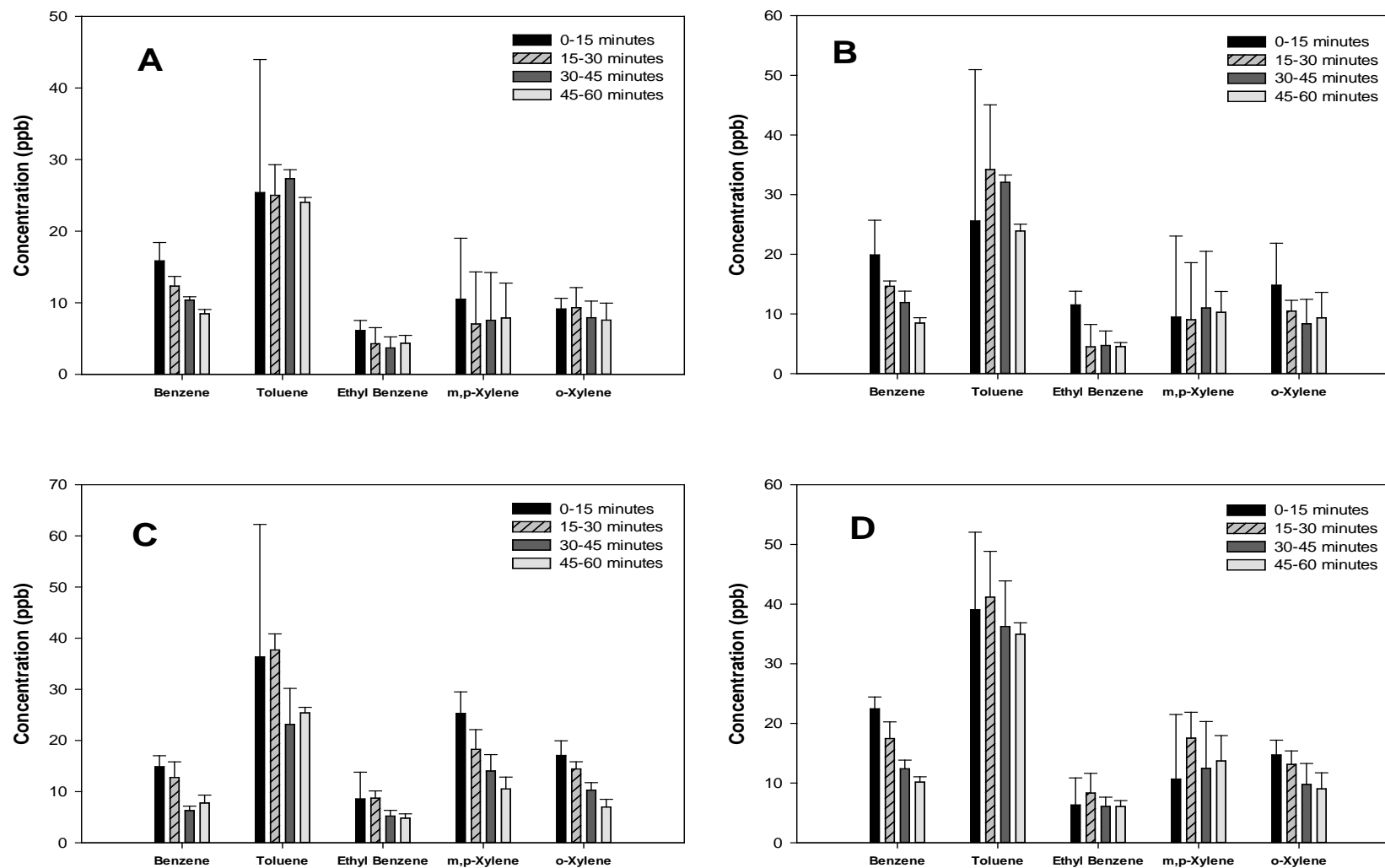


Figure 5. Average BTEX components concentration (+SD) in air from baffled-flask study at 21°C with (A) SLC oil, (B) dispersed SLC at DOR=20, (C) dispersed SLC at DOR=50, and (D) dispersed SLC at DOR=100 using thermal desorption method.

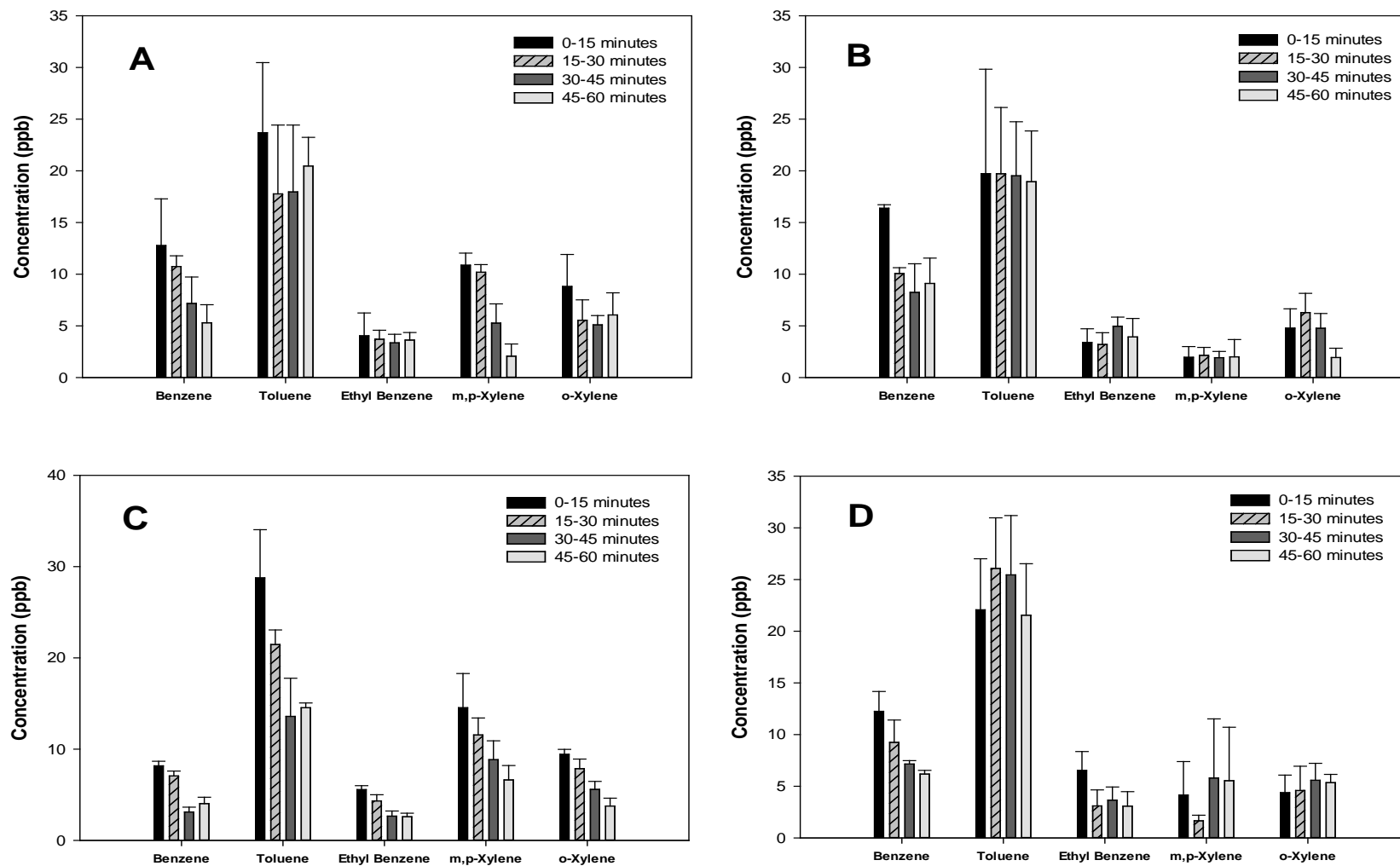


Figure 6. Average BTEX components concentration (+SD) in air from baffled-flask study at 4°C with (A) SLC oil, (B) dispersed SLC at DOR=20, (C) dispersed SLC at DOR=50, and (D) dispersed SLC at DOR=100 using thermal desorption method.

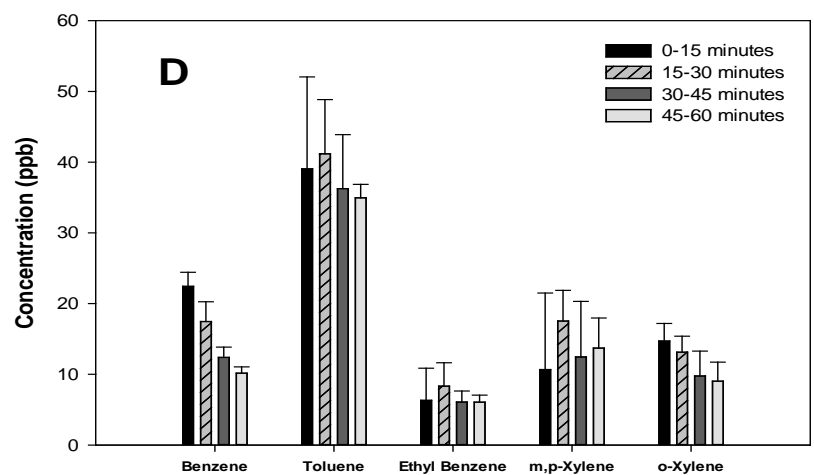
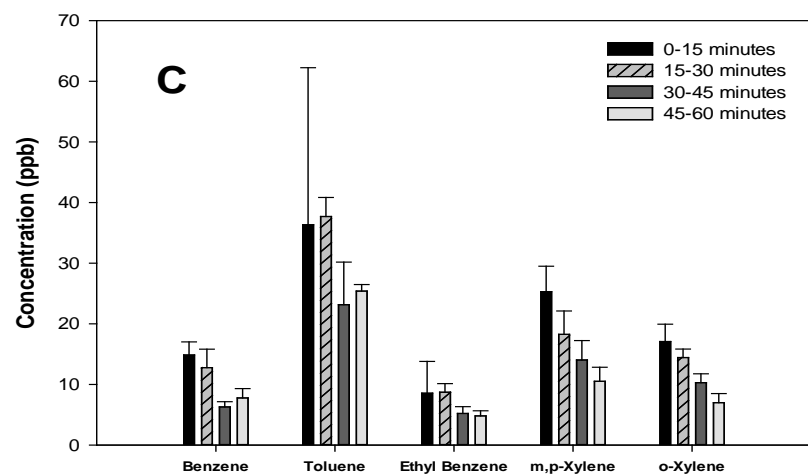
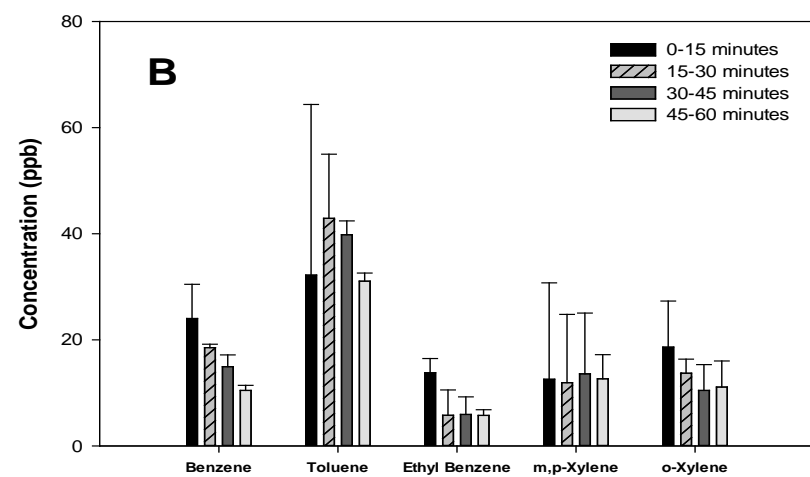
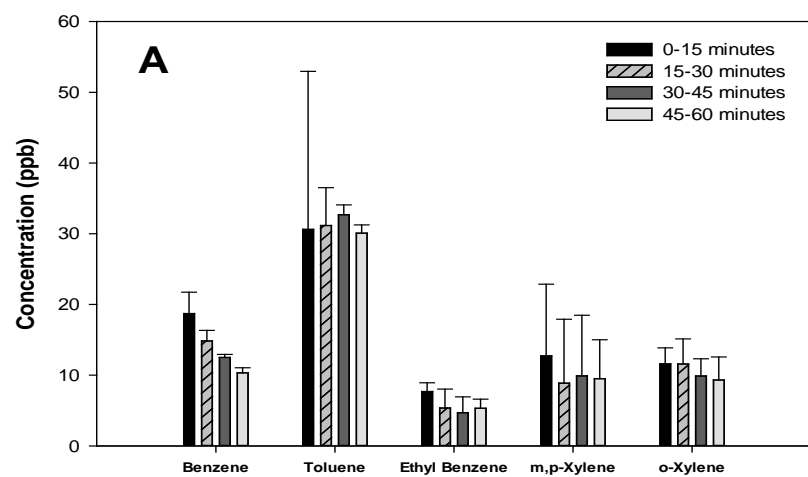


Figure 7. Average BTEX components concentration (+SD) in air from baffled-flask study at 21°C with (A) SLC oil, (B) dispersed SLC at DOR=20, (C) dispersed SLC at DOR=50, and (D) dispersed SLC at DOR=100 using direct sampling and microFast GC method.

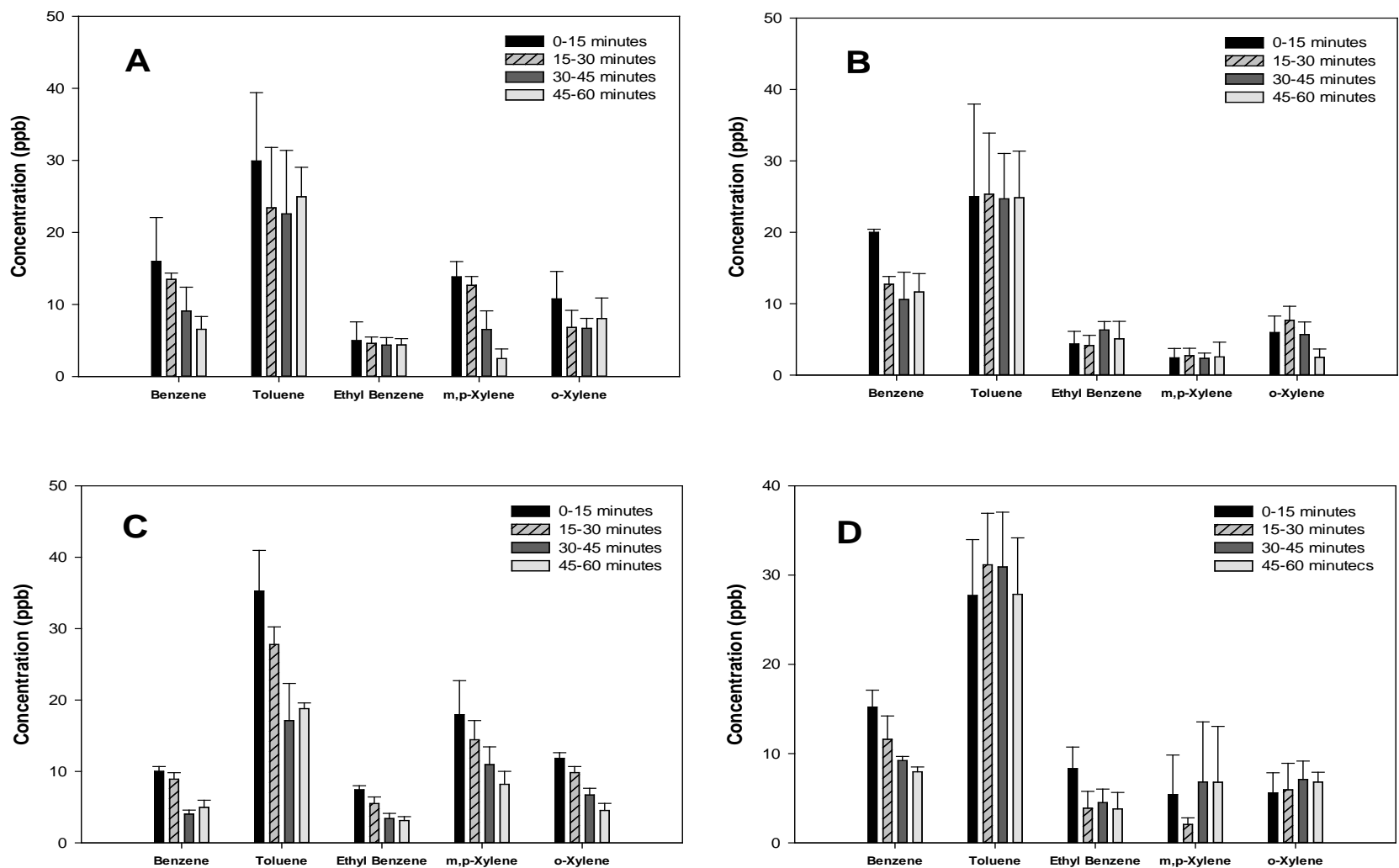


Figure 8. Average BTEX components concentration (+SD) in air from baffled-flask study at 4°C with (A) SLC oil, (B) dispersed SLC at DOR=20, (C) dispersed SLC at DOR=50, and (D) dispersed SLC at DOR=100 using direct sampling and microFast GC method.

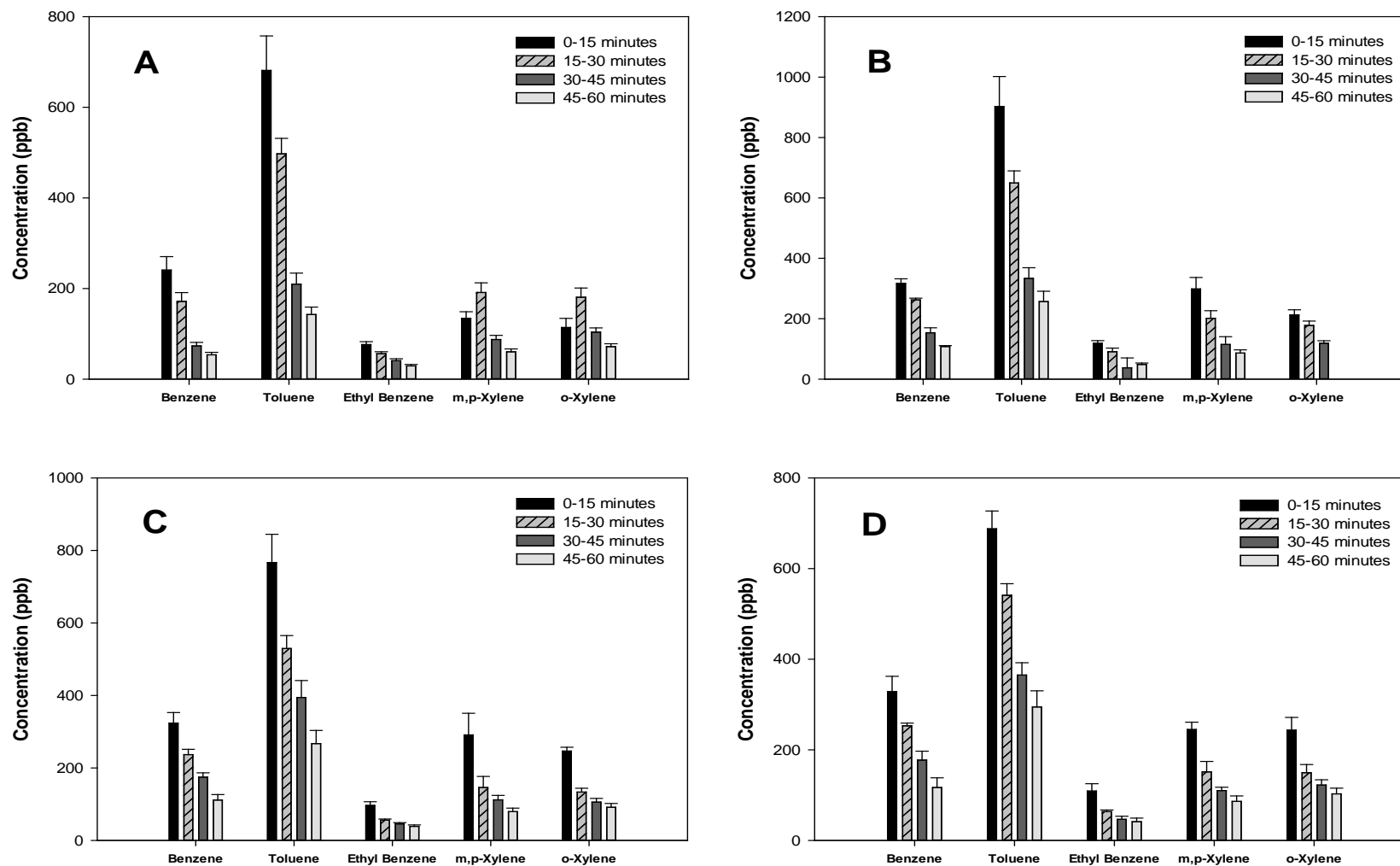


Figure 9. Average BTEX components concentration (+SD) in water from baffled-flask study at 21°C with (A) SLC oil, (B) dispersed SLC at DOR=20, (C) dispersed SLC at DOR=50, and (D) dispersed SLC at DOR=100 using headspace sampling and microFast GC method.

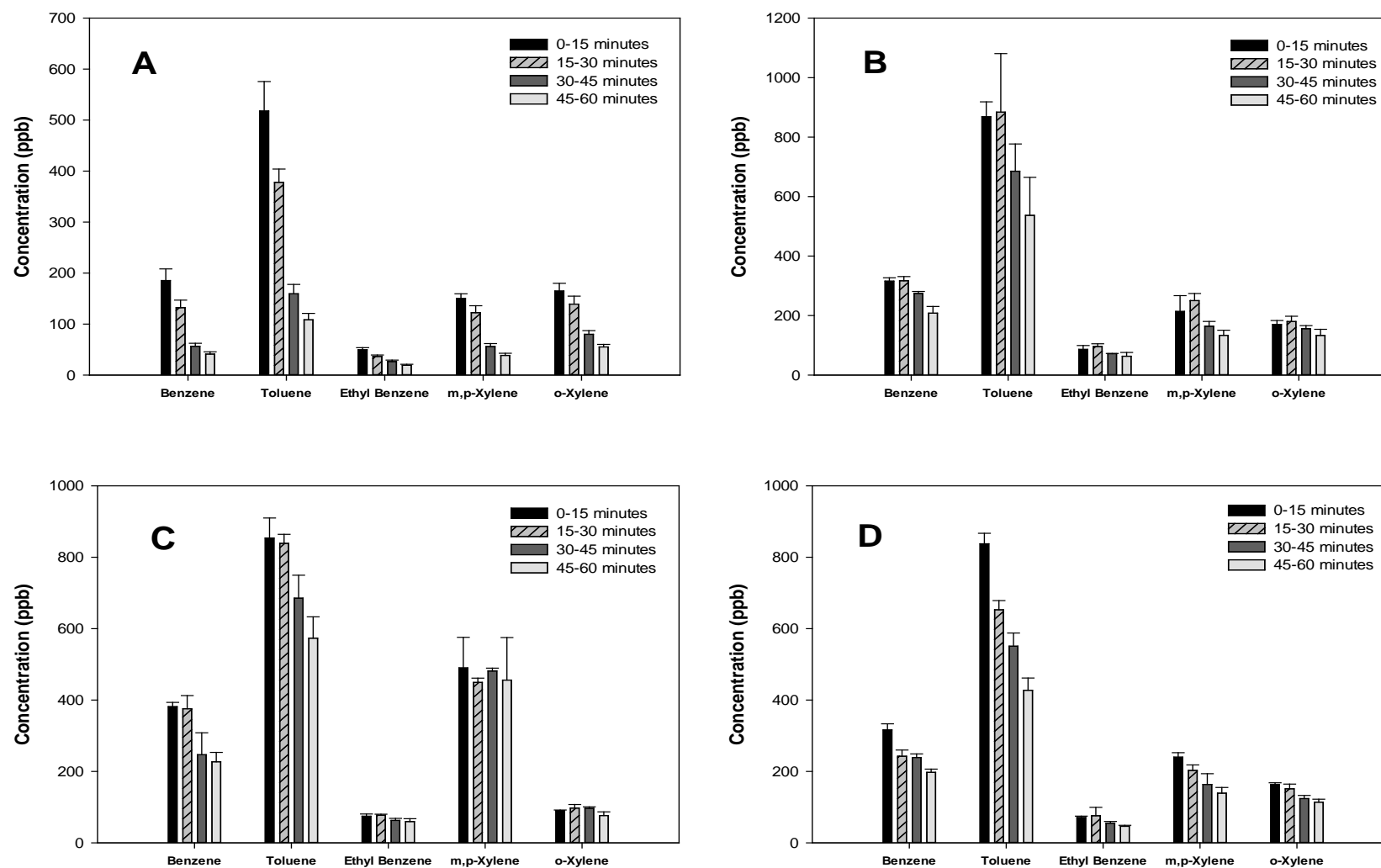


Figure 10. Average BTEX components concentration (+SD) in water from baffled-flask study at 4°C with (A) SLC oil, (B) dispersed SLC at DOR=20, (C) dispersed SLC at DOR=50, and (D) dispersed SLC at DOR=100 using headspace sampling and microFast GC method.

Table 5. Average concentration of BTEX components in air from baffled-flask study at temperature (21°C and 4°C) with (A) SLC oil, (B) dispersed SLC at DOR=20, (C) dispersed SLC at DOR=50, and (D) dispersed SLC at DOR=100 using thermal desorption method.

Temperature = 20°C

Time (min.)	0-15		15-30		30-45		45-60	
	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV
	conc. (ppb)		conc. (ppb)		conc. (ppb)		conc. (ppb)	
A Benzene	16	3	12	1	10	0	8	1
Toluene	25	19	25	4	27	1	24	1
Ethyl Benzene	6	1	4	2	4	2	4	1
m,p-Xylene	10	9	7	7	8	7	8	5
o-Xylene	9	1	9	3	8	2	8	2

B

Time (min.)	0-15		15-30		30-45		45-60	
	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV
	conc. (ppb)		conc. (ppb)		conc. (ppb)		conc. (ppb)	
Benzene	20	6	15	1	12	2	8	1
Toluene	26	25	34	11	32	1	24	1
Ethyl Benzene	12	2	4	4	5	2	5	1
m,p-Xylene	9	14	9	10	11	10	10	3
o-Xylene	15	7	10	2	8	4	9	4

C

Time (min.)	0-15		15-30		30-45		45-60	
	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV
	conc. (ppb)		conc. (ppb)		conc. (ppb)		conc. (ppb)	
Benzene	12	2	10	2	5	1	6	1
Toluene	29	21	30	4	19	6	21	1
Ethyl Benzene	7	4	7	1	4	1	4	1
m,p-Xylene	20	4	15	3	11	2	9	1
o-Xylene	14	2	12	1	8	1	6	1

D

Time (min.)	0-15		15-30		30-45		45-60	
	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV
	conc. (ppb)		conc. (ppb)		conc. (ppb)		conc. (ppb)	
Benzene	18	2	14	2	10	1	8	0
Toluene	32	9	34	7	29	8	28	2
Ethyl Benzene	5	4	6	2	5	1	5	1
m,p-Xylene	8	8	14	4	10	6	11	4
o-Xylene	12	1	11	2	8	3	7	2

Temperature = 4°C

Time (min.)	0-15		15-30		30-45		45-60	
	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV
	conc. (ppb)		conc. (ppb)		conc. (ppb)		conc. (ppb)	
A Benzene	13	5	11	1	7	3	5	2
Toluene	24	7	18	7	18	6	20	3
Ethyl Benzene	4	2	4	1	3	1	4	1
m,p-Xylene	11	1	10	1	5	2	2	1
o-Xylene	9	3	6	2	5	1	6	2

B

Time (min.)	0-15		15-30		30-45		45-60	
	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV
	conc. (ppb)		conc. (ppb)		conc. (ppb)		conc. (ppb)	
Benzene	16	0	10	1	8	3	13	2
Toluene	20	10	20	6	20	5	10	5
Ethyl Benzene	3	1	3	1	5	1	1	2
m,p-Xylene	2	1	2	1	2	1	2	2
o-Xylene	5	2	6	2	5	1	2	1

C

Time (min.)	0-15		15-30		30-45		45-60	
	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV
	conc. (ppb)		conc. (ppb)		conc. (ppb)		conc. (ppb)	
Benzene	8	1	7	1	3	1	4	1
Toluene	29	5	21	2	14	4	15	1
Ethyl Benzene	6	0	4	1	3	1	3	0
m,p-Xylene	15	4	12	2	9	2	7	2
o-Xylene	9	1	8	1	6	1	4	1

D

Time (min.)	0-15		15-30		30-45		45-60	
	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV
	conc. (ppb)		conc. (ppb)		conc. (ppb)		conc. (ppb)	
Benzene	12	2	9	2	7	0	6	0
Toluene	22	5	26	5	25	6	22	5
Ethyl Benzene	7	2	3	2	4	1	3	1
m,p-Xylene	4	3	2	1	6	6	6	5
o-Xylene	4	2	5	2	6	2	5	1

Table 6. Average concentration of BTEX components in air from baffled-flask study at temperature (20°C and 4°C) with (A) SLC oil, (B) dispersed SLC at DOR=20, (C) dispersed SLC at DOR=50, and (D) dispersed SLC at DOR=100 using direct sampling and microFast GC method.

Temperature = 20°C									
Time (min.)	0-15		15-30		30-45		45-60		Replicate
	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV	
	conc. (ppb)		conc. (ppb)		conc. (ppb)		conc. (ppb)		
Benzene	19	3	15	1	13	0	10	1	
Toluene	31	22	31	5	33	1	30	1	
Ethyl Benzene	8	1	5	3	5	2	5	1	
m,p-Xylene	13	10	9	9	10	9	10	6	
o-Xylene	12	2	12	4	10	2	9	3	

Time (min.)	0-15		15-30		30-45		45-60		Replicate
	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV	
	conc. (ppb)		conc. (ppb)		conc. (ppb)		conc. (ppb)		
Benzene	24	6	19	1	15	2	10	1	
Toluene	32	32	43	12	40	3	31	2	
Ethyl Benzene	14	3	6	5	6	3	6	1	
m,p-Xylene	13	18	12	13	14	11	13	5	
o-Xylene	19	9	14	3	10	5	11	5	

Time (min.)	0-15		15-30		30-45		45-60		Replicate
	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV	
	conc. (ppb)		conc. (ppb)		conc. (ppb)		conc. (ppb)		
Benzene	15	2	13	3	6	1	8	2	
Toluene	36	26	38	3	23	7	25	1	
Ethyl Benzene	9	5	9	1	5	1	5	1	
m,p-Xylene	25	4	18	4	14	3	11	2	
o-Xylene	17	3	14	1	10	1	7	2	

Time (min.)	0-15		15-30		30-45		45-60		Replicate
	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV	
	conc. (ppb)		conc. (ppb)		conc. (ppb)		conc. (ppb)		
Benzene	22	2	17	3	12	1	10	1	
Toluene	39	13	41	8	36	8	35	2	
Ethyl Benzene	6	5	8	3	6	2	6	1	
m,p-Xylene	11	11	18	4	12	8	14	4	
o-Xylene	15	2	13	2	10	4	9	3	

Temperature = 4°C									
Time (min.)	0-15		15-30		30-45		45-60		Replicate
	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV	
	conc. (ppb)		conc. (ppb)		conc. (ppb)		conc. (ppb)		
Benzene	16	6	13	1	9	3	7	2	
Toluene	30	9	23	8	23	9	25	4	
Ethyl Benzene	5	3	5	1	4	1	4	1	
m,p-Xylene	14	2	13	1	7	3	2	1	
o-Xylene	11	4	7	2	7	1	8	3	

Time (min.)	0-15		15-30		30-45		45-60		Replicate
	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV	
	conc. (ppb)		conc. (ppb)		conc. (ppb)		conc. (ppb)		
Benzene	20	0	13	1	11	4	12	3	
Toluene	25	13	25	9	25	6	25	7	
Ethyl Benzene	4	2	4	1	6	1	5	2	
m,p-Xylene	2	1	3	1	2	1	3	2	
o-Xylene	6	2	8	2	6	2	2	1	

Time (min.)	0-15		15-30		30-45		45-60		Replicate
	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV	
	conc. (ppb)		conc. (ppb)		conc. (ppb)		conc. (ppb)		
Benzene	10	1	9	1	4	1	5	1	
Toluene	35	6	28	2	17	5	19	1	
Ethyl Benzene	7	1	5	1	3	1	3	1	
m,p-Xylene	18	5	14	3	11	2	8	2	
o-Xylene	12	1	10	1	7	1	5	1	

Time (min.)	0-15		15-30		30-45		45-60		Replicate
	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV	
	conc. (ppb)		conc. (ppb)		conc. (ppb)		conc. (ppb)		
Benzene	15	2	12	3	9	0	8	1	
Toluene	28	6	31	6	31	6	28	6	
Ethyl Benzene	8	2	4	2	5	2	4	2	
m,p-Xylene	5	4	2	1	7	7	7	6	
o-Xylene	6	2	6	3	7	2	7	1	

Table 7. Concentration of BTEX components in water from baffled-flask study at temperature (20°C and 4°C) with (A) SLC oil, (B) dispersed SLC at DOR=20, (C) dispersed SLC at DOR=50, and (D) dispersed SLC at DOR=100 using headspace sampling and microFast GC method.

Temperature = 20°C									
Time (min.)	0-15		15-30		30-45		45-60		Replicate
	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV	
	conc. (ppb)		conc. (ppb)		conc. (ppb)		conc. (ppb)		
Benzene	241	30	172	19	73	8	54	6	A
Toluene	681	76	497	34	210	24	143	16	
Ethyl Benzene	76	6	56	4	41	4	29	3	
m,p-Xylene	134	14	191	21	87	9	60	6	
o-Xylene	114	20	181	20	104	9	72	6	

Time (min.)	0-15		15-30		30-45		45-60		Replicate
	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV	
	conc. (ppb)		conc. (ppb)		conc. (ppb)		conc. (ppb)		
Benzene	317	16	262	6	153	17	108	3	B
Toluene	903	99	649	40	333	35	257	34	
Ethyl Benzene	118	9	91	12	37	32	48	5	
m,p-Xylene	298	38	202	25	115	26	86	10	
o-Xylene	212	17	178	15	119	8	0	0	

Time (min.)	0-15		15-30		30-45		45-60		Replicate
	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV	
	conc. (ppb)		conc. (ppb)		conc. (ppb)		conc. (ppb)		
Benzene	324	29	237	15	174	12	111	15	C
Toluene	767	78	530	36	394	47	267	36	
Ethyl Benzene	96	10	56	3	45	4	39	4	
m,p-Xylene	291	60	146	31	112	12	79	10	
o-Xylene	246	11	133	11	105	10	91	11	

Time (min.)	0-15		15-30		30-45		45-60		Replicate
	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV	
	conc. (ppb)		conc. (ppb)		conc. (ppb)		conc. (ppb)		
Benzene	328	34	253	6	177	20	117	22	D
Toluene	688	39	541	26	365	27	294	36	
Ethyl Benzene	109	16	63	4	47	7	41	8	
m,p-Xylene	245	16	151	23	110	7	86	12	
o-Xylene	243	28	149	18	122	12	103	13	

Temperature = 4°C									
Time (min.)	0-15		15-30		30-45		45-60		Replicate
	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV	
	conc. (ppb)		conc. (ppb)		conc. (ppb)		conc. (ppb)		
Benzene	185	23	132	15	56	6	41	4	A
Toluene	518	58	378	26	159	18	108	13	
Ethyl Benzene	50	4	36	3	26	3	19	2	
m,p-Xylene	150	9	122	14	56	6	39	4	
o-Xylene	165	15	139	16	80	7	55	5	

Time (min.)	0-15		15-30		30-45		45-60		Replicate
	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV	
	conc. (ppb)		conc. (ppb)		conc. (ppb)		conc. (ppb)		
Benzene	315	11	317	14	275	6	208	23	B
Toluene	869	50	884	197	686	91	537	128	
Ethyl Benzene	86	13	96	9	72	1	63	12	
m,p-Xylene	214	53	250	24	164	16	134	17	
o-Xylene	170	14	180	18	156	10	133	21	

Time (min.)	0-15		15-30		30-45		45-60		Replicate
	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV	
	conc. (ppb)		conc. (ppb)		conc. (ppb)		conc. (ppb)		
Benzene	381	12	376	37	247	61	227	26	C
Toluene	854	56	839	25	686	64	574	60	
Ethyl Benzene	74	6	77	3	63	6	59	8	
m,p-Xylene	490	86	450	12	481	8	456	119	
o-Xylene	90	2	97	10	96	4	77	10	

Time (min.)	0-15		15-30		30-45		45-60		Replicate
	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV	
	conc. (ppb)		conc. (ppb)		conc. (ppb)		conc. (ppb)		
Benzene	316	17	243	17	239	10	197	9	D
Toluene	838	30	653	26	551	37	427	35	
Ethyl Benzene	71	4	76	23	55	5	46	3	
m,p-Xylene	240	13	203	15	164	30	139	16	
o-Xylene	163	5	151	13	124	9	114	8	

Table 8. Mass fraction of BTEX components in air and water removed from SLC oil during baffled-flask experiment.

Matrix	Oil (21°C)				
	Benzene	Toluene	Ethyl Benzene	m,p-Xylenes	o-Xylene
Air	0.60	0.46	0.58	0.19	0.54
Water	0.15	0.15	0.14	0.06	0.16
Total	0.75	0.62	0.72	0.25	0.71

Matrix	Oil (4°C)				
	Benzene	Toluene	Ethyl Benzene	m,p-Xylenes	o-Xylene
Air	0.47	0.37	0.47	0.17	0.41
Water	0.12	0.12	0.09	0.05	0.15
Total	0.59	0.49	0.56	0.21	0.56

Matrix	Dispersed Oil - DOR=20 (21°C)				
	Benzene	Toluene	Ethyl Benzene	m,p-Xylenes	o-Xylene
Air	0.71	0.54	0.80	0.24	0.69
Water	0.24	0.21	0.20	0.09	0.18
Total	0.95	0.75	1.00	0.33	0.87

Matrix	Dispersed Oil - DOR=20 (4°C)				
	Benzene	Toluene	Ethyl Benzene	m,p-Xylenes	o-Xylene
Air	0.60	0.35	0.46	0.05	0.28
Water	0.32	0.30	0.22	0.10	0.22
Total	0.91	0.64	0.67	0.14	0.50

Matrix	Dispersed Oil - DOR=50 (21°C)				
	Benzene	Toluene	Ethyl Benzene	m,p-Xylenes	o-Xylene
Air	0.44	0.45	0.69	0.32	0.63
Water	0.24	0.20	0.16	0.08	0.20
Total	0.68	0.65	0.85	0.40	0.83

Matrix	Dispersed Oil - DOR=50 (4°C)				
	Benzene	Toluene	Ethyl Benzene	m,p-Xylenes	o-Xylene
Air	0.29	0.36	0.49	0.24	0.42
Water	0.35	0.30	0.19	0.24	0.13
Total	0.64	0.66	0.68	0.49	0.55

Matrix	Dispersed Oil - DOR=100 (21°C)				
	Benzene	Toluene	Ethyl Benzene	m,p-Xylenes	o-Xylene
Air	0.65	0.56	0.68	0.26	0.60
Water	0.25	0.19	0.18	0.08	0.22
Total	0.90	0.75	0.86	0.33	0.82

Matrix	Dispersed Oil - DOR=100 (4°C)				
	Benzene	Toluene	Ethyl Benzene	m,p-Xylenes	o-Xylene
Air	0.46	0.44	0.52	0.10	0.32
Water	0.28	0.25	0.17	0.10	0.19
Total	0.74	0.68	0.69	0.20	0.51

RECIRCULATING TANK EXPERIMENT

A series of macro-scale laboratory studies were performed to further compare air and water analytical methods and attempt to determine mass balance of BTEX components within a 250-L recirculating tank system (Figure 12) following addition of Corexit 9500 to SLC oil. The experimental recirculating tank was designed and operated for calibration of in-situ fluorometry instrumentation prior to oil spill drills or field deployment. The tank system is equipped with a high-speed recirculating pump (1/4 hp) to evenly distribute dispersed oil throughout the tank, dual sampling ports, and in-line quick connection ports to attach sampling equipment. During the experiment a six (6) position vacuum line block was installed approximately 12 inches above the water surface prior to addition of oil and dispersant. The block was used to hold the thermal desorption and direct sampling air lines in place during sampling. The recirculating tank experiment employed the same multitube flowmeter system, vacuum system, and sampling valves used in the baffled-flask experiment. The vacuum flow rate was maintained at 85 ml/min. for all recirculating tank experiments. Approximately 70-ml of SLC oil was applied to each treatment and replicate during the recirculating tank experiment, yielding a nominal oil concentration of 340 ppm. Prior to spiking, the oil was mixed with a known volume of dispersant Corexit 9500 to create the desired dispersant to oil ratio (DOR) for each test. As with the baffled-flask experiment, air (desorption tubes and direct) and water samples were collected at 15 minute intervals. Water samples were collected by placing a 12 inch piece of PTFE tubing onto the syringe and collecting a 20-ml

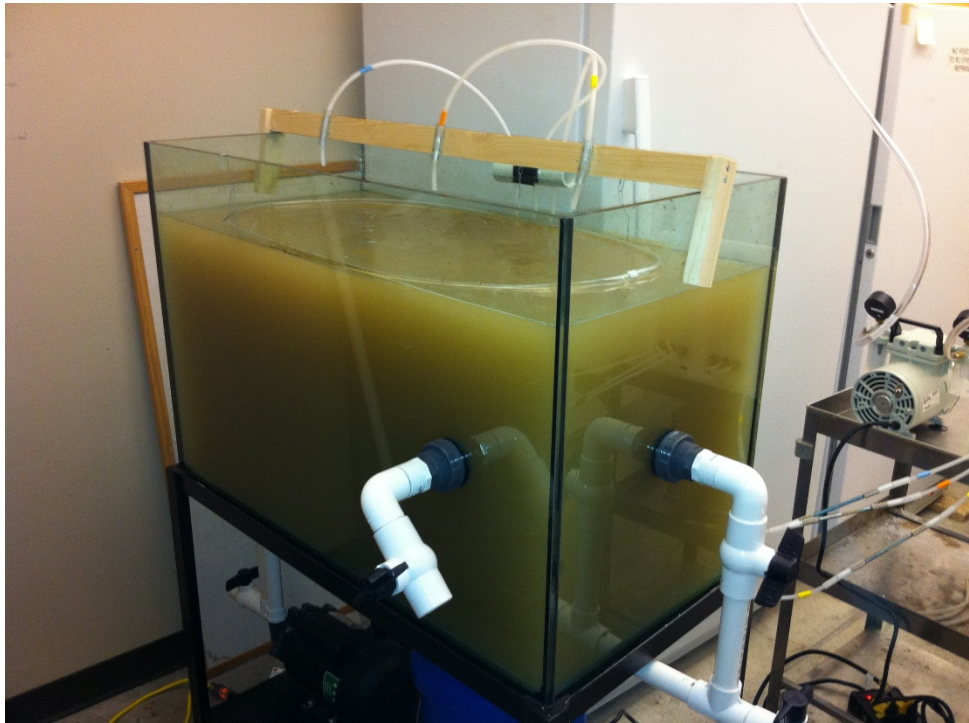
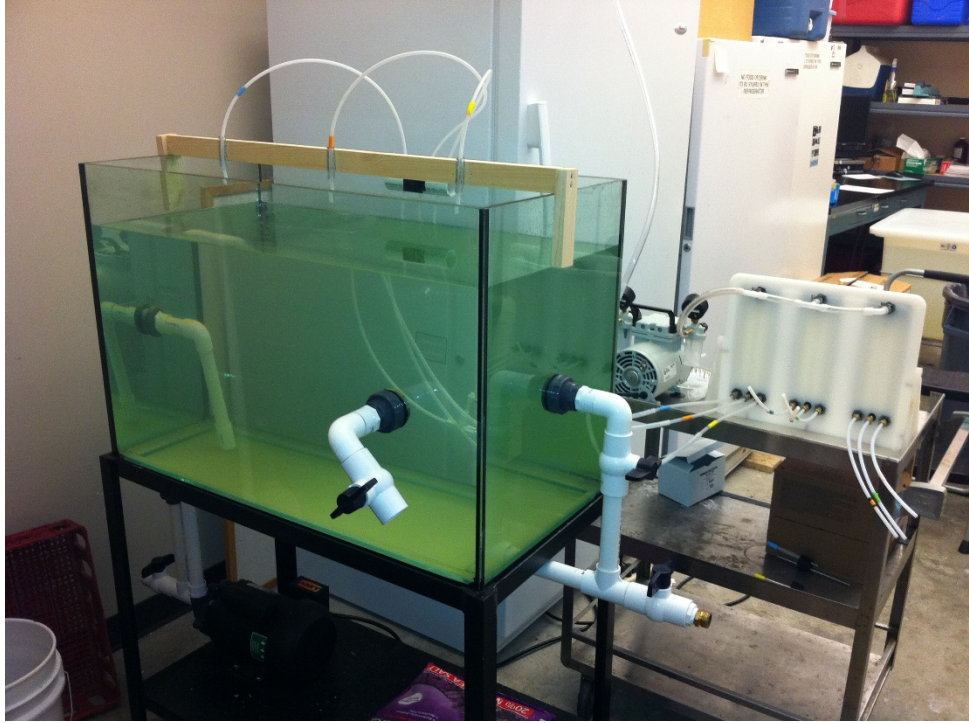


Figure 11. Photographs of the recirculating tank apparatus.

sample approximately six (6) inches beneath the water surface. Air was pushed through the tube as the sampler was lowered into the water so as not to introduce floating oil into the sample. Air and water samples were prepared and analyzed using the same methods employed during the baffled-flask experiment. Three (3) control runs (no dispersant) were conducted using fresh SLC oil to determine BTEX concentrations and mass balance following natural dispersion. Two (2) DORs (DOR=20 and 100) were evaluated during the recirculating tank experiment. Three (3) dispersant runs were conducted for each specific DOR using fresh SLC oil to determine BTEX concentration and mass balance following chemical dispersion. Each run was concluded after 60 minutes and was maintained at ambient room temperature (21°C). The experimental variables and analysis matrix for the recirculating tank experiment are displayed in Table 12. All results were be interpreted using current statistical analysis techniques.

Table 9. Variables and analysis matrix for recirculating tank experiment.

Treatment	# of Samples at Time Interval				Total # of Analytical Determinations	
	15 min.	30 min.	45 min.	60 min.	Air/Water-MicroFast	Air-Desorp. Tube
Control-Rep.#1	3	3	3	3	24	12
Control-Rep.#2	3	3	3	3	24	12
Control-Rep.#3	3	3	3	3	24	12
DOR#1-Rep.#1	3	3	3	3	24	12
DOR#1-Rep.#2	3	3	3	3	24	12
DOR#1-Rep.#3	3	3	3	3	24	12
DOR#2-Rep.#1	3	3	3	3	24	12
DOR#2-Rep.#2	3	3	3	3	24	12
DOR#2-Rep.#3	3	3	3	3	24	12

Summary of Recirculating Tank Experiments

Figures 12-20 contain the results of the air and water analysis from the recirculating tank experiments. As with the baffled-flask experiments, the results from the air sampling indicate there is a 10-23 % difference in average concentrations between the thermal desorption and direct sampling methods. The DOR=20 and DOR=100 treatments displayed a 24% and 10% reduction in average BTEX components in the air for the non-dispersed control oil treatment, respectively. Although there were decreases in BTEX levels, air monitoring results indicated there was only an 8.1% overall difference between the control oil and the average oil + dispersant treatments. Results indicated there was a 20% difference in BTEX component concentrations between the dispersant treatments. The high degree of variability between the control and dispersed treatment BTEX concentration results within the air samples may be due to excessive loss of volatiles from the open tank system. BTEX component concentrations within the water ranged between 10-200 times greater than those found in the air samples. Water sampling results indicated there was a 215% increase in BTEX component concentrations within the water when dispersant was added to the oil. A mass balance of the system indicates less than 20% of BTEX components were lost to the water phase, less than 35% loss to the atmosphere, and remainder retained in the oil. The mass balance is estimated because the shallow open system exposes more oil to the surface, thus increasing the flux of volatiles from the water. The averaged results for the recirculating tank study are displayed in Tables 10-12. Tables A7-A15 contain raw data for the recirculating tank study.

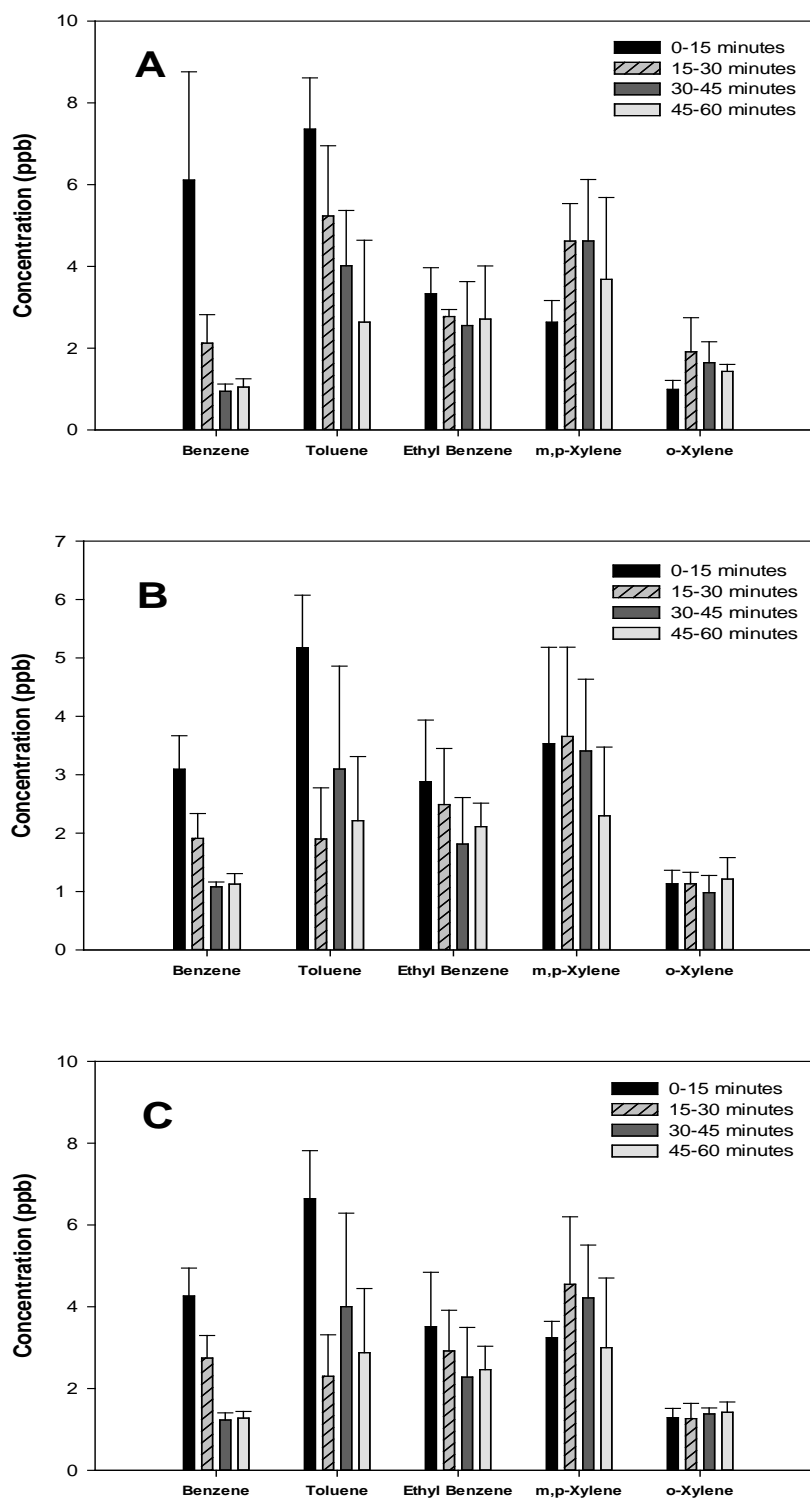


Figure 12. Average BTEX components concentration (+SD) in air from recirculating tank study at 21°C with (A) SLC oil, (B) dispersed SLC at DOR=20, and (C) dispersed SLC at DOR=100 using thermal desorption method (Run #1).

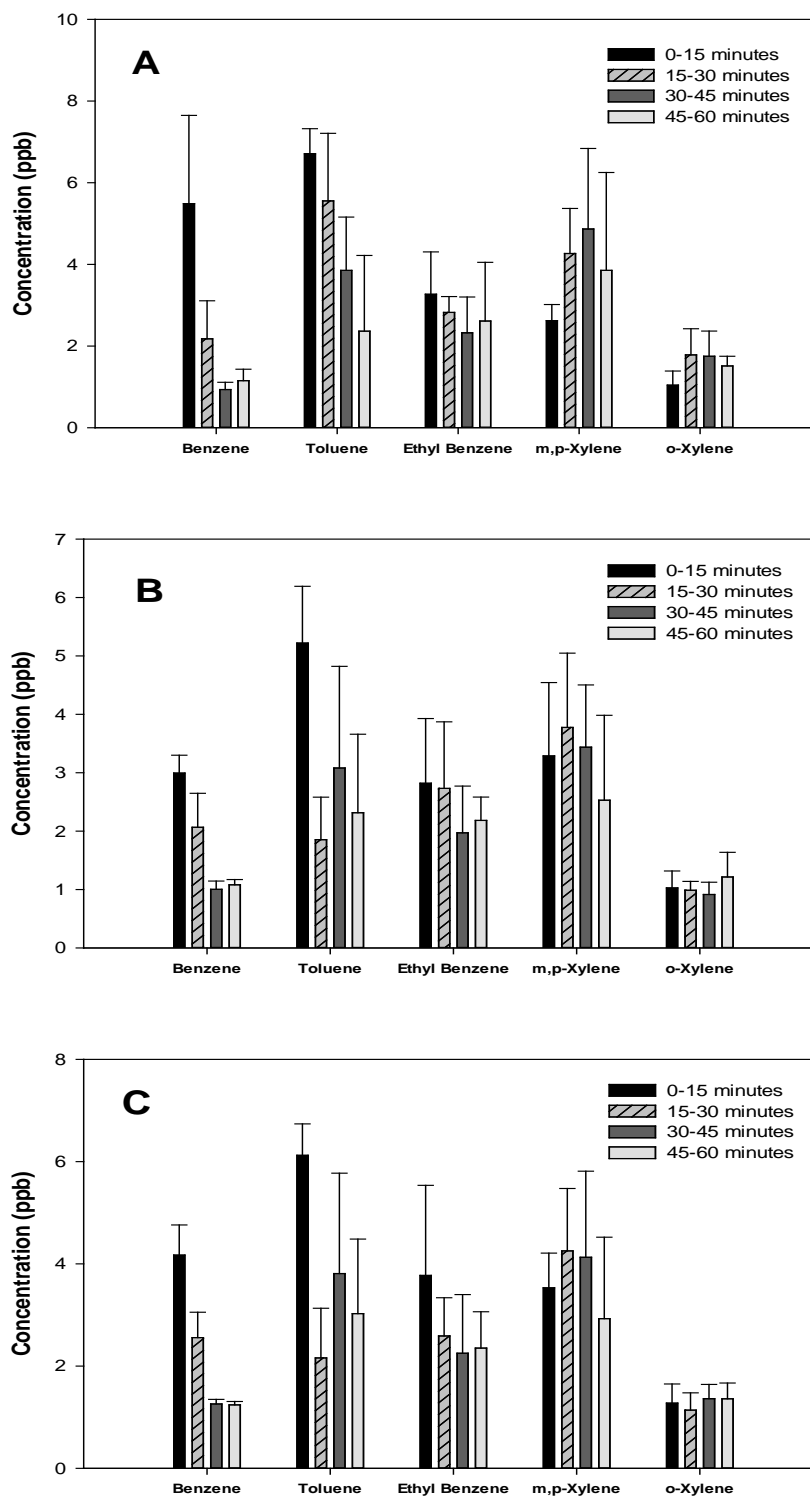


Figure 13. Average BTEX components concentration (+SD) in air from recirculating tank study at 21°C with (A) SLC oil, (B) dispersed SLC at DOR=20, and (C) dispersed SLC at DOR=100 using thermal desorption method (Run #2).

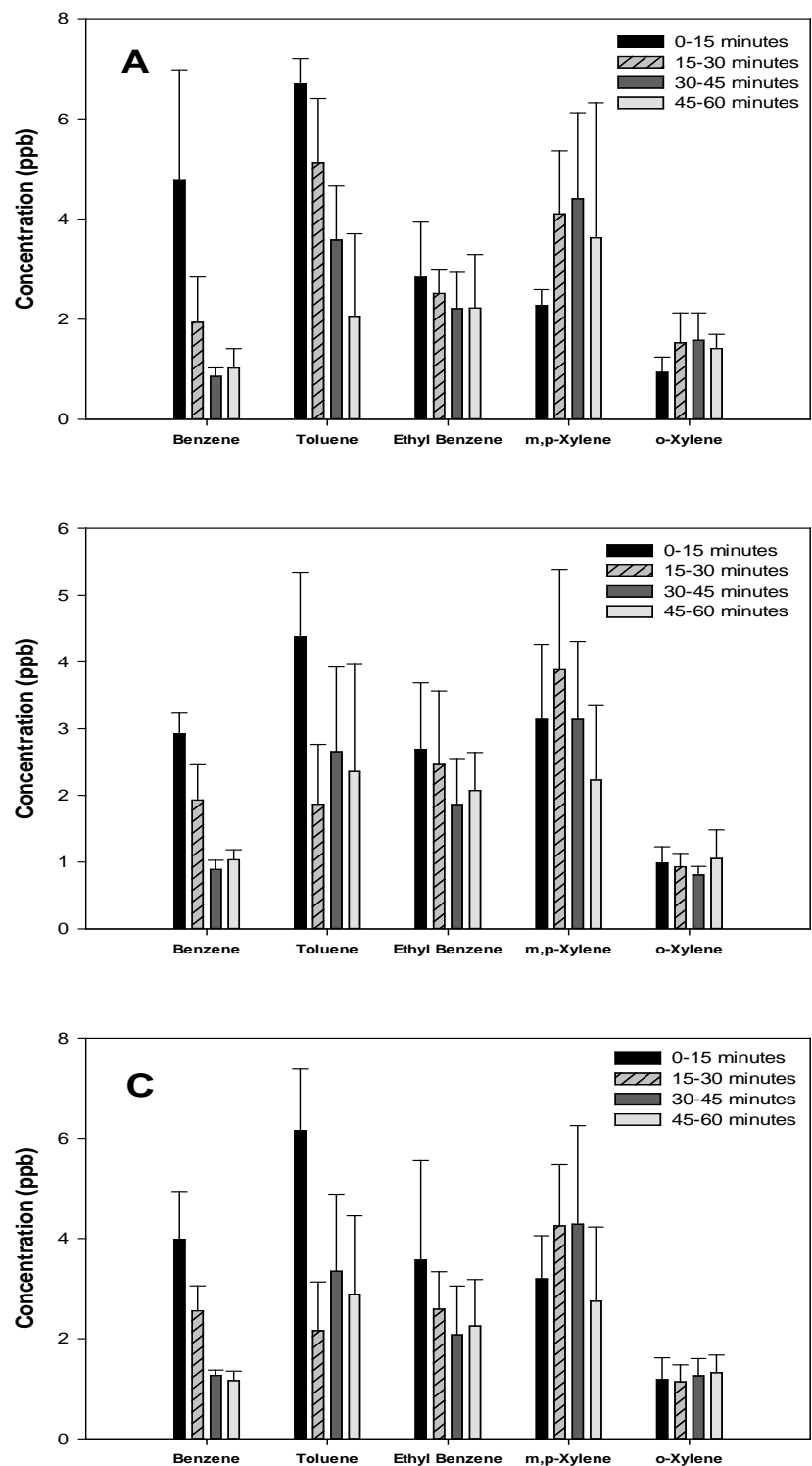


Figure 14. Average BTEX components concentration (+SD) in air from recirculating tank study at 21°C with (A) SLC oil, (B) dispersed SLC at DOR=20, and (C) dispersed SLC at DOR=100 using thermal desorption method (Run #3).

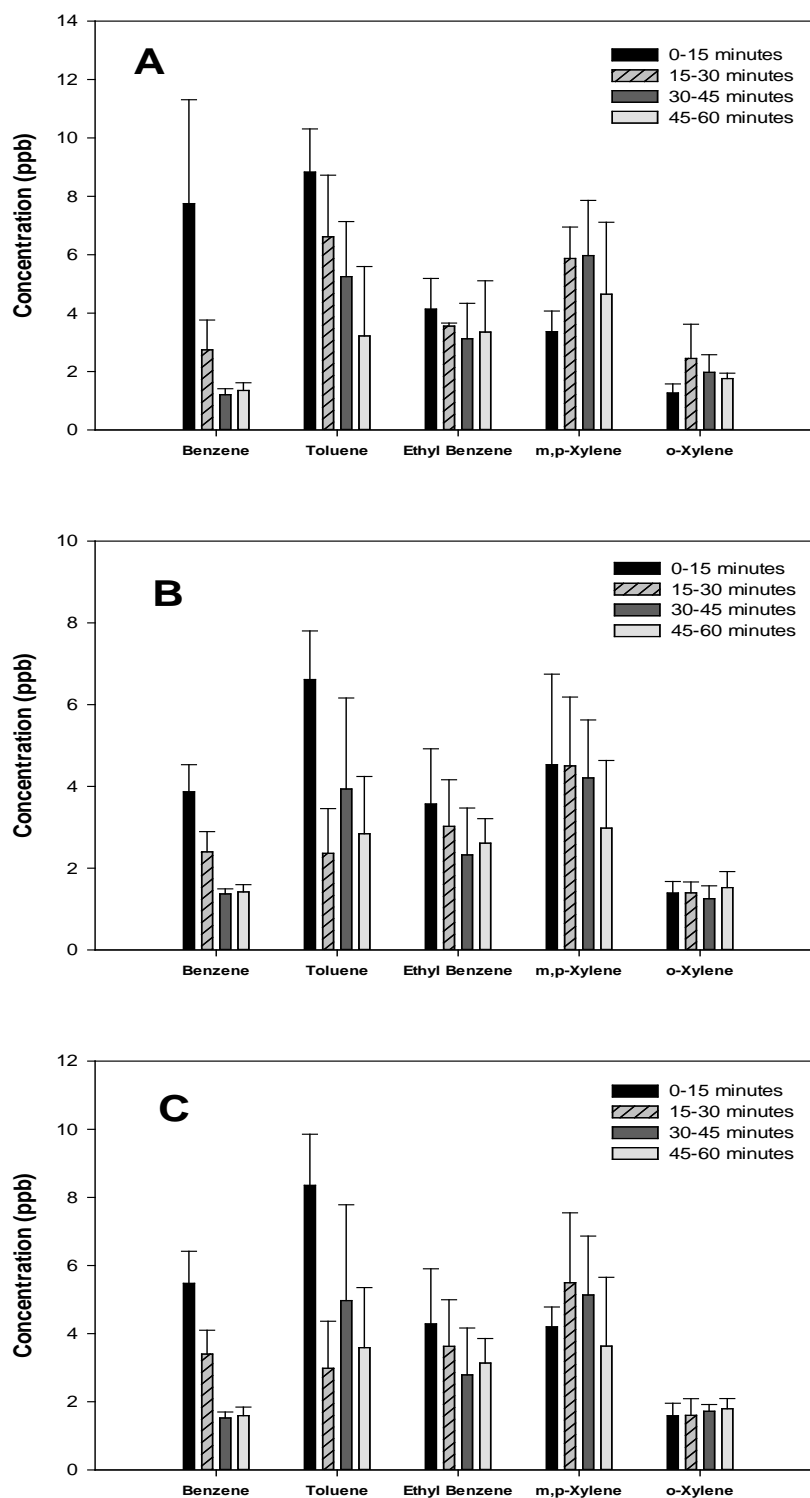


Figure 15. Average BTEX components concentration (+SD) in air from recirculating tank study at 21°C with (A) SLC oil, (B) dispersed SLC at DOR=20, and (C) dispersed SLC at DOR=100 using direct sampling and microFast GC method (Run #1).

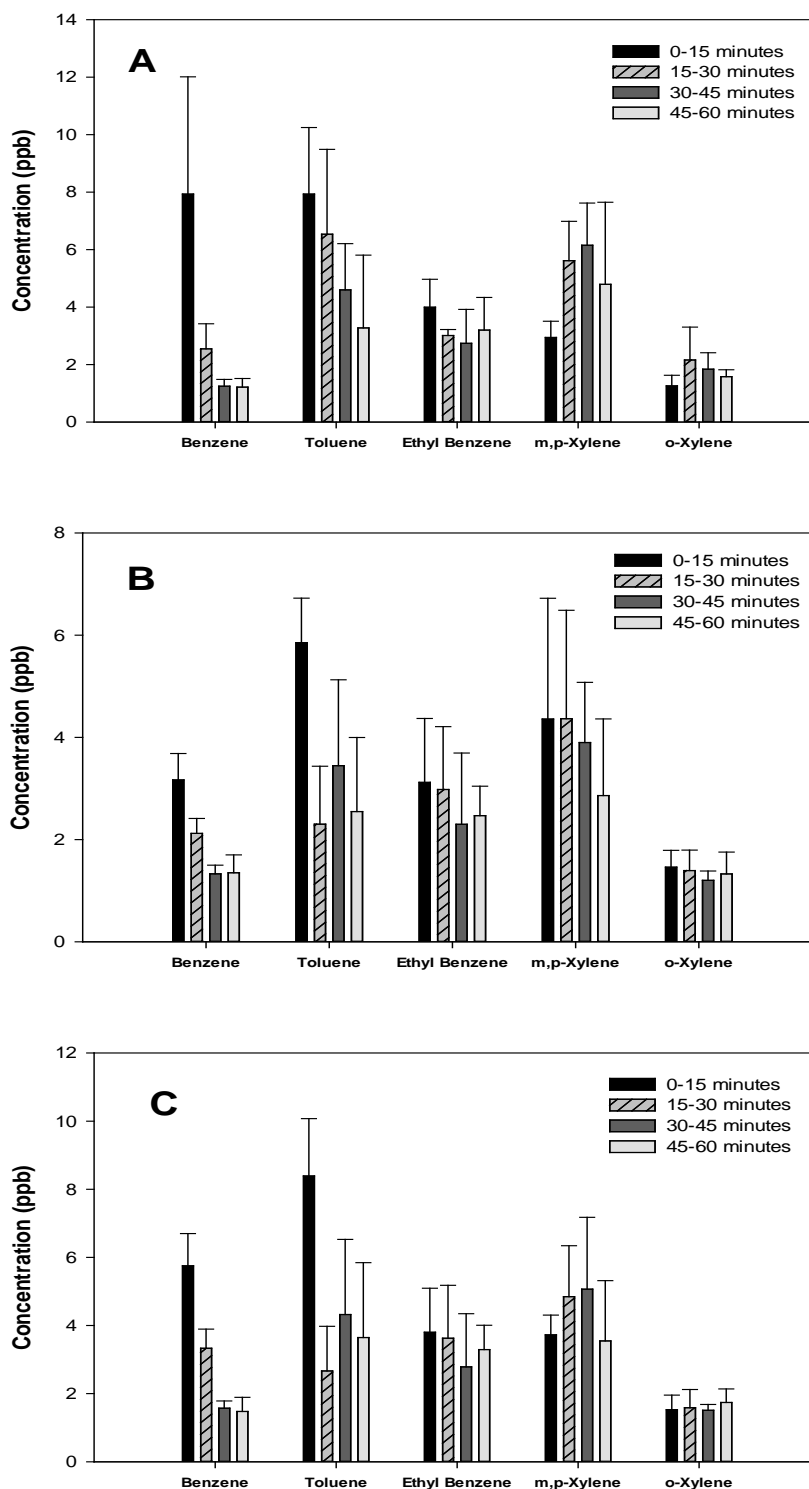


Figure 16. Average BTEX components concentration (+SD) in air from recirculating tank study at 21°C with (A) SLC oil, (B) dispersed SLC at DOR=20, and (C) dispersed SLC at DOR=100 using direct sampling and microFast GC method (Run #2).

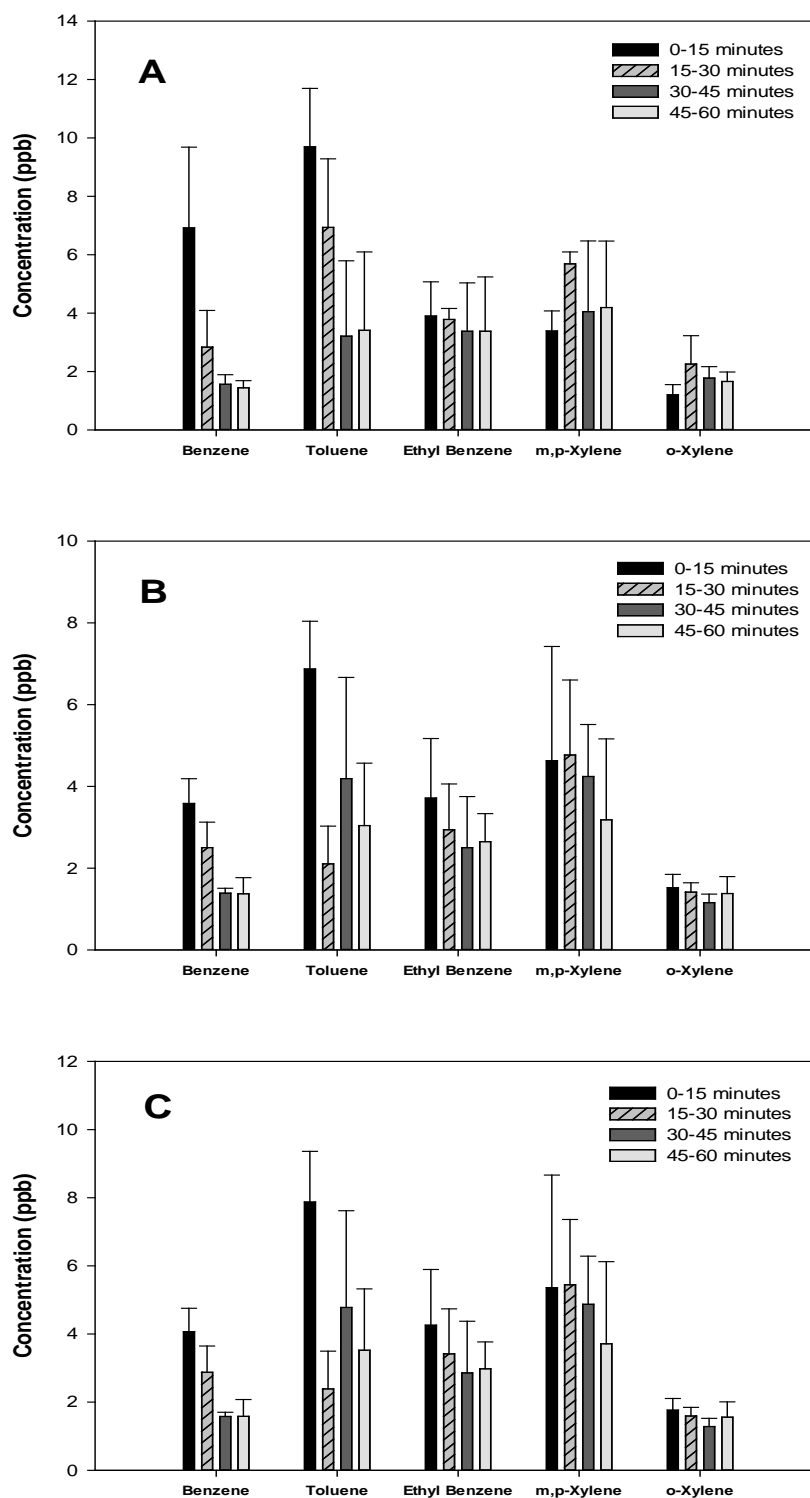


Figure 17. Average BTEX components concentration (+SD) in air from recirculating tank study at 21°C with (A) SLC oil, (B) dispersed SLC at DOR=20, and (C) dispersed SLC at DOR=100 using direct sampling and microFast GC method (Run #3).

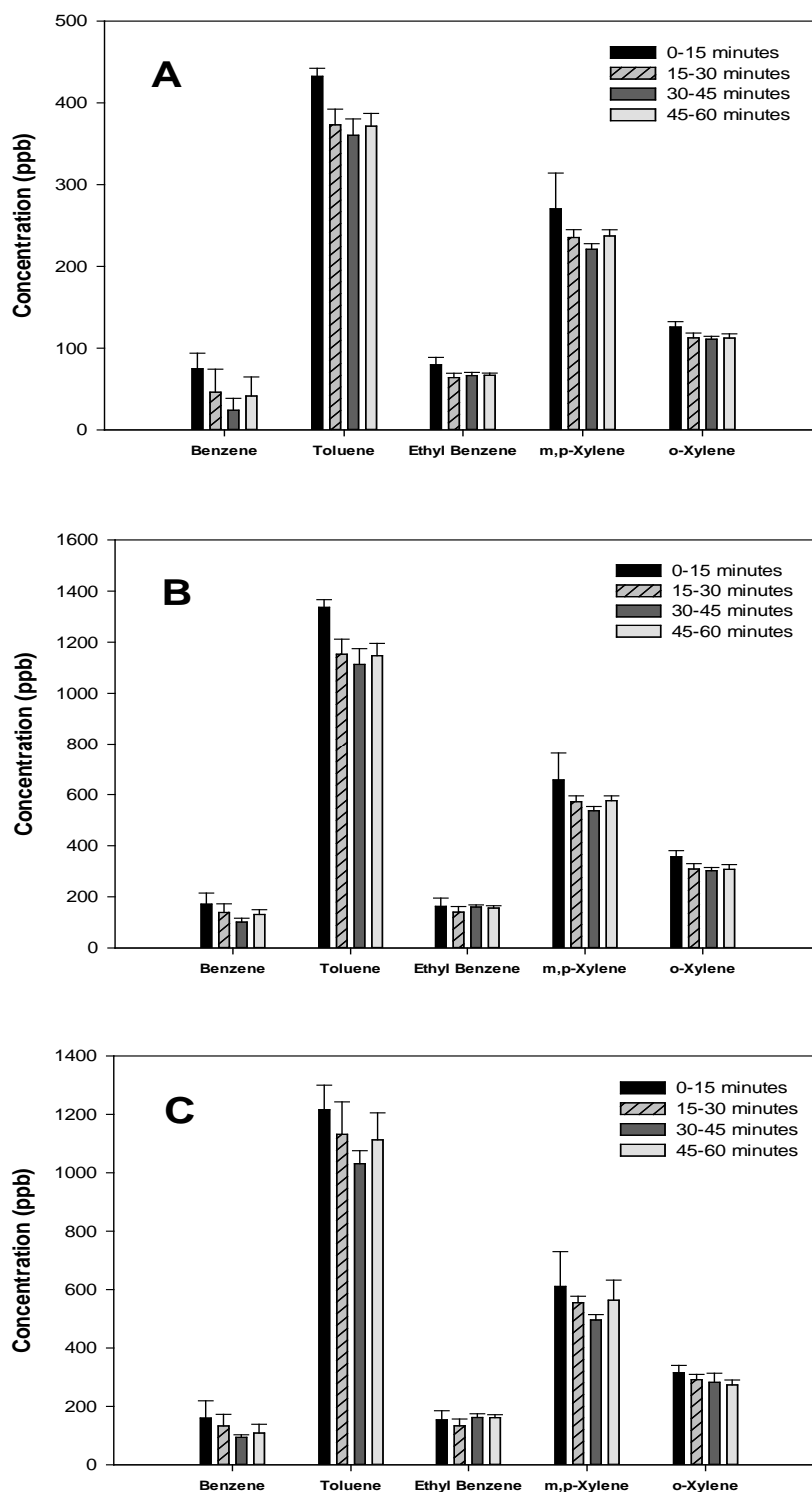


Figure 18. Average BTEX components concentration (+SD) in water from recirculating tank study at 21°C with (A) SLC oil, (B) dispersed SLC at DOR=20, and (C) dispersed SLC at DOR=100 using headspace sampling and microFast GC method (Run #1).

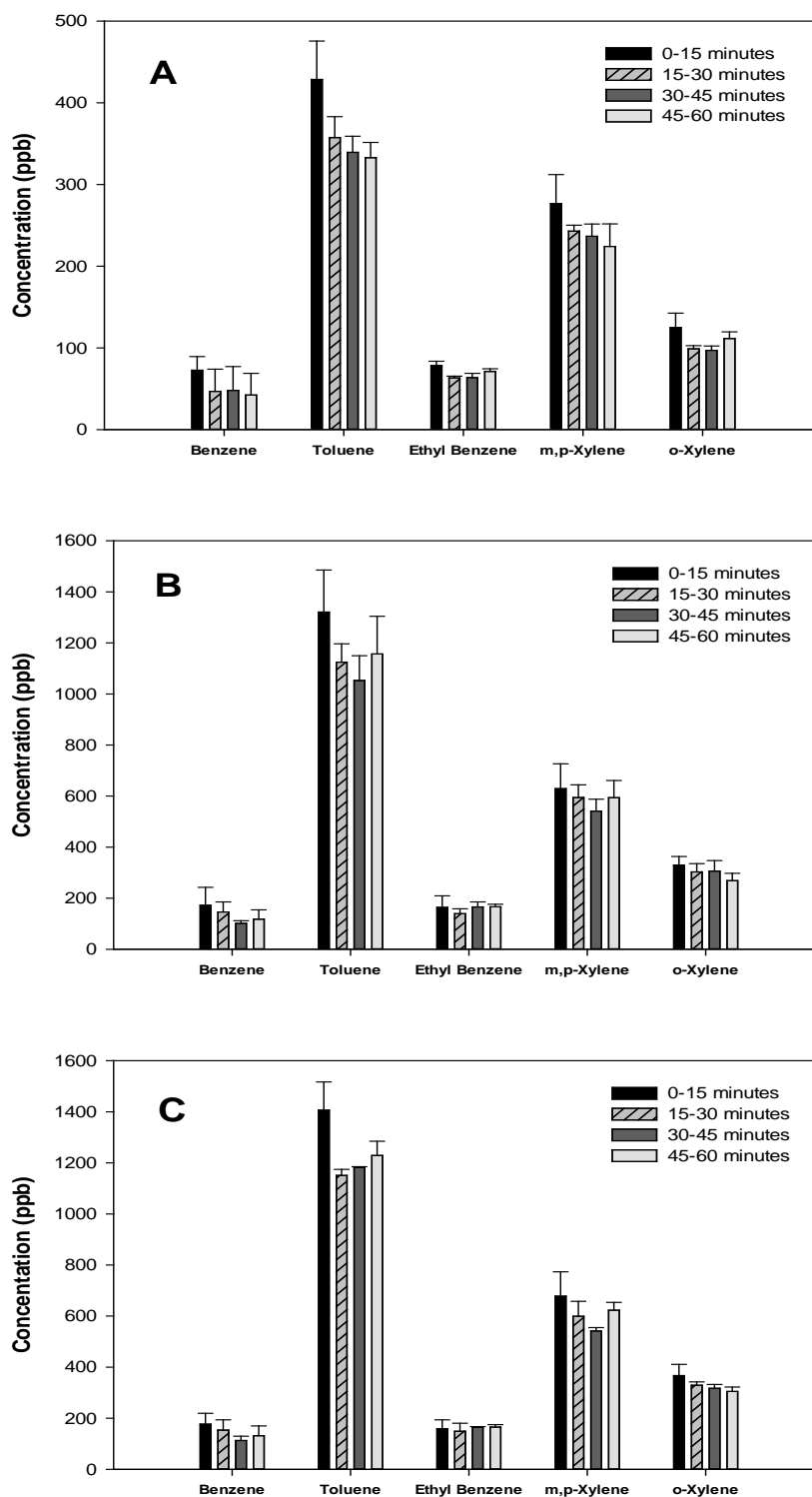


Figure 19. Average BTEX components concentration (+SD) in water from recirculating tank study at 21°C with (A) SLC oil, (B) dispersed SLC at DOR=20, and (C) dispersed SLC at DOR=100 using headspace sampling and microFast GC method (Run #2).

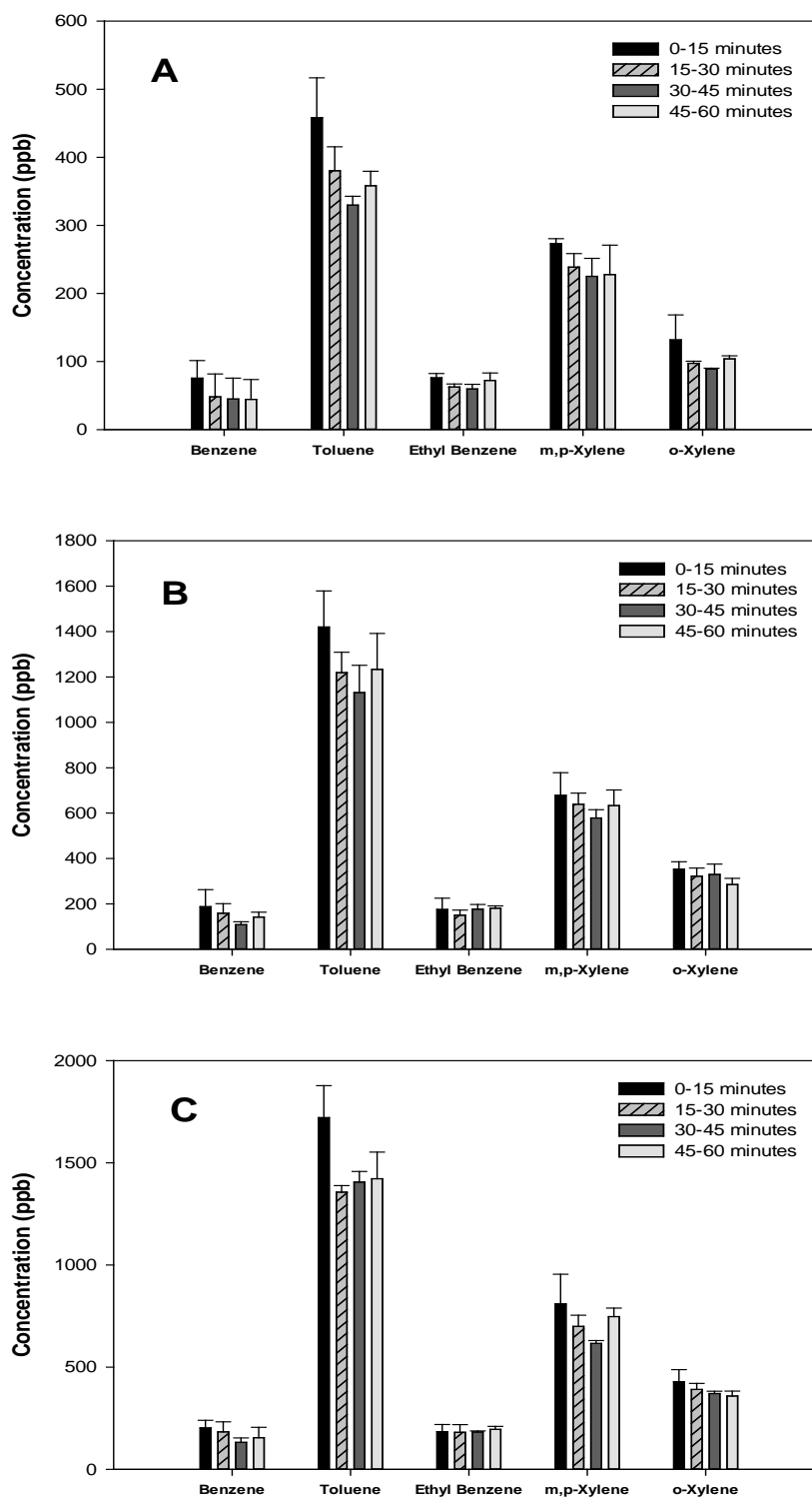


Figure 20. Average BTEX components concentration (+SD) in water from recirculating tank study at 21°C with (A) SLC oil, (B) dispersed SLC at DOR=20, and (C) dispersed SLC at DOR=100 using headspace sampling and microFast GC method (Run #3)

Table 10. Average concentration of BTEX components in air from recirculating tank study at 21°C with (A) SLC oil, (B) dispersed SLC at DOR=20, and (C) dispersed SLC at DOR=100 using direct sampling and microFast GC method.

RUN #1 - A

Time (min.)	0-15		15-30		30-45		45-60	
Replicate	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV
	conc. (ppb)		conc. (ppb)		conc. (ppb)		conc. (ppb)	
Benzene	7.76	3.55	2.74	1.02	1.21	0.20	1.35	0.27
Toluene	8.83	1.48	6.62	2.11	5.25	1.89	3.22	2.37
Ethyl Benzene	4.13	1.05	3.55	0.10	3.12	1.21	3.35	1.75
m,p-Xylene	3.36	0.71	5.87	1.08	5.97	1.89	4.64	2.47
o-Xylene	1.26	0.31	2.45	1.17	1.97	0.60	1.76	0.18

RUN #1 - B

Time (min.)	0-15		15-30		30-45		45-60	
Replicate	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV
	conc. (ppb)		conc. (ppb)		conc. (ppb)		conc. (ppb)	
Benzene	3.87	0.67	2.40	0.50	1.37	0.12	1.42	0.18
Toluene	6.62	1.19	2.36	1.09	3.94	2.23	2.84	1.40
Ethyl Benzene	3.57	1.35	3.02	1.14	2.32	1.15	2.61	0.60
m,p-Xylene	4.53	2.22	4.50	1.68	4.21	1.42	2.98	1.66
o-Xylene	1.39	0.28	1.39	0.27	1.25	0.31	1.53	0.39

RUN #1 - C

Time (min.)	0-15		15-30		30-45		45-60	
Replicate	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV
	conc. (ppb)		conc. (ppb)		conc. (ppb)		conc. (ppb)	
Benzene	5.48	0.94	3.40	0.70	1.52	0.18	1.59	0.25
Toluene	8.35	1.50	2.98	1.38	4.97	2.82	3.59	1.77
Ethyl Benzene	4.28	1.62	3.63	1.37	2.79	1.37	3.13	0.72
m,p-Xylene	4.20	0.58	5.50	2.05	5.13	1.73	3.63	2.02
o-Xylene	1.59	0.37	1.60	0.49	1.72	0.20	1.80	0.30

RUN #2 - A

Time (min.)	0-15		15-30		30-45		45-60	
Replicate	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV
	conc. (ppb)		conc. (ppb)		conc. (ppb)		conc. (ppb)	
Benzene	7.93	4.08	2.54	0.88	1.24	0.24	1.21	0.30
Toluene	7.93	2.32	6.54	2.95	4.60	1.61	3.27	2.53
Ethyl Benzene	3.99	0.97	3.01	0.21	2.74	1.18	3.20	1.14
m,p-Xylene	2.94	0.56	5.61	1.37	6.15	1.47	4.79	2.86
o-Xylene	1.26	0.37	2.16	1.14	1.84	0.57	1.58	0.24

RUN #2 - B

Time (min.)	0-15		15-30		30-45		45-60	
Replicate	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV
	conc. (ppb)		conc. (ppb)		conc. (ppb)		conc. (ppb)	
Benzene	3.17	0.52	2.12	0.29	1.33	0.17	1.35	0.35
Toluene	5.85	0.87	2.30	1.14	3.45	1.68	2.55	1.45
Ethyl Benzene	3.12	1.25	2.98	1.23	2.30	1.40	2.47	0.58
m,p-Xylene	4.36	2.36	4.37	2.12	3.90	1.18	2.86	1.50
o-Xylene	1.46	0.33	1.39	0.40	1.20	0.18	1.33	0.43

RUN #2 - C

Time (min.)	0-15		15-30		30-45		45-60	
Replicate	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV
	conc. (ppb)		conc. (ppb)		conc. (ppb)		conc. (ppb)	
Benzene	5.76	0.95	3.33	0.56	1.57	0.21	1.48	0.41
Toluene	8.39	1.68	2.67	1.31	4.32	2.21	3.65	2.20
Ethyl Benzene	3.80	1.29	3.62	1.56	2.79	1.56	3.29	0.71
m,p-Xylene	3.73	0.58	4.85	1.50	5.07	2.11	3.55	1.77
o-Xylene	1.53	0.43	1.59	0.53	1.51	0.17	1.74	0.40

RUN #3 - A

Time (min.)	0-15		15-30		30-45		45-60	
Replicate	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV
	conc. (ppb)		conc. (ppb)		conc. (ppb)		conc. (ppb)	
Benzene	6.92	2.76	2.83	1.26	1.56	0.33	1.44	0.25
Toluene	9.70	2.00	6.94	2.35	3.21	2.58	3.41	2.69
Ethyl Benzene	3.90	1.17	3.78	0.37	3.38	1.66	3.38	1.86
m,p-Xylene	3.38	0.69	5.68	0.41	4.05	2.42	4.19	2.28
o-Xylene	1.20	0.35	2.25	0.97	1.77	0.39	1.66	0.33

RUN #3 - B

Time (min.)	0-15		15-30		30-45		45-60	
Replicate	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV
	conc. (ppb)		conc. (ppb)		conc. (ppb)		conc. (ppb)	
Benzene	3.58	0.61	2.50	0.62	1.39	0.12	1.37	0.39
Toluene	6.87	1.17	2.11	0.92	4.19	2.48	3.04	1.53
Ethyl Benzene	3.71	1.46	2.94	1.12	2.50	1.25	2.65	0.69
m,p-Xylene	4.63	2.80	4.77	1.84	4.24	1.27	3.18	1.98
o-Xylene	1.52	0.33	1.41	0.23	1.16	0.21	1.38	0.41

RUN #3 - C

Time (min.)	0-15		15-30		30-45		45-60	
Replicate	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV
	conc. (ppb)		conc. (ppb)		conc. (ppb)		conc. (ppb)	
Benzene	4.07	0.68	2.87	0.77	1.58	0.13	1.58	0.49
Toluene	7.87	1.49	2.39	1.11	4.78	2.84	3.52	1.80
Ethyl Benzene	4.26	1.64	3.42	1.32	2.86	1.51	2.98	0.79
m,p-Xylene	5.37	3.30	5.45	1.92	4.87	1.42	3.71	2.41
o-Xylene	1.76	0.34	1.59	0.25	1.28	0.24	1.56	0.45

Table 11. Average concentration of BTEX components in air from recirculating tank study at 21°C with (A) SLC oil, (B) dispersed SLC at DOR=20, and (C) dispersed SLC at DOR=100 using thermal desorption method.

RUN #1 - A	Time (min.)		0-15		15-30		30-45		45-60		
	Replicate		AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV	
			conc. (ppb)		conc. (ppb)		conc. (ppb)		conc. (ppb)		
			Benzene	6.11	2.65	2.12	0.70	0.94	0.18	1.05	0.20
			Toluene	7.36	1.25	5.24	1.72	4.02	1.35	2.64	2.00
			Ethyl Benzene	3.33	0.64	2.77	0.17	2.55	1.07	2.71	1.30
			m,p-Xylene	2.63	0.53	4.62	0.92	4.62	1.50	3.68	2.01
			o-Xylene	0.99	0.22	1.91	0.83	1.64	0.51	1.43	0.17

RUN #1 - B	Time (min.)		0-15		15-30		30-45		45-60		
	Replicate		AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV	
			conc. (ppb)		conc. (ppb)		conc. (ppb)		conc. (ppb)		
			Benzene	3.10	0.57	1.91	0.43	1.08	0.08	1.13	0.18
			Toluene	5.18	0.90	1.90	0.88	3.10	1.76	2.21	1.10
			Ethyl Benzene	2.88	1.06	2.49	0.96	1.81	0.80	2.11	0.40
			m,p-Xylene	3.53	1.65	3.66	1.53	3.41	1.23	2.30	1.18
			o-Xylene	1.13	0.23	1.13	0.20	0.98	0.29	1.21	0.37

RUN #1 - C	Time (min.)		0-15		15-30		30-45		45-60		
	Replicate		AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV	
			conc. (ppb)		conc. (ppb)		conc. (ppb)		conc. (ppb)		
			Benzene	4.26	0.68	2.74	0.55	1.23	0.17	1.27	0.16
			Toluene	6.64	1.18	2.30	1.01	4.00	2.29	2.88	1.57
			Ethyl Benzene	3.51	1.33	2.92	0.99	2.28	1.21	2.46	0.57
			m,p-Xylene	3.24	0.40	4.55	1.65	4.22	1.30	3.00	1.71
			o-Xylene	1.29	0.23	1.26	0.37	1.38	0.14	1.42	0.25

RUN #2 - A	Time (min.)		0-15		15-30		30-45		45-60		
	Replicate		AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV	
			conc. (ppb)		conc. (ppb)		conc. (ppb)		conc. (ppb)		
			Benzene	5.49	2.16	2.18	0.93	0.93	0.17	1.15	0.28
			Toluene	6.71	0.62	5.56	1.66	3.85	1.31	2.36	1.85
			Ethyl Benzene	3.27	1.04	2.82	0.39	2.32	0.88	2.61	1.44
			m,p-Xylene	2.62	0.39	4.26	1.10	4.87	1.97	3.85	2.40
			o-Xylene	1.04	0.35	1.78	0.64	1.75	0.62	1.51	0.24

RUN #2 - B	Time (min.)		0-15		15-30		30-45		45-60		
	Replicate		AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV	
			conc. (ppb)		conc. (ppb)		conc. (ppb)		conc. (ppb)		
			Benzene	2.99	0.31	2.07	0.58	1.00	0.14	1.08	0.09
			Toluene	5.22	0.97	1.85	0.73	3.08	1.74	2.32	1.35
			Ethyl Benzene	2.82	1.11	2.73	1.14	1.97	0.80	2.18	0.40
			m,p-Xylene	3.29	1.26	3.78	1.27	3.44	1.07	2.53	1.45
			o-Xylene	1.03	0.29	0.99	0.15	0.92	0.21	1.22	0.42

RUN #2 - C	Time (min.)		0-15		15-30		30-45		45-60		
	Replicate		AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV	
			conc. (ppb)		conc. (ppb)		conc. (ppb)		conc. (ppb)		
			Benzene	4.17	0.59	2.56	0.50	1.26	0.09	1.24	0.07
			Toluene	6.12	0.62	2.16	0.97	3.81	1.96	3.03	1.46
			Ethyl Benzene	3.77	1.76	2.59	0.75	2.25	1.15	2.35	0.71
			m,p-Xylene	3.53	0.68	4.25	1.22	4.13	1.68	2.93	1.60
			o-Xylene	1.27	0.37	1.14	0.34	1.36	0.28	1.36	0.31

RUN #3 - A	Time (min.)		0-15		15-30		30-45		45-60		
	Replicate		AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV	
			conc. (ppb)		conc. (ppb)		conc. (ppb)		conc. (ppb)		
			Benzene	4.77	2.21	1.94	0.91	0.86	0.17	1.02	0.39
			Toluene	6.70	0.51	5.13	1.28	3.58	1.08	2.06	1.65
			Ethyl Benzene	2.84	1.10	2.51	0.47	2.21	0.72	2.22	1.07
			m,p-Xylene	2.27	0.32	4.10	1.26	4.41	1.72	3.63	2.69
			o-Xylene	0.94	0.31	1.53	0.60	1.58	0.55	1.41	0.28

RUN #3 - B	Time (min.)		0-15		15-30		30-45		45-60		
	Replicate		AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV	
			conc. (ppb)		conc. (ppb)		conc. (ppb)		conc. (ppb)		
			Benzene	2.93	0.31	1.93	0.53	0.89	0.14	1.03	0.15
			Toluene	4.38	0.96	1.87	0.90	2.66	1.27	2.36	1.61
			Ethyl Benzene	2.69	1.00	2.46	1.10	1.86	0.68	2.07	0.57
			m,p-Xylene	3.14	1.12	3.88	1.49	3.14	1.17	2.23	1.13
			o-Xylene	0.99	0.24	0.93	0.20	0.81	0.13	1.05	0.43

RUN #3 - C	Time (min.)		0-15		15-30		30-45		45-60		
	Replicate		AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV	
			conc. (ppb)		conc. (ppb)		conc. (ppb)		conc. (ppb)		
			Benzene	3.99	0.95	2.56	0.50	1.27	0.10	1.16	0.19
			Toluene	6.15	1.23	2.16	0.97	3.34	1.54	2.89	1.57
			Ethyl Benzene	3.57	1.98	2.59	0.75	2.08	0.97	2.25	0.93
			m,p-Xylene	3.19	0.86	4.25	1.22	4.29	1.97	2.75	1.48
			o-Xylene	1.18	0.44	1.14	0.34	1.26	0.34	1.32	0.35

Table 12. Average concentration of BTEX components in water from recirculating tank study at 21°C with (A) SLC oil, (B) dispersed SLC at DOR=20, and (C) dispersed SLC at DOR=100 using headspace sampling and microFast GC method.

RUN #1 - A

Time (min.)	0-15		15-30		30-45		45-60	
Replicate	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV
	conc. (ppb)		conc. (ppb)		conc. (ppb)		conc. (ppb)	
Benzene	75	16	46	23	24	12	41	19
Toluene	433	8	373	16	360	16	371	13
Ethyl Benzene	80	7	64	4	66	3	67	2
m,p-Xylene	271	36	235	8	221	6	237	6
o-Xylene	126	5	112	5	111	3	112	4

RUN #1 - B

Time (min.)	0-15		15-30		30-45		45-60	
Replicate	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV
	conc. (ppb)		conc. (ppb)		conc. (ppb)		conc. (ppb)	
Benzene	171	35	139	28	101	12	131	15
Toluene	1336	25	1153	48	1113	50	1148	39
Ethyl Benzene	162	27	140	18	160	7	156	7
m,p-Xylene	657	87	572	19	537	13	576	15
o-Xylene	357	19	309	17	302	10	307	15

RUN #1 - C

Time (min.)	0-15		15-30		30-45		45-60	
Replicate	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV
	conc. (ppb)		conc. (ppb)		conc. (ppb)		conc. (ppb)	
Benzene	160	48	133	32	94	7	108	25
Toluene	1216	69	1132	91	1031	36	1113	75
Ethyl Benzene	154	26	133	19	162	10	162	8
m,p-Xylene	611	97	555	18	496	15	564	56
o-Xylene	315	20	291	15	282	25	274	14

RUN #2 - A

Time (min.)	0-15		15-30		30-45		45-60	
Replicate	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV
	conc. (ppb)		conc. (ppb)		conc. (ppb)		conc. (ppb)	
Benzene	73	14	47	22	48	24	42	22
Toluene	429	38	358	21	339	16	333	15
Ethyl Benzene	78	4	63	2	64	4	71	3
m,p-Xylene	277	29	243	6	237	12	224	23
o-Xylene	125	14	99	3	97	4	111	7

RUN #2 - B

Time (min.)	0-15		15-30		30-45		45-60	
Replicate	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV
	conc. (ppb)		conc. (ppb)		conc. (ppb)		conc. (ppb)	
Benzene	172	58	146	32	101	8	118	30
Toluene	1321	134	1125	58	1053	79	1157	121
Ethyl Benzene	164	37	139	16	166	16	166	8
m,p-Xylene	629	80	594	41	541	38	593	55
o-Xylene	330	27	303	27	306	34	269	24

RUN #2 - C

Time (min.)	0-15		15-30		30-45		45-60	
Replicate	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV
	conc. (ppb)		conc. (ppb)		conc. (ppb)		conc. (ppb)	
Benzene	177	35	154	33	112	14	131	32
Toluene	1406	90	1151	20	1182	3	1229	46
Ethyl Benzene	159	28	149	26	164	2	165	8
m,p-Xylene	678	78	599	48	542	11	623	25
o-Xylene	367	36	329	11	317	12	305	14

HIGH-PRESSURE STATIC VESSEL STUDY

A series of high-pressure static vessel laboratory studies were performed to determine mass balance of BTEX components within a 1-L stainless steel pressure vessel with the addition of Corexit 9500 to a SLC oil. The study was designed to simulate VOC dissolution in oil plumes at various depths (pressures) and temperatures. The main vessel (Figures 21 and 22) was manufactured by Applied Separations, Inc. (Allentown, PA) and designed to withstand pressures up to 10,000 psi. Accessories included with the vessel are a high-pressure liquid pump (Scientific Systems, Inc.) with integrated pressure sensor, temperature probe, high-pressure stirrer unit, microprocessor logging unit, and sampling / fill ports. A 16-gauge needle and 0.2 μm PTFE syringe filter (Figure 23) were attached to the sampling port. The high-pressure liquid pumping system is designed to maintain a constant pressure level throughout the experiments. BTEX concentrations in artificial sea water were measured at various temperatures (4°C, 13°, and 21°C) and pressures (50 psi, 500 psi, and 2300 psi) using control SLC oil (no dispersant) and chemically-dispersed (DOR=100) SLC oil treatments. The experimental variables and analysis matrix for pressure vessel experiment are displayed in Table 22.

Table 13. Experimental Variables and Analysis Matrix for high-pressure vessel

Treatment	# of Samples at Pressure Interval			Total # of Analytical Determinations Water-microFAST
	50 psi	500 psi	2300 psi	
Control				
4°C	3	3	3	9
13°C	3	3	3	9
24°C	3	3	3	9
DOR=100				
4°C	3	3	3	9
13°C	3	3	3	9
24°C	3	3	3	9

Salinity=34‰

DOR=Dispersant to oil ratio

Corexit 9500

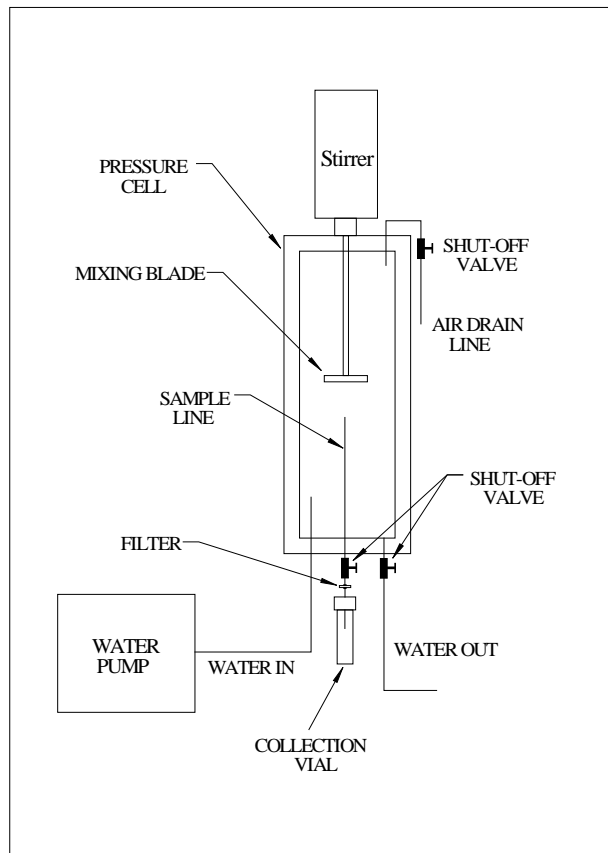


Figure 21. Experimental design for the determination of BTEX dissolution in water at elevated pressures.

Even though some of the temperature-pressure treatment combinations may not be realistic, the investigators have determined the results will be useful in constructing an accurate BTEX dissolution curve for the specific temperature-pressure range. Pressure experiments were conducted by placing approximately 1050 ml of artificial seawater (salinity=34‰) into the 1-L vessel. The cap/stirrer assembly was slowly screwed into the vessel. Excess water drains from the system through two (2) overflow ports in the assembly wall. The upper assembly drain valve is opened and the pumping system is activated and fills the vessel at a rate of 10 ml/min. Once residual air bubbles are forced out through the upper drain valve the pump is deactivated, drain valve closed, and the stirrer is activated (350 rpm). The water and pressure vessel is allowed to equilibrate for 24 hours in the environmental room when tested at the lower temperature ranges. The equilibration time allowed the water and stainless steel (SS) vessel to cool down to operating temperatures and remain at temperature for the duration of testing. A 1.0-ml aliquot is added to a 3-ml PP syringe containing 2-ml of artificial seawater. Excess air is removed from the syringe and immediately attached to the fill port. The fill valve is opened and the oily water mixture is injected into the vessel. The valve is immediately closed. When testing dispersed oil a 3-ml volume of water is pulled into the syringe and spiked with 5- μ l of dispersant. The 3-ml dispersant solution was injected into the fill port to rinse any oil adhering to the inner wall of the fill line. The dispersant rinsing procedure was repeated two (2) additional times. A surrogate recovery study using 5-alpha androstane showed the injection procedure to be 97% effective. If control oil was tested only water is used to flush the fill port. The test mixture is allowed to equilibrate for approximately 2 hours before sampling. A PTFE-topped 40-ml sample vial is moved beneath the sampling needle and slowly pushed upward until the needle pierces the septum. The sampling valve is slowly opened at an estimated rate of 10 ml/min. Once the vial is

filled with 10-ml of filtered water it is prepared and analyzed as outlined in the headspace and microFast GC methodology. Analytical method development and instrument calibrations were performed prior to startup of this experiment. During sampling, the pressure within the system dropped approximately 20-25% before the pumping system regained set pressure. Investigators were concerned the pressure drop may bias the results so sample treatment replicates (triplicate) were measured using new water and oil for each replicate. Results were interpreted using current statistical analysis techniques.

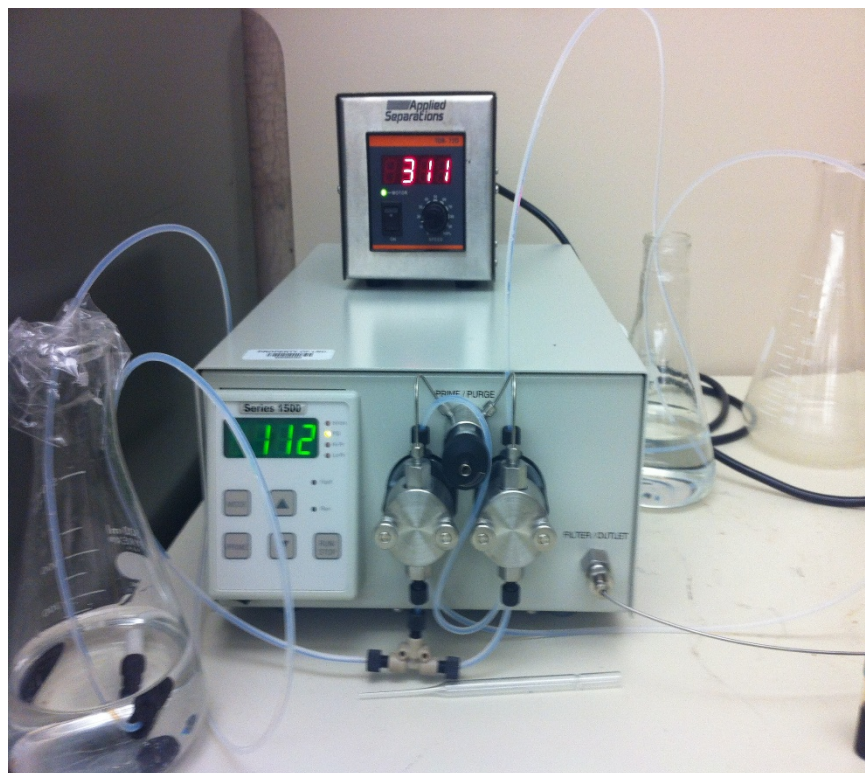
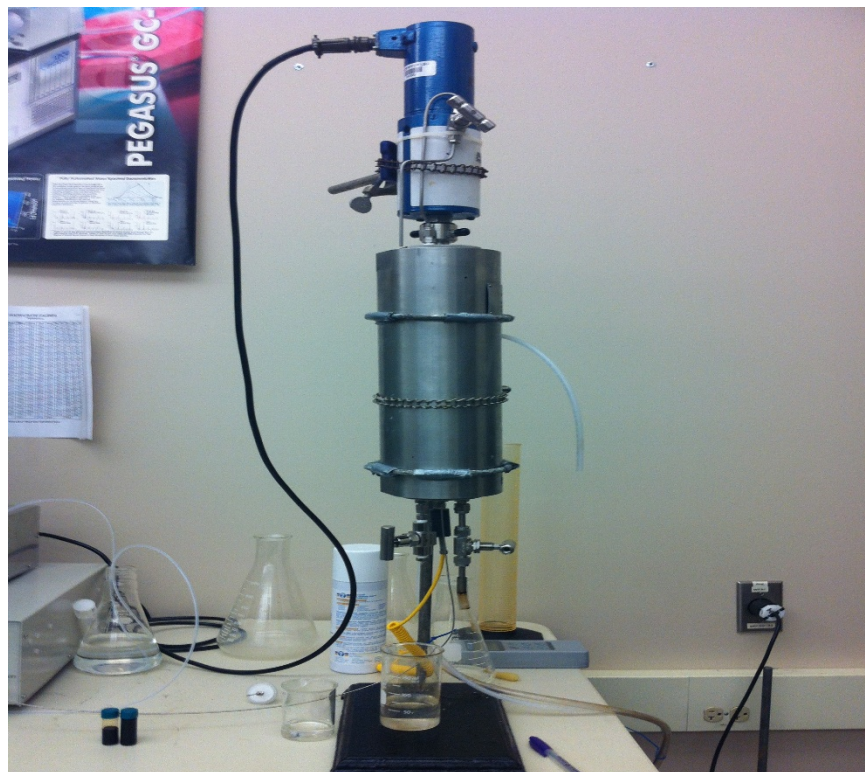


Figure 22. Photographs of high-pressure vessel and pumping system.

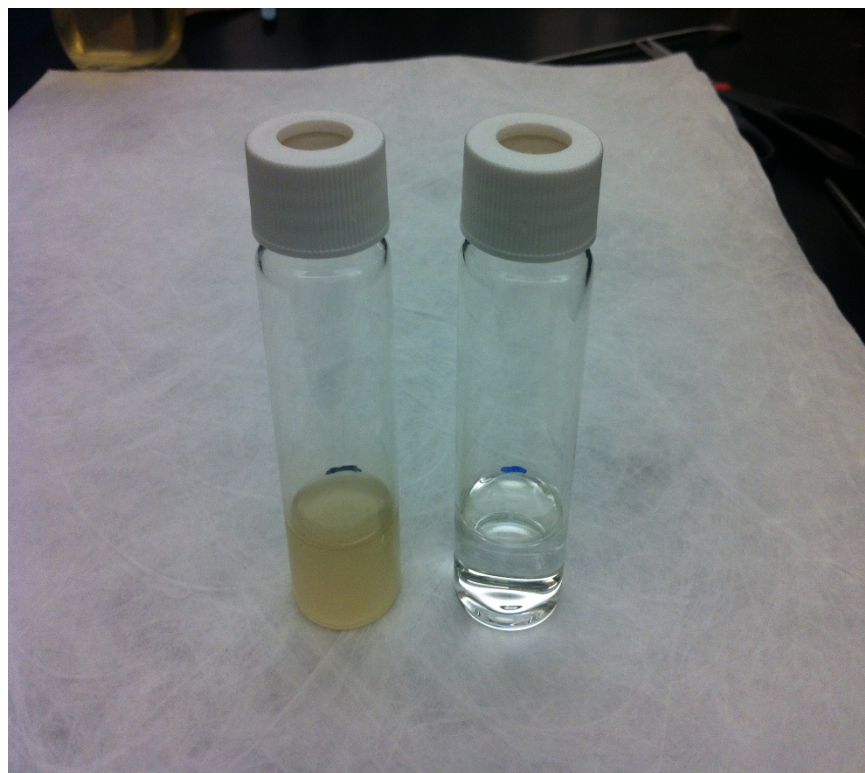
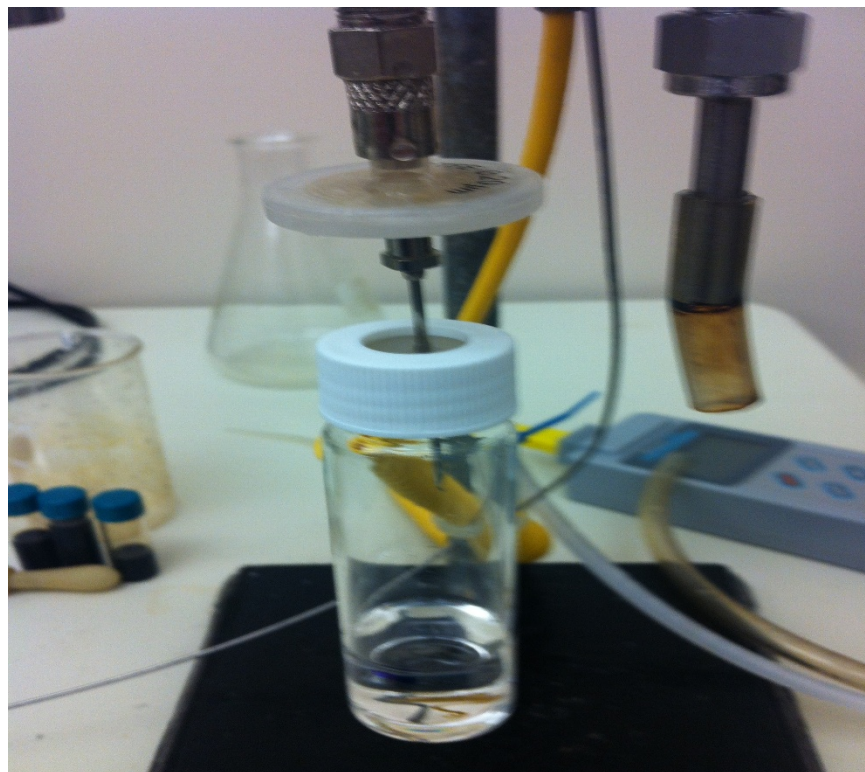


Figure 23. Photographs of high-pressure vessel sampling port and unfiltered (left)/filtered (right) water samples

Summary of High-Pressure Vessel Study

Figures 24-28 contain the results of the water analysis from the high-pressure vessel experiments. The averaged results for the high-pressure vessel experiments are displayed in Tables 14-15. Experimental results showed there was a 192% increase in overall BTEX concentration with the application of dispersant to oil within the tested pressure and temperature ranges. A more detailed analysis of the control and dispersed oil experiments is presented below.

Control Oil

At 2300 psi the results showed there was a 19% and 95% increase in overall BTEX concentration as the temperature was increased from 5°C to 13°C and 21°C, respectively. A temperature increase from 13°C to 21°C (2300 psi) produced a 63% increase in overall BTEX levels. At 500 psi the results showed there was a 28% and 155% increase in overall BTEX concentration as the temperature was increased from 5°C to 13°C and 21°C, respectively. A temperature increase from 13°C to 21°C (500 psi) produced a 100% increase in overall BTEX levels. At 50 psi the results showed there was a 9.7% and 128% increase in overall BTEX concentration as the temperature was increased from 5°C to 13°C and 21°C, respectively. A temperature increase from 13°C to 21°C (50 psi) produced a 108% increase in overall BTEX levels.

Dispersed oil

At 2300 psi the results showed there was a 28% and 74% increase in overall BTEX concentration as the temperature was increased from 5°C to 13°C and 21°C, respectively. A temperature increase from 13°C to 21°C (2300 psi) produced a 74% increase in overall BTEX

levels. At 500 psi the results showed there was a 32% and 83% increase in overall BTEX concentration as the temperature was increased from 5°C to 13°C and 21°C, respectively. A temperature increase from 13°C to 21°C (500 psi) produced a 39% increase in overall BTEX levels. At 50 psi the results showed there was a 39% and 88% increase in overall BTEX concentration as the temperature was increased from 5°C to 13°C and 21°C, respectively. A temperature increase from 13°C to 21°C (50 psi) produced a 35% increase in overall BTEX levels.

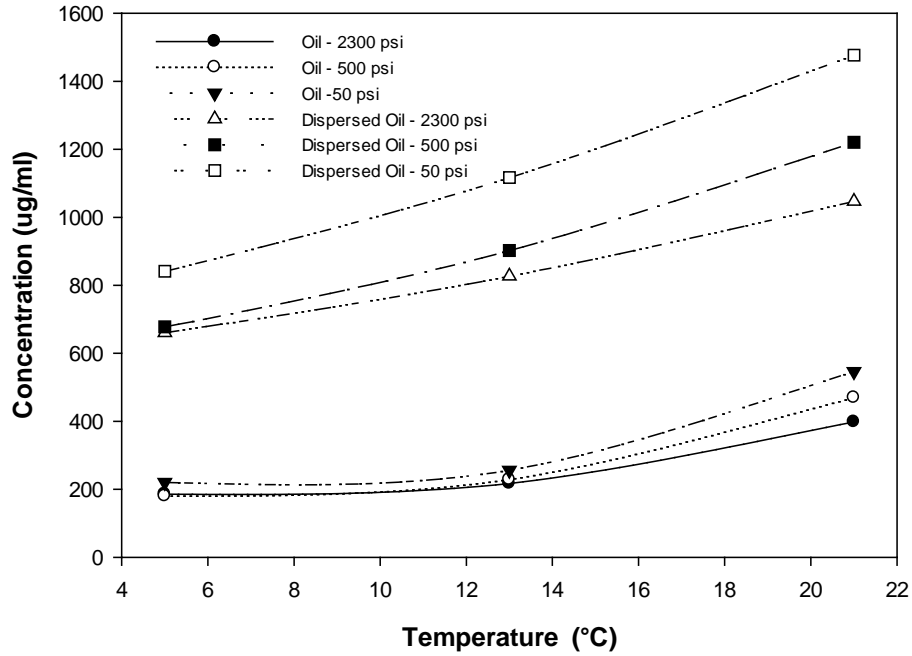


Figure 24. Average benzene concentration in water with (DOR=100) and without dispersant addition at specified pressures and temperatures using SLC oil.

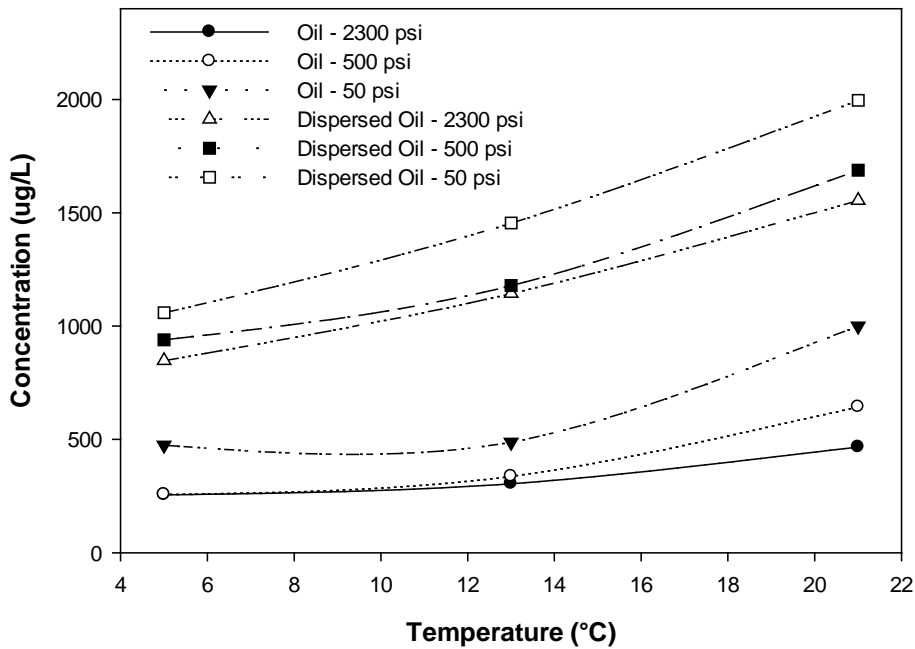


Figure 25. Average toluene concentration in water with (DOR=100) and without dispersant addition at specified pressures and temperatures using SLC oil.

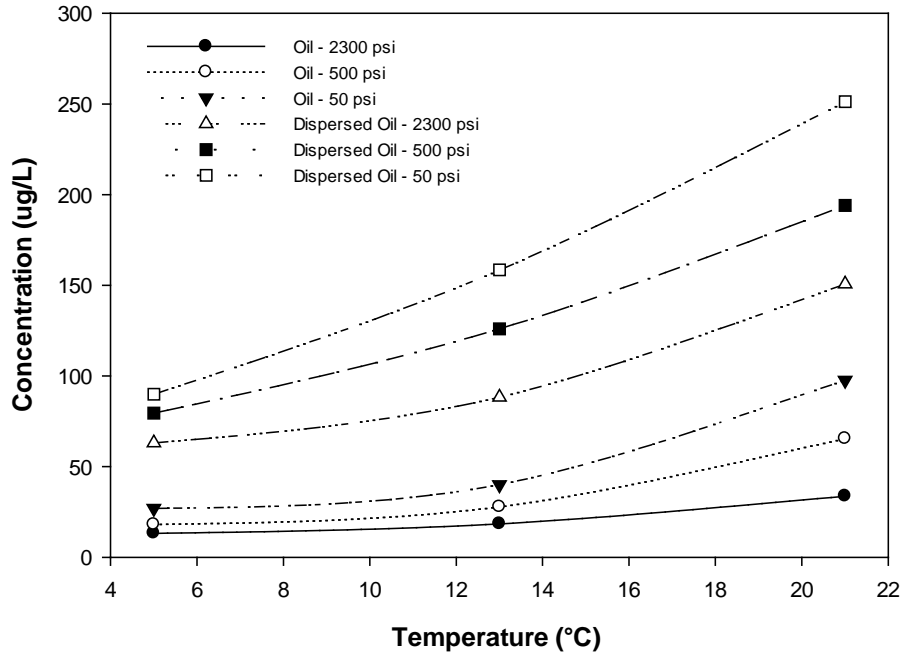


Figure 26. Average ethyl benzene concentration in water with (DOR=100) and without dispersant addition at specified pressures and temperatures using SLC oil.

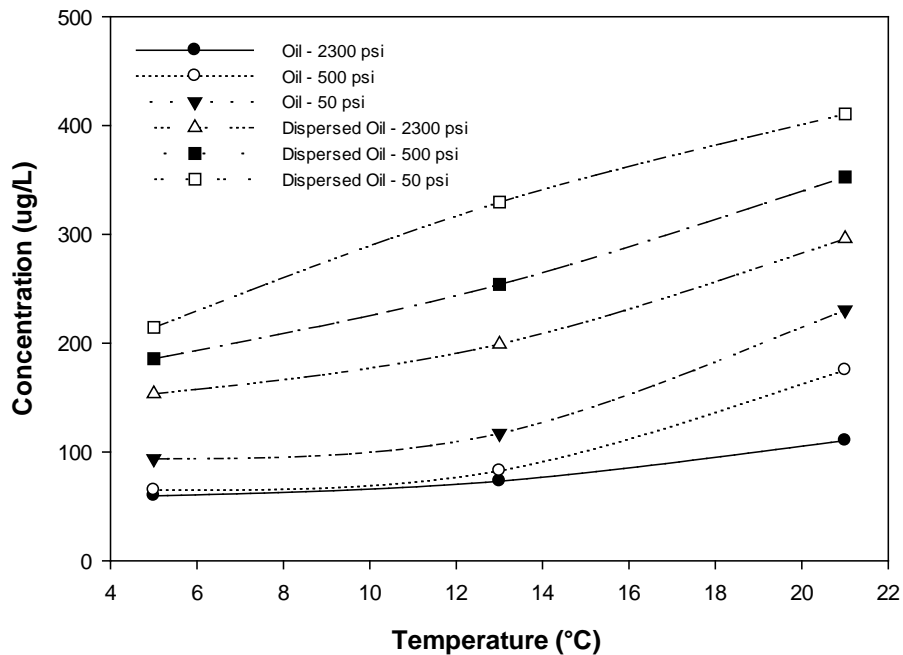


Figure 27. Average m, p-xylenes concentration in water with (DOR=100) and without dispersant addition at specified pressures and temperatures using SLC oil.

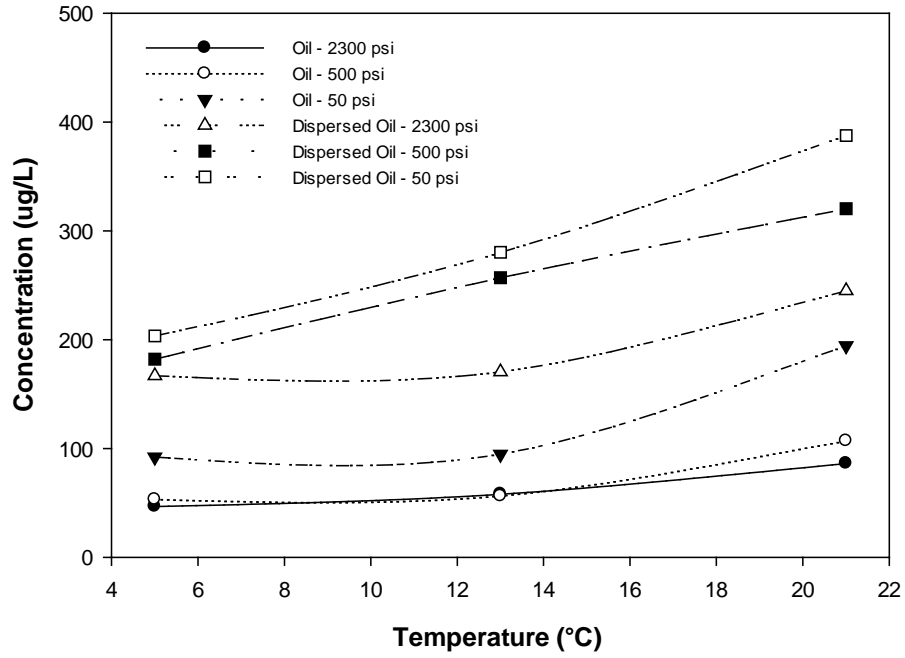


Figure 28. Average o-xylene concentration in water with (DOR=100) and without dispersant addition at specified pressures and temperatures using SLC oil.

Table 14. Concentration of BTEX components in water for pressure vessel experiment with SLC oil at specific pressures and temperatures.

Treatment	Replicate	Benzene			Toluene			Ethyl Benzene			m,p - Xylene			o - Xylene		
		Conc. (ug/L)	Average Conc. (ug/L)	STDEV	Conc. (ug/L)	Average Conc. (ug/L)	STDEV	Conc. (ug/L)	Average Conc. (ug/L)	STDEV	Conc. (ug/L)	Average Conc. (ug/L)	STDEV	Conc. (ug/L)	Average Conc. (ug/L)	STDEV
Oil 2300 psi 5°C	1	190	186	8	254	255	5	14	13	1	59	60	1	45	47	1
	2	191			261			13			60			48		
	3	176			252			12			61			47		
Oil 2300 psi 13°C	1	189	217	24	271	304	29	15	18	3	64	73	9	52	58	5
	2	229			324			20			74			60		
	3	233			318			21			81			62		
Oil 2300 psi 21°C	1	317	398	71	431	466	32	29	34	4	94	110	14	79	86	7
	2	447			474			34			116			92		
	3	430			493			38			121			88		
Oil 500 psi 5°C	1	181	180	2	247	257	8	16	18	2	62	65	3	59	53	7
	2	182			262			18			68			45		
	3	177			261			20			65			55		
Oil 500 psi 13°C	1	216	228	13	317	336	17	24	28	5	72	83	10	55	56	3
	2	242			344			33			85			59		
	3	226			348			26			91			55		
Oil 500 psi 21°C	1	456	469	13	621	643	21	65	65	2	176	175	7	100	107	6
	2	469			663			65			168			109		
	3	481			644			68			182			111		
Oil 50 psi 5°C	1	210	220	9	477	474	3	28	27	3	90	94	4	93	92	2
	2	224			475			24			94			90		
	3	227			471			29			97			94		
Oil 50 psi 13°C	1	260	256	4	484	487	6	40	40	2	116	117	2	95	95	4
	2	252			495			38			119			91		
	3	255			483			42			115			99		
Oil 50 psi 21°C	1	531	546	34	956	999	50	98	98	6	229	230	6	180	194	15
	2	584			1054			92			225			194		
	3	521			988			103			238			210		

Table 15. Concentration of BTEX components in water for pressure vessel experiment with dispersed SLC oil at specific pressures and temperatures.

Treatment	Replicate	Benzene			Toluene			Ethyl Benzene			m,p - Xylene			o - Xylene		
		Conc. (ug/L)	Average Conc. (ug/L)	STDEV	Conc. (ug/L)	Average Conc. (ug/L)	STDEV	Conc. (ug/L)	Average Conc. (ug/L)	STDEV	Conc. (ug/L)	Average Conc. (ug/L)	STDEV	Conc. (ug/L)	Average Conc. (ug/L)	STDEV
Dispersed Oil 2300 psi 5°C	1	715	660	53	847	847	46	60	63	8	164	153	10	173	167	6
	2	609			801			72			152			165		
	3	657			893			56			145			162		
Dispersed Oil 2300 psi 13°C	1	820	827	48	1137	1144	52	88	88	5	196	199	22	175	170	19
	2	783			1095			83			222			149		
	3	878			1199			93			179			186		
Dispersed Oil 2300 psi 21°C	1	1002	1047	45	1554	1554	30	150	151	5	290	296	11	260	245	15
	2	1047			1584			147			309			230		
	3	1092			1524			156			289			245		
Dispersed Oil 500 psi 5°C	1	724	678	43	1017	939	72	71	79	7	174	186	16	183	182	11
	2	670			924			85			179			170		
	3	640			876			82			204			193		
Dispersed Oil 500 psi 13°C	1	933	902	70	1353	1179	159	132	126	6	254	254	14	262	257	5
	2	823			1143			125			240			253		
	3	952			1042			121			268			255		
Dispersed Oil 500 psi 21°C	1	1401	1221	156	1757	1688	62	235	194	36	338	353	13	333	320	11
	2	1118			1672			175			354			313		
	3	1145			1636			172			365			316		
Dispersed Oil 50 psi 5°C	1	832	841	23	1030	1059	38	91	90	10	210	214	4	203	203	8
	2	825			1044			79			217			196		
	3	868			1102			99			216			211		
Dispersed Oil 50 psi 13°C	1	1088	1117	41	1573	1455	111	176	158	15	331	330	11	295	280	16
	2	1164			1352			153			340			263		
	3	1100			1441			147			318			283		
Dispersed Oil 50 psi 21°C	1	1499	1477	134	1964	1996	141	269	251	19	370	411	47	357	388	28
	2	1334			2150			254			401			395		
	3	1598			1873			231			462			411		

OHMSETT FIELD STUDY

The Ohmsett field study consisted of a series of field experiments to accurately detect VOC flux into air and water phase after South Louisiana crude oil (MC252 surrogate from Dorado field) is chemically-dispersed into the marine environment. The field tests performed by Dr. Ed Overton, Mr. Scott Miles, Mr. Bryson Agnew, and Ohmsett (MAR, Inc.) personnel at the Ohmsett wave tank research facility in Leonardo, NJ. Mr. Ed Levine (NOAA SSC) and members of the USCG Atlantic Strike Team were scheduled to attend the testing but federal budget restrictions forced their cancellation. The full-scale dispersant tests/VOC monitoring study required approximately one (1) week to complete. The air background and three (3) oil control runs were performed on days 1 and 2 of field testing at the Ohmsett facility. Oil dispersant runs 1 and 2 were performed on day 3 of field testing. Oil dispersant run 3 was conducted on day 3 of field testing. LSU researchers attempted to perform an addition control and dispersant run at the end of day 3, but encountered high winds which pushed oil to side of wave tank. MAR personnel were involved with oil and wave tank management operations responsible for fluorescence and laser in-situ scattering transmissometer (LISST-100X) monitoring. The LISST-110X is designed to measure suspended particle size (mass mean diameter) of natural and dispersed oils. LSU personnel operated a real-time VOC instrument (microFAST GC w/internal desorption trap) and passive VOC desorption tubes (absorbent resin packed) for monitoring air during each dispersant run. Each experimental run began with generation of breaking waves (33 cpm @ 6 in.) for approximately one (1) minute. The control room bridge was set at a marked distance along the tank and oil was slowly released over a 60 second time period. Each run released an average of 21 gallons of SLC oil. After the oil was released, the bridge was returned and Corexit 9500 dispersant was released onto the slick at a dosage rate in the proximity to DOR=1:20. The bridge was returned to the designated starting point and slowly

traveled above the slick as it moved down the tank. If possible, the bridge made several passes over the slick to acquire more samples. The experimental variables and analysis matrix for the Ohmsett field study is displayed in Table 16. Water samples were collected in a 40-ml PTFE top sample vial and 500-ml amber bottle for each sampling period. BTEX concentration in water was monitored using the water preparation methods from the laboratory studies and the microFAST GC. All BTEX air (direct sampling) and water analyzes were performed at the Ohmsett laboratory using the microFAST GC system. The 500-ml water samples were stored at 4°C in the Ohmsett laboratory and shipped to LSU for total petroleum hydrocarbon (TPH) and total polynuclear aromatic hydrocarbon (PAH) analysis. Air samples were collected using the same protocol used for the baffled-flask and recirculating tank studies. The thermal desorption tube method was modified to accommodate the collection of larger volumes of air. Two desorption tubes were connected using SS couplings and an additional 100-mg of absorption resin (Tenax GR) was added to each tube. The dual desorption tube set contained a total of 600-mg Tenax GR. Due to the large volumes of air collected and possibility of sample breakthrough for the lower molecular weight compounds (e.g. benzene and toluene), two dual desorption tube sets were used to collect air at the designated sampling time. One set of tubes (flow rate = 110 ml/min) was used specifically for collection of benzene and toluene and the other set of tubes (flow rate = 1100 ml/min) used for collection of ethyl benzene and the xylenes. Triplicate sets of tubes were run for each flow rate. Desorption tubes were collected and stored in a 4°C refrigerator at the Ohmsett facility. The tubes were shipped to LSU at the end of testing and immediately analyzed.

Table 16. Ohmsett field study treatments and analytical matrix.

Treatment Run	# of Replicate Samples at Time							Total # of Analytical Determinations			
	0 min.	2 min.	3 min.	5 min.	7 min.	10 min.	13 min.	Air*		Water**	
								In-situ GC	Desorp. Tubes	GC/MS	In-situ Fluor.
Air Background Control	3	3	3	3	3	3	3	18	Cont.	3	Cont.
SLC Control #1	3	3	3	3	3	3	3	18	Cont.	3	Cont.
SLC Control #2	3	3	3	3	3	3	3	18	Cont.	3	Cont.
SLC Control #3	3	3	3	3	3	3	3	18	Cont.	3	Cont.
SLC + Disp. (DOR=20) #1	3	3	3	3	3	3	3	18	Cont.	3	Cont.
SLC + Disp. (DOR=20) #2	3	3	3	3	3	3	3	18	Cont.	3	Cont.
SLC + Disp. (DOR=20) #3	3	3	3	3	3	3	3	18	Cont.	3	Cont.

Salinity=30‰

Cont.=Continuous

*Air samples collected approximately 1m above breaking waves

**500-ml water samples were collected approximately 1m below surface

Direct air monitoring was performed using the methodology employed for the baffled-flask and recirculating tank studies. The direct air sampling system was operated at 110 ml/min. Triplicate direct air samples were collected for all experiments. A baseline analysis of the wave tank water and air above the water surface was performed by running the air and water monitoring equipment through a normal wave tank operational run. The baseline analysis indicates the presence of additional background chemical noise (e.g. automotive and equipment exhaust). Instrument calibrations were performed prior to startup of this experiment.



Figure 29. Ohmsett control room bridge and oil distribution system.



Figure 30. Ohmsett wave tank prior to oil release.



Figure 31. SLC oil being released in Ohmsett wave tank.



Figure 32. SLC oil being dispersed in Ohmsett wave tank.

Summary of Ohmsett Field Study

Analysis of direct sampling and thermal desorption data indicate that BTEX component concentrations 1 m above the control oil slick ranged from below detection limit (BDL) to an average of 604 ppb for benzene. The highest detectable air reading for control oil was collected with oil control run #3 at the 3 minute sampling interval and showed an average concentration of 604 ppb for benzene. The highest detectable air reading for dispersed oil was collected with oil dispersant run #2 at the 3 minute sampling interval and showed an average concentration of 135 ppb and 186 ppb for benzene and toluene, respectively. The inconsistent air monitoring readings may be due to the combined movement of the monitoring platform, elevated wind speeds, and the drifting of the oil slick towards the west side of the wave tank. The averaged Ohmsett field study air monitoring results are shown in Tables 17-18. Tables A16-A27 contain raw air data for the Ohmsett field study.

Analysis of water sampling data indicate that BTEX component concentrations 1 m below the control oil slick ranged from below detection limit (BDL) to an average of 107 ppb for toluene. The highest detectable water reading for control oil was collected with oil control run #2 at the 2 minute sampling interval and showed benzene ranging from 25 ppb to 199 ppb. Analysis of water sampling data indicate that BTEX component concentrations 1 m below the dispersed oil slick ranged from below detection limit (BDL) to an average of 17,799 ppb for toluene. The high average may be biased as indicated by the large standard deviation with the sampling. The highest detectable water reading for dispersed oil was collected with oil dispersant run #1 at the 7 minute sampling interval and showed toluene ranging from 2,548 ppb to 44,528 ppb. The data from the dispersed oil runs indicated the majority of dispersion occurred 5 minutes after dispersant application. A review of the TPH data (Table A33) confirmed the highest concentration of TPH was detected between 5 and 10

minutes after dispersant application. Researchers were unable to establish a correlation between the recirculating tank experiment and the Ohmsett field study due to the low quantity of oil released (i.e. low readings) during the field study. Ohmsett field notes are contained in MAR/Ohmsett Task Order F-529 publication. The DOR for dispersant runs 1, 2, and 3 were 1:17.4, 1:19.3, and 1:18.9, respectively. The water temperature during the testing period ranged between 26.8 and 29.5°C. The air temperature during the testing period ranged between 19.7 and 29.9°C. The minimum and maximum wind speeds during testing were 5 and 20 mph, respectively. The averaged Ohmsett field study water monitoring results are shown in Table 19. Sampling times and data were varied or omitted from tables 17-19 due to equipment failure and weather problems. Water samples for control run 1 were omitted due to sampling pump failure. Tables A28-A32 contains raw water data for the Ohmsett field study.

Table 17. Direct air sampling air results for Ohmsett field test using SLC oil.

Control Run #1	Time (min.)	0		2		5		7		13	
	Replicate	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV
		Conc. (ppb)		Conc. (ppb)		Conc. (ppb)		Conc. (ppb)		Conc. (ppb)	
	Benzene	ND	—	ND	—	BDL	—	ND	—	ND	—
Toluene	BDL	—	BDL	—	BDL	—	BDL	—	BDL	—	
Ethyl Benzene	ND	—	ND	—	ND	—	ND	—	ND	—	
m,p-Xylene	ND	—	ND	—	ND	—	ND	—	ND	—	
o-Xylene	ND	—	ND	—	ND	—	ND	—	ND	—	

Control Run #2	Time (min.)	0		2		5		7		13	
	Replicate	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV
		Conc. (ppb)		Conc. (ppb)		Conc. (ppb)		Conc. (ppb)		Conc. (ppb)	
	Benzene	ND	—	ND	—	58	35	47	13	ND	—
Toluene	BDL	—	BDL	—	BDL	—	BDL	—	24	SP	
Ethyl Benzene	ND	—	ND	—	ND	—	ND	—	ND	—	
m,p-Xylene	ND	—	ND	—	ND	—	ND	—	ND	—	
o-Xylene	ND	—	ND	—	ND	—	ND	—	ND	—	

Control Run #3	Time (min.)	0		2		3		7		10		13	
	Replicate	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV
		Conc. (ppb)		Conc. (ppb)		Conc. (ppb)		Conc. (ppb)		Conc. (ppb)		Conc. (ppb)	
	Benzene	216	—	567	420	604	169	253	58	57	—	BDL	—
Toluene	BDL	—	BDL	—	BDL	—	56	4	122	12	103	11	
Ethyl Benzene	ND	—	ND	—	ND	—	ND	—	ND	—	ND	—	
m,p-Xylene	ND	—	ND	—	ND	—	ND	—	ND	—	ND	—	
o-Xylene	ND	—	ND	—	ND	—	ND	—	ND	—	ND	—	

Dispersed Run #1	Time (min.)	0		2		3		5		7		13	
	Replicate	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV
		Conc. (ppb)		Conc. (ppb)		Conc. (ppb)		Conc. (ppb)		Conc. (ppb)		Conc. (ppb)	
	Benzene	ND	—	ND	—	ND	—	ND	—	ND	—	ND	—
Toluene	BDL	—	BDL	—	BDL	—	BDL	—	BDL	—	BDL	—	
Ethyl Benzene	ND	—	ND	—	ND	—	ND	—	ND	—	ND	—	
m,p-Xylene	BDL	—	BDL	—	BDL	—	BDL	—	BDL	—	BDL	—	
o-Xylene	BDL	—	BDL	—	BDL	—	BDL	—	BDL	—	BDL	—	

Dispersed Run #2	Time (min.)	0		2		3		5		7		10		13	
	Replicate	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV
		Conc. (ppb)		Conc. (ppb)		Conc. (ppb)		Conc. (ppb)		Conc. (ppb)		Conc. (ppb)		Conc. (ppb)	
	Benzene	BDL	—	BDL	—	182	34	14	5	17	—	14	—	BDL	—
Toluene	BDL	—	BDL	—	BDL	—	BDL	—	BDL	—	BDL	—	BDL	—	
Ethyl Benzene	ND	—	ND	—	ND	—	ND	—	ND	—	ND	—	ND	—	
m,p-Xylene	BDL	—	BDL	—	BDL	—	BDL	—	BDL	—	BDL	—	BDL	—	
o-Xylene	ND	—	ND	—	ND	—	ND	—	ND	—	ND	—	ND	—	

Dispersed Run #3	Time (min.)	0		2		3		5		7		10		13	
	Replicate	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV
		Conc. (ppb)		Conc. (ppb)		Conc. (ppb)		Conc. (ppb)		Conc. (ppb)		Conc. (ppb)		Conc. (ppb)	
	Benzene	ND	—	ND	—	BDL	—	BDL	—	ND	—	BDL	—	BDL	—
Toluene	BDL	—	BDL	—	BDL	—	BDL	—	BDL	—	BDL	—	BDL	—	
Ethyl Benzene	ND	—	BDL	—	BDL	—	BDL	—	BDL	—	BDL	—	BDL	—	
m,p-Xylene	BDL	—	BDL	—	BDL	—	BDL	—	BDL	—	BDL	—	BDL	—	
o-Xylene	ND	—	BDL	—	BDL	—	BDL	—	BDL	—	BDL	—	BDL	—	

ND=Not detected, BDL=Below detection limit, SP=Single point of reference

Table 18. Desorption tube air results for Ohmsett field test using SLC oil.

Control Run #1	Time (min.)	0		2		5		7		13	
	Replicate	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV
		Conc. (ppb)									
	Benzene	ND	—	ND	—	BDL	—	ND	—	ND	—
	Toluene	BDL	—	BDL	—	BDL	—	BDL	—	BDL	—
	Ethyl Benzene	ND	—	ND	—	ND	—	ND	—	ND	—
	m,p-Xylene	ND	—	ND	—	ND	—	ND	—	ND	—
	o-Xylene	ND	—	ND	—	ND	—	ND	—	ND	—

Control Run #2	Time (min.)	0		2		5		7		13	
	Replicate	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV
		Conc. (ppb)		Conc. (ppb)		Conc. (ppb)		Conc. (ppb)		Conc. (ppb)	
	Benzene	ND	—	ND	—	42	15	37	8	—	—
	Toluene	BDL	—	BDL	—	15	5	55	9	33	12
	Ethyl Benzene	ND	—	ND	—	ND	—	ND	—	ND	—
	m,p-Xylene	ND	—	ND	—	ND	—	ND	—	ND	—
	o-Xylene	ND	—	ND	—	ND	—	ND	—	ND	—

Control Run #3	Time (min.)	0		2		3		7		10		13	
	Replicate	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV
		Conc. (ppb)		Conc. (ppb)		Conc. (ppb)		Conc. (ppb)		Conc. (ppb)		Conc. (ppb)	
	Benzene	241	55.37	187	73	483	103	202	22	44	6	33	9
	Toluene	BDL	—	BDL	—	550	123	56	13	109	21	89	30
	Ethyl Benzene	ND	—	ND	—	ND	—	ND	—	ND	—	ND	—
	m,p-Xylene	ND	—	ND	—	ND	—	ND	—	ND	—	ND	—
	o-Xylene	ND	—	ND	—	ND	—	ND	—	ND	—	ND	—

Dispersed Run #1	Time (min.)	0		2		3		5		7		10	
	Replicate	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV
		Conc. (ppb)		Conc. (ppb)		Conc. (ppb)		Conc. (ppb)		Conc. (ppb)		Conc. (ppb)	
	Benzene	ND	—	ND	—	ND	—	ND	—	ND	—	ND	—
	Toluene	BDL	—	BDL	—	BDL	—	BDL	—	BDL	—	BDL	—
	Ethyl Benzene	ND	—	ND	—	ND	—	ND	—	ND	—	ND	—
	m,p-Xylene	BDL	—	BDL	—	BDL	—	BDL	—	BDL	—	BDL	—
	o-Xylene	BDL	—	BDL	—	BDL	—	BDL	—	BDL	—	BDL	—

Dispersed Run #2	Time (min.)	0		2		3		5		7		10		13	
	Replicate	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV
		Conc. (ppb)		Conc. (ppb)		Conc. (ppb)		Conc. (ppb)		Conc. (ppb)		Conc. (ppb)		Conc. (ppb)	
	Benzene	ND	—	BDL	—	135	24	12	3	16	5	18	4	BDL	—
	Toluene	BDL	—	BDL	—	186	27	BDL	—	BDL	—	BDL	—	BDL	—
	Ethyl Benzene	ND	—	ND	—	ND	—	ND	—	ND	—	ND	—	ND	—
	m,p-Xylene	BDL	—	BDL	—	BDL	—	BDL	—	BDL	—	BDL	—	BDL	—
	o-Xylene	ND	—	BDL	—	BDL	—	BDL	—	BDL	—	BDL	—	BDL	—

Dispersed Run #3	Time (min.)	0		2		3		5		7		10		13	
	Replicate	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV
		Conc. (ppb)		Conc. (ppb)		Conc. (ppb)		Conc. (ppb)		Conc. (ppb)		Conc. (ppb)		Conc. (ppb)	
	Benzene	ND	—	ND	—	BDL	—	14	3	ND	—	ND	—	BDL	—
	Toluene	BDL	—	BDL	—	BDL	—	44	6	44	7	39	18	BDL	—
	Ethyl Benzene	ND	—	BDL	—	BDL	—	BDL	—	BDL	—	ND	—	BDL	—
	m,p-Xylene	BDL	—	BDL	—	BDL	—	BDL	—	BDL	—	BDL	—	BDL	—
	o-Xylene	ND	—	BDL	—	BDL	—	BDL	—	BDL	—	BDL	—	BDL	—

ND=Not detected, BDL=Below detection limit, SP=Single point of reference

Table 19. Water sampling results for Ohmsett field test using SLC oil.

Control Run #2	Time (min.)	0		2		5		7		13	
	Replicate	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV
		Conc. (ppb)		Conc. (ppb)		Conc. (ppb)		Conc. (ppb)		Conc. (ppb)	
	Benzene	ND	—	44	SP	ND	—	11	SP	BDL	—
	Toluene	BDL	—	106	88	28	17	107	85	75	48
	Ethyl Benzene	ND	—	BDL	—	ND	—	BDL	—	ND	—
	m,p-Xylene	BDL	—	39	38	BDL	—	ND	—	17	SP
	o-Xylene	ND	—	29	SP	BDL	—	37	34	BDL	—

Control Run #3	Time (min.)	0		2		5		7		13	
	Replicate	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV
		Conc. (ppb)		Conc. (ppb)		Conc. (ppb)		Conc. (ppb)		Conc. (ppb)	
	Benzene	BDL	—	ND	—	ND	—	18	SP	BDL	—
	Toluene	BDL	—	77	76	40	37	44	37	27	14
	Ethyl Benzene	ND	—	BDL	—	ND	—	BDL	—	25	SP
	m,p-Xylene	BDL	—	15	4	BDL	—	91	SP	11	SP
	o-Xylene	ND	—	11	SP	BDL	—	28	19	BDL	—

Dispersed Run #1	Time (min.)	0		2		3		5		7		13	
	Replicate	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV
		Conc. (ppb)		Conc. (ppb)		Conc. (ppb)		Conc. (ppb)		Conc. (ppb)		Conc. (ppb)	
	Benzene	ND	—	408	350	21	SP	2243	1760	4981	6297	3846	1732
	Toluene	43	14	873	1079	97	49	9806	8457	17799	23225	11836	5263
	Ethyl Benzene	ND	—	ND	—	ND	—	495	446	606	756	520	236
	m,p-Xylene	BDL	—	390	388	31	24	4630	4082	6841	9232	4583	2100
	o-Xylene	ND	—	167	161	15	SP	1718	1617	2352	3096	2026	926

Dispersed Run #2	Time (min.)	0		2		3		5		7		10	
	Replicate	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV
		Conc. (ppb)		Conc. (ppb)		Conc. (ppb)		Conc. (ppb)		Conc. (ppb)		Conc. (ppb)	
	Benzene	35	13	52	33	96	19	305	242	992	SP	161	187
	Toluene	192	43	240	76	347	65	1139	902	1059	1784	596	844
	Ethyl Benzene	BDL	—	BDL	—	11	2	46	42	145	SP	BDL	—
	m,p-Xylene	43	15	60	26	111	37	413	350	1457	SP	406	495
	o-Xylene	21	8	30	15	56	9	192	148	629	SP	181	216

Dispersed Run #3	Time (min.)	0		2		3		5		7		10		13	
	Replicate	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV
		Conc. (ppb)		Conc. (ppb)		Conc. (ppb)		Conc. (ppb)		Conc. (ppb)		Conc. (ppb)		Conc. (ppb)	
	Benzene	129	47	234	70	309	169	1132	226	1412	229	1313	1124	752	199
	Toluene	386	170	668	208	990	516	2460	955	3941	861	3798	3010	1991	269
	Ethyl Benzene	15	7	23	10	31	15	65	24	148	30	155	143	75	23
	m,p-Xylene	141	65	230	51	316	157	856	362	1302	259	1398	1147	798	84
	o-Xylene	69	39	114	31	166	73	399	177	657	69	567	422	368	64

ND=Not detected, BDL=Below detection limit, SP=Single point of reference

PROJECT CONFERENCE & RECOMMENDATIONS

Investigators from LSU worked with Mr. Ed Levine (NOAA SSC) and Lt. Aaron Jozsef (USCG) to develop recommended monitoring protocols as well as recommendations and countermeasures to optimize dispersant use for VOC control and worker safety. Our research has shown that dispersants are effective in reducing VOC emissions to the atmosphere during surface releases. During dispersant and cleanup operations it is essential there be monitoring and safety regulations in place. Responders and cleanup workers must be aware of all possible health threats and have everything in place to protect them with safeguards such as personnel protective equipment (PPE) and air quality monitoring. The release of VOCs during oil spills and the use of dispersants to lower VOC emissions to the atmosphere needs to be verified with scientific control. The following are recommendations for monitoring and optimizing dispersant use for VOC control and worker safety:

- Scientific testing and monitoring of controlled sub-surface and dispersed sub-surface releases of crude oil at the Ohmsett facility.
- Addition of BTEX testing within the water column as part of the Special Monitoring of Applied Response Technologies (SMART) protocol tier 3 additional monitoring plan.
- Require reassessment of meteorological and environmental conditions (e.g. air and water temperature, wind speed and direction, sea state, current speed and direction, etc.) whenever any of the above conditions change.
- Scientific testing of alternative dispersants for lowering VOC emissions to the atmosphere under controlled laboratory conditions with additional studies in test tanks.

- Scientific testing of alternate countermeasures (e.g. environmentally friendly vapor suppression foam or cyclodextrin-based solutions) to reduce VOC emissions when other cleanup technologies are not applicable.
- Submittal of BSEE final report to United States Coast Guard Research & Development (USCG R&D) for review.
- Recommend real-time air and water monitoring of BTEX as an optional monitoring technology available to the SMART protocol.

REAL-TIME AIR MONITORING PROTOCOL FOR OIL DISPERSANT & CLEANUP OPERATIONS

Mission Statement

To provide a real-time monitoring protocol for rapid collection of real-time, scientifically based information to assist the oil spill responders with decision-making during dispersant and cleanup operations.

Overview of Dispersant & Cleanup Operations

Chemical dispersion of oil offers a simple, rapid, and relatively safe means for reducing the net environmental impact of an oil spill. The benzene content of crude oil averages 0.2 % (2,000 ppm), although fractions as high as 0.64 % (6,400 ppm) have been reported in some North American crudes. Because of benzene's high vapor pressure (100mm Hg at 26°C) and low boiling point (80.1°C), it evaporates rapidly from crude oil. When used appropriately, dispersants can be an effective method of response to an oil spill. They are capable of rapidly removing large amounts of certain oil types from the sea surface by transferring it into the water column. Following dispersant application, wave energy will cause the oil slick to break up into small oil droplets that are rapidly diluted and subsequently biodegraded by micro-organisms occurring naturally in the marine

environment. They can also delay the formation of persistent water-in-oil emulsions. As with other response techniques, the decision to use dispersants must be given careful consideration and take into account oil characteristics, sea and weather conditions, as well as surrounding environmental sensitivities. With the acceptance of chemical dispersants as a spill response option, concerns have been raised regarding the possible effects of the volatile organic compounds (VOCs) in the atmosphere and water on the responders and cleanup workers downwind of the spill. This real-time monitoring protocol is designed to address these concerns and better aid federal and state decision makers in assessing health dangers associated with dispersant operations.

Monitoring Procedures

General Considerations

In general, real-time air and water is conducted when there is a concern that the workers in remediation operations may be exposed to VOCs from oil slicks or dispersed oil. It follows that monitoring should be conducted when the predicted downwind trajectory of the VOC indicates that the gases may reach workers, and the concentrations of gases at responder's work-level height may exceed safe levels. Monitoring is not required, however, when impacts are not anticipated.

Execution of dispersant operations has a narrow window of opportunity. It is imperative that the monitoring teams are alerted of possible dispersant operations as soon as application is being considered, even if implementation is not certain.

Sampling and Reporting

Monitoring operations should deploy one or more monitoring teams. Two or more monitoring units should be deployed if a large spill is expected. Each team should be equipped with a real-time air monitor capable of detecting individual benzene, toluene,

ethyl benzene, and xylenes (BTEX) components and quantitating benzene at a level of 0.5 ppm (action level) in air. If long-term operations (>4 hour) are required in areas of known BTEX exposure, workers should be equipped with passive (diffusive) samplers prefilled with Tenax TA sorbent to determine time-weighted average (TWA). A global positioning system and other equipment required for collecting and documenting the data should accompany each individual team. Each real-time air monitoring instrument provides a peak area response of the individual BTEX component for each sample analysis. The response may be recorded on a data logger, strip chart, or downloaded to a computer laptop. Calculate mass, W (ng), of benzene in sample by comparison of sample peak height with daily calibration graph. Consult specific instrument manufacturer for instruction on initial and calibration graph determination. Determine concentration, C, of benzene in the injected sample, V (mL):

$$C = M \frac{M}{V}, \text{ mg}/m^3$$

In addition, peak response and concentrations should be logged manually every few hours by the monitoring team in the recorder data log.

Monitoring Frequency and Locations

The monitoring teams are deployed at designated areas of concern to determine ambient concentrations of BTEX before the dispersant or cleanup operations start. During the dispersant or cleanup operations, air samples should be collected every 10 minutes and readings recorded both in the data recorder of the instrument and manually in the recorder data log. The frequency of sampling may differ, depending changing environmental and spill conditions. After the operation has ended and the oil slick has dispersed or been removed, the teams remain in place for approximately 30 minutes and sample air and record

ambient VOC concentrations. If the ambient air readings approach or exceed the permissible exposure limit (PEL), the team leader conveys this information to a technical specialist (Scientific Support Coordinator), which reviews and interprets the data and passes them, with appropriate recommendations, to the group industrial hygienist and the Unified Command.

Monitoring locations are dictated by the potential for VOC exposure to human and environmentally sensitive areas. Taking into account the prevailing winds and atmospheric conditions, the location and magnitude of the spill, modeling output (if available), the location of response workers, and input from state and federal health officials, the monitoring teams are deployed where the potential exposure to VOCs may be most substantial (sensitive locations). Precise monitoring locations should be flexible and determined on a case-by-case basis. In general, one team is deployed at the upwind edge of a sensitive location. A second team is deployed at the downwind end of this location. Both teams remain at their designated locations, moving only to improve sampling capabilities.

Level of Concern

The Level of Concern (LOC) for real-time air monitoring of BTEX during oil dispersant and cleanup operations follow the Occupational Safety & Health Administration (OSHA) guidelines. As of May, 2010, OSHA recommends a PEL of 0.5 ppm benzene in air and 1 ppm time weighted average (TWA). Furthermore, the OSHA emphasizes that this LOC does not constitute a fine line between safe and unsafe conditions, but should instead be used as an action level: If it is exceeded substantially, human exposure to benzene may be elevated to a degree that justifies precautionary actions. However, if BTEX levels remain generally below the recommended limit with few or no transitory excursions above it, there is no reason to believe that the worker population is being exposed to BTEX concentrations above the OSHA PEL.

It is important to keep in mind that real-time VOC monitoring is one factor among several, including oil slick modeling and trajectory analysis, visual observations, and behavior of the oil slick. The Unified Command must determine early on in the response what conditions, in addition to the LOC, justify termination of dispersant, cleanup operations or other action to protect worker health. The Unified Command should work closely with local Public Health agencies in determining operational thresholds.

Communication of monitoring results should flow from the field (Monitoring Group Supervisor) to those persons in the Unified Command who can interpret the results and use the data. Typically, this falls under the responsibility of a Technical Specialist on air monitoring in the Planning Section of the command structure.

The observation and monitoring data will flow from the Air Monitoring Teams to the Monitoring Group Supervisor. The Group Supervisor forwards the data to the Technical Specialist. The Technical Specialist or his/her representative reviews the data and, most importantly, formulates recommendations based on the data. The Technical Specialist communicates these recommendations to the Unified Command.

Quality assurance and control should be applied to the data at all levels. The Technical Specialist is the custodian of the data during the operation, but ultimately the data belongs to the Unified Command. The Unified Command should ensure that the data are properly archived, presentable, and accessible for the benefit of future monitoring operations.

Roles and Responsibilities

Team Leader

The Team Leader

- Selects specific team location
- Conducts monitoring
- Ensures health and safety of team
- Ensures monitoring QA/QC
- Establishes communication with the group supervisor
- Conveys to him/her monitoring data as needed

Monitoring Group Supervisor

The Group Supervisor

- Oversees the deployment of the teams in the group
- Ensures safe operation of the teams
- Ensures QA/QC of monitoring and data
- Establishes communication with the field teams and the command post
- Conveys to the command post particulate level trends as needed
- Addresses monitoring technical and operational problems, if encountered

Air Monitoring Technical Specialist

The Technical Specialist or his/her representative

- Establishes communication with the Monitoring Group Supervisor
- Receives the data from the Group Supervisor
- Ensures QA/QC of the data
- Analyzes the data in the context of other available information and incident-specific conditions, formulates recommendations to the Unified Command
- Forwards the recommendations to the Unified Command
- Makes the recommendations and data available to other entities in the ICS, as needed
- Archives the data for later use

Role and function	Training	Number
Monitoring Team Leader : Leads the monitoring team	SMART Monitor Training	1 per team
Monitor Assistant: Assists with data collection.	SMART Monitor Training	1 per team
Group Supervisor: Coordinates and directs teams; field QA/QC of data; links with UC.	SMART Monitor training. Group Supervisor training	1 per group
Technical Specialist: Overall QA/QC of data; reads and interprets data; provides recommendations to the Unified Command	SMART Monitor training. Scientific aspects of ISB	1 per response

Command, Control, and Data Flow

Air monitoring operations are directed by the Operations Section Chief or deputy. The Operations Section Chief provides the Monitoring Group Supervisor with tactical directions and support regarding deployment, resources, communications, and general mission as adapted to the specific incident. The Operations Section consults with the air monitoring Technical Specialist about the specifics of the monitoring operations, especially if they affect the data collected. The Monitoring Group Supervisor provides specific direction to the monitoring teams during field deployment and operations.

The observation and monitoring data flow from the Monitoring Teams to the Monitoring Group Supervisor. After initial QA/QC the Group Supervisor passes the data to the Technical Specialist. The Technical Specialist or his/her representative reviews the data, applies QA/QC if needed, and, most importantly, formulates recommendations based on the data. The Technical Specialist forwards these recommendations to the Unified Command.

Air Monitoring Training Outline

General

Training for air monitoring operations consists of an initial Monitor Level Training for all, Group Supervisor Training for supervisors, and refresher training sessions every six months for all.

Monitor Level Training

The Monitor Level Training includes monitoring concepts, instrument operation, work procedures, and a field exercise.

Topic	Duration
• Brief review of VOC air monitoring.	1 hour
• Monitoring strategy: Who, where, when. • Open water, inland. • Reporting: What and to whom • LOC: What is the LOC, how to report it.	1 hour
• Basic instrument operation (hands-on): How the air monitoring instrument operates and how to operate it: brief description of mechanism, setup, and calibration, reading the data, what do the data mean; trouble shooting. • Using GPS • Downloading data	2 hours
Field exercise: Set up the instruments outdoors and measure background readings over a pooled oil container. Practice recording the data and reporting it. When done, practice downloading the data.	4 hours

Group Supervisor Training

Group Supervisor training may include two options:

- Independent training at each unit; or
- An additional structured day of training as suggested below

Topic	Duration
• Review of ICS and the role of the Monitoring Group in it • Roles of Monitoring Group Supervisor • What the data mean • QA/QC of data • Command and control of teams • Communication with the Technical Specialist	1 hour
Field exercise: Practice deploying instruments in the field with emphasis on reporting, QA/QC of data, communication between teams and the group supervisor, and group supervisor to the Technical Specialist.	3-6 hours
Back to the base, practice downloading the data	30 min.
Lessons learned	30 min.

Refresher Training

Topic	Duration
Review of SMART: What is it, why do it, what is it good for.	15 min.
<ul style="list-style-type: none">• Monitoring and reporting: Who, where, and when• Level of concern• What do the data mean• Reporting the data• Work with the Technical Specialist (SSC).	30-45 min.
<ul style="list-style-type: none">• Basic instrument operation (hands-on): How the monitoring instrument works, how to operate it; brief description of mechanism, setup, and calibration;• Reading the data, trouble-shooting.• Using GPS.	2 hours
Downloading data	30 min.
<ul style="list-style-type: none">• Field exercise: Outside the classroom, set up the instrument and measure background readings.• Practice recording the data and reporting it.• Back to the base, download data.	1-2 hours

Air Monitoring Job Aid Checklist

This checklist is designed to assist air monitoring by listing some of the tasks to accomplish before, during, and after the monitoring operations.

Check	Item	Do
	Preparations	
	Activate personnel	Notify monitoring personnel and the Technical Specialist (SSC where applicable)
	Conduct equipment check	<ul style="list-style-type: none"> • Check equipment using equipment checkup list. • Verify that the monitoring instruments are operational and fully charged • Include safety equipment
	Coordinate logistics	Coordinate logistics (e.g., deployment platform) with ICS Operations
	Amend Site Safety Plan	Amend site safety plan to include monitoring operations
	Monitoring Operations	
	Monitoring Group setup	<ul style="list-style-type: none"> • Coordinate with Operations Section Chief • Coordinate with Technical Specialist
	Conduct Briefing	<ul style="list-style-type: none"> • Monitoring: what, where, who, how • Safety and emergency procedures
	Deploy to location	Coordinate with Operations Section Chief
	Select site	<ul style="list-style-type: none"> • Safe • Consistent with monitoring plan • As little interference as possible • Communication with Group Supervisor and UC possible
	Set up instrumentation	Unpack monitoring instruments and set up, verify calibration, if applicable
	Mark position	<ul style="list-style-type: none"> • Use GPS to mark position in recorder sheet • Re-enter position if changing location
	Collect background data	Start monitoring. If possible, record background data before the dispersant operation begins
	Collect air data	<ul style="list-style-type: none"> • Continue monitoring as long as conditions require Monitor for background readings for 15-30 minutes after operation has stopped
	Record data	Enter: <ul style="list-style-type: none"> • Air readings every 10 minutes, or other fixed intervals • Initial position from GPS, new position if moving • Initial wind speed and direction, air temperature, relative humidity, re-enter if conditions change
	Conduct quality assurance and control	<ul style="list-style-type: none"> • Verify that instrument is logging the data • Record data, location, relative humidity, temp, wind, interferences in the recorder data sheet <ul style="list-style-type: none"> • Note and record interference from other sources of particulates such as industry, vehicles, and vessels

Air Monitoring Job Aid Checklist (Continued)

	Report by team	Report to Group Supervisor: <ul style="list-style-type: none"> • Initial background readings • Benzene readings (every 10 min.) • Benzene readings when exceeding 0.5 ppm, (every 5 min.) • Interferences • Safety problems • QA/QC and monitoring problems
	Report by Group Supervisor	Report to the Technical Specialist (SSC): <ul style="list-style-type: none"> • Initial background readings • Benzene reading, when exceeding 0.5 ppm • Data QA/QC and monitoring problems
	Report by Technical Specialist (SSC)	Report to the Unified Command: <ul style="list-style-type: none"> • Benzene reading, when exceeding 0.5 ppm • Recommend go/no-go
	Post Monitoring	
	Debrief and lessons learned	<ul style="list-style-type: none"> • What went right, what went wrong • Problems and possible solutions • Capture comments and suggestions
	Preserve data	<ul style="list-style-type: none"> • Download logged data from monitoring instrument to a computer • Collect and review Recorder data logs • Generate report
	Prepare for next monitoring operation	Clean, recharge, restock equipment

Air Monitoring Equipment List

(For each team, unless otherwise noted)

Check	Item	Qty.	Remarks
	Air monitoring instrument, accessories and manuals	1 or more	
	Computer and cables	1/group	Should include downloading software
	Printer	1/group	
	Recorder data sheets	10	
	Write-in-the-rain notebooks, pens		
	Job aid check list	1	
	GPS	1	
	Extra batteries for GPS	1 set	
	Radio	1	
	Cell phone	1	
	Binoculars	1	
	Stop watch	1	
	Camera	1	digital camera or camcorder optional
	Film		
	Thermometer	1	
	Humidity meter	1	
	Anemometer	1	

Air Monitor Instrument Performance Requirements

This protocol does not require nor endorse a specific brand of air monitoring instrument. Rather, specifies performance criteria, and instruments meeting them may be used for air monitoring.

Performance Criteria

- Rugged and portable: The monitor should be suitable for field work, withstand shock, and be easily transportable in a vehicle, small boat or helicopter. Maximum size of the packaged instrument should not exceed that of a carry-on piece of luggage
- Operating temperature: 15-120 °F
- Suitability: The instrument should be suitable for the media measured, i.e., ambient air
- Operating duration: Eight hours or more
- Readout: The instrument should be capable of analyzing an air sample minimum of every 5 minutes
- Data logging or computer: The instrument should provide data logging for 8 hours or more
- Reliability: The instrument should be based on tried-and-true technology and operate as specified
- Sensitivity: A minimum sensitivity of 0.5 ppm benzene
- Concentration range: At least 0.5-100 ppm

Data download: The instrument should be compatible with readily available computer technology, and provide software for downloading data

CONCLUSIONS

Our initial hypothesis was that direct sampling and passive thermal desorption technologies could be coupled with portable monitoring equipment to accurately detect the presence of BTEX components following an oil spill. In addition, the project investigated the effect of temperature and pressure on oil and dispersed oil during subsea releases. The results

presented here suggest that direct air and water sampling coupled with microFast GC analysis is effective for real-time monitoring of volatile organic compounds during surface and subsurface dispersant operations. Our laboratory results indicate there is no significant increase in BTEX component concentrations released to the atmosphere following application of chemical dispersants to oil spills. In addition, our results indicate that chemical dispersion of oil greatly enhances the flux of BTEX components from the oil phases to the water phase. The results obtained from the pressure vessel testing show that high pressure (>50 psi) and low temperatures (<4°C) have little effect on dissolution rates for volatile oil components during subsea spills. Our research also showed that the addition of chemical dispersant greatly enhanced the dissolution of BTEX components into the water phase over the entire pressure and temperature range.

All of our data and research results showed that our methods and protocol were capable of assessing VOC impacts under controlled environmental conditions. In reality, our field investigations showed that under normal field conditions encountered during most spills (e.g. choppy waves, high winds) ambient BTEX concentrations were below OSHA's permissible exposure limit of 1 ppm for benzene. In theory, BTEX overexposure may be possible during "ideal adverse" spill conditions, such as calm seas and no breeze.

We are continuing our investigation into the behavior of crude oils following chemical dispersant application during subsea spill incidents. Future studies will include experiments to examine the effect of various dispersants and dosage rates on oils in high pressure and low temperature environments. The goal of these studies would be to determine the most effective dispersant and dosage rates for dispersion of oil in deep subsea environments. Additional research plans include studying the rate of VOC dissolution from dispersed and non-dispersed

oils as a function of particle size as the oil droplets travel through the water column following a deep sea spill incident. Results from this type of study would assist investigators in developing VOC transport and degradation models following subsurface dispersant application.

APPENDIX

Table A1. Concentration of BTEX components in air from baffled-flask study at 21°C with (A) SLC oil, (B) dispersed SLC at DOR=20, (C) dispersed SLC at DOR=50, and (D) dispersed SLC at DOR=100 using thermal desorption method.

Time (min.)	0-15					15-30					30-45					45-60				
	Replicate	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG
	Concentration (ppb)					Concentration (ppb)					Concentration (ppb)					Concentration (ppb)				
A Benzene	19	16	13	16	3	13	13	11	12	1	11	10	10	10	0	8	9	9	8	1
Toluene	47	16	13	25	19	23	22	30	25	4	29	27	26	27	1	24	24	25	24	1
Ethyl Benzene	8	5	6	6	1	4	2	7	4	2	5	3	3	4	2	6	3	4	4	1
m,p-Xylene	18	1	13	10	9	4	2	15	7	7	15	4	3	8	7	13	5	5	8	5
o-Xylene	11	8	9	9	1	9	7	12	9	3	10	6	7	8	2	10	6	7	8	2

Time (min.)	0-15					15-30					30-45					45-60				
	Replicate	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG
	Concentration (ppb)					Concentration (ppb)					Concentration (ppb)					Concentration (ppb)				
B Benzene	26	14	20	20	6	15	15	14	15	1	12	14	10	12	2	7	9	9	8	1
Toluene	55	8	14	26	25	46	25	32	34	11	32	31	33	32	1	25	23	25	24	1
Ethyl Benzene	14	10	10	12	2	9	2	3	4	4	8	3	3	5	2	5	4	4	5	1
m,p-Xylene	25	2	1	9	14	20	3	4	9	10	22	5	6	11	10	14	8	9	10	3
o-Xylene	23	10	12	15	7	13	10	9	10	2	13	8	5	8	4	14	6	7	9	4

Time (min.)	0-15					15-30					30-45					45-60				
	Replicate	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG
	Concentration (ppb)					Concentration (ppb)					Concentration (ppb)					Concentration (ppb)				
C Benzene	14	10	12	12	2	13	8	10	10	2	5	5	4	5	1	6	8	5	6	1
Toluene	44	6	38	29	21	35	27	28	30	4	26	16	14	19	6	21	22	21	21	1
Ethyl Benzene	10	2	8	7	4	8	7	6	7	1	5	4	3	4	1	5	4	3	4	1
m,p-Xylene	25	20	17	20	4	18	12	15	15	3	13	12	8	11	2	10	8	8	9	1
o-Xylene	16	12	13	14	2	13	12	11	12	1	10	8	8	8	1	7	5	5	6	1

Time (min.)	0-15					15-30					30-45					45-60				
	Replicate	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG
	Concentration (ppb)					Concentration (ppb)					Concentration (ppb)					Concentration (ppb)				
D Benzene	18	17	20	18	2	15	11	15	14	2	10	11	9	10	1	8	9	8	8	0
Toluene	40	22	34	32	9	42	32	28	34	7	36	30	21	29	8	26	29	28	28	2
Ethyl Benzene	10	3	3	5	4	9	7	4	6	2	6	4	4	5	1	6	4	4	5	1
m,p-Xylene	17	4	4	8	8	18	11	13	14	4	17	5	7	10	6	15	8	9	11	4
o-Xylene	13	12	11	12	1	13	9	10	11	2	11	7	6	8	3	9	6	7	7	2

Table A2. Concentration of BTEX components in air from baffled-flask study at 4°C with (A) SLC oil, (B) dispersed SLC at DOR=20, (C) dispersed SLC at DOR=50, and (D) dispersed SLC at DOR=100 using thermal desorption method.

Time (min.)	0-15					15-30					30-45					45-60				
	Replicate	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG
	Concentration (ppb)					Concentration (ppb)					Concentration (ppb)					Concentration (ppb)				
A Benzene	16	15	8	13	5	10	12	11	11	1	8	4	9	7	3	4	5	7	5	2
Toluene	24	31	17	24	7	25	12	16	18	7	17	12	25	18	6	17	22	22	20	3
Ethyl Benzene	2	6	4	4	2	5	3	3	4	1	2	4	4	3	1	3	3	4	4	1
m,p-Xylene	10	12	10	11	1	11	9	10	10	1	3	5	7	5	2	3	1	2	2	1
o-Xylene	5	11	10	9	3	8	5	4	6	2	4	5	6	5	1	4	6	8	6	2

Time (min.)	0-15					15-30					30-45					45-60				
	Replicate	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG
	Concentration (ppb)					Concentration (ppb)					Concentration (ppb)					Concentration (ppb)				
B Benzene	16	17	16	16	0	11	9	10	10	1	9	11	5	8	3	12	9	7	13	2
Toluene	15	12	31	20	10	27	16	16	20	6	26	16	17	20	5	16	25	16	10	5
Ethyl Benzene	2	3	5	3	1	4	2	3	3	1	4	5	6	5	1	5	5	2	1	2
m,p-Xylene	2	1	3	2	1	3	1	2	2	1	2	1	3	2	1	1	1	4	2	2
o-Xylene	3	5	7	5	2	6	4	8	6	2	6	4	4	5	1	3	1	2	2	1

Time (min.)	0-15					15-30					30-45					45-60				
	Replicate	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG
	Concentration (ppb)					Concentration (ppb)					Concentration (ppb)					Concentration (ppb)				
C Benzene	9	8	8	8	1	8	7	7	7	1	4	3	3	3	1	4	5	4	4	1
Toluene	34	24	28	29	5	23	20	21	21	2	18	11	11	14	4	14	15	15	15	1
Ethyl Benzene	6	5	5	6	0	5	4	4	4	1	3	3	2	3	1	3	2	2	3	0
m,p-Xylene	19	11	14	15	4	13	9	12	12	2	11	9	7	9	2	8	6	6	7	2
o-Xylene	10	9	9	9	1	8	9	7	8	1	7	5	5	6	1	5	3	3	4	1

Time (min.)	0-15					15-30					30-45					45-60				
	Replicate	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG
	Concentration (ppb)					Concentration (ppb)					Concentration (ppb)					Concentration (ppb)				
D Benzene	14	13	10	12	2	12	8	8	9	2	7	7	7	7	0	6	7	6	6	0
Toluene	27	17	22	22	5	32	22	24	26	5	31	19	26	25	6	17	20	27	22	5
Ethyl Benzene	5	7	8	7	2	5	2	3	3	2	5	3	3	4	1	3	2	5	3	1
m,p-Xylene	8	2	3	4	3	1	2	2	2	1	12	2	3	6	6	3	2	11	6	5
o-Xylene	6	5	3	4	2	7	2	5	5	2	7	6	4	6	2	5	5	6	5	1

Table A3. Concentration of BTEX components in air from baffled-flask study at 21°C with (A) SLC oil, (B) dispersed SLC at DOR=20, (C) dispersed SLC at DOR=50, and (D) dispersed SLC at DOR=100 using direct sampling and microFast GC method.

A

Time (min.)	0-15					15-30					30-45					45-60				
Replicate	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV
	Concentration (ppb)					Concentration (ppb)					Concentration (ppb)					Concentration (ppb)				
Benzene	22	19	16	19	3	16	16	13	15	1	13	12	12	13	0	10	10	11	10	1
Toluene	56	19	16	31	22	30	26	37	31	5	34	33	31	33	1	31	29	31	30	1
Ethyl Benzene	9	7	7	8	1	6	3	8	5	3	7	3	4	5	2	7	4	5	5	1
m,p-Xylene	21	1	16	13	10	5	2	19	9	9	20	5	5	10	9	16	7	6	10	6
o-Xylene	14	10	11	12	2	11	9	16	12	4	12	8	10	10	2	13	7	8	9	3

B

Time (min.)	0-15					15-30					30-45					45-60				
Replicate	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV
	Concentration (ppb)					Concentration (ppb)					Concentration (ppb)					Concentration (ppb)				
Benzene	31	18	24	24	6	19	19	18	19	1	14	17	13	15	2	10	11	10	10	1
Toluene	69	10	17	32	32	55	31	42	43	12	42	37	40	40	3	33	30	31	31	2
Ethyl Benzene	17	12	13	14	3	11	3	3	6	5	10	4	4	6	3	7	5	5	6	1
m,p-Xylene	34	3	2	13	18	27	4	5	12	13	27	7	7	14	11	18	10	10	13	5
o-Xylene	29	13	15	19	9	17	13	12	14	3	16	10	6	10	5	17	8	9	11	5

C

Time (min.)	0-15					15-30					30-45					45-60				
Replicate	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV
	Concentration (ppb)					Concentration (ppb)					Concentration (ppb)					Concentration (ppb)				
Benzene	17	13	15	15	2	16	10	13	13	3	7	7	5	6	1	7	10	7	8	2
Toluene	56	7	46	36	26	41	35	37	38	3	31	21	18	23	7	24	26	26	25	1
Ethyl Benzene	12	3	11	9	5	10	9	7	9	1	6	5	4	5	1	6	4	4	5	1
m,p-Xylene	30	25	21	25	4	22	14	19	18	4	17	14	11	14	3	13	9	9	11	2
o-Xylene	20	14	18	17	3	16	14	14	14	1	12	10	9	10	1	9	6	6	7	2

D

Time (min.)	0-15					15-30					30-45					45-60				
Replicate	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV
	Concentration (ppb)					Concentration (ppb)					Concentration (ppb)					Concentration (ppb)				
Benzene	23	20	24	22	2	20	15	18	17	3	12	14	11	12	1	9	11	10	10	1
Toluene	52	26	40	39	13	50	39	35	41	8	43	38	28	36	8	33	36	36	35	2
Ethyl Benzene	12	3	4	6	5	11	9	5	8	3	8	6	5	6	2	7	5	6	6	1
m,p-Xylene	23	4	5	11	11	23	15	16	18	4	21	7	9	12	8	19	11	12	14	4
o-Xylene	18	14	13	15	2	16	11	13	13	2	14	8	7	10	4	12	7	8	9	3

Table A4. Concentration of BTEX components in air from baffled-flask study at 4°C with (A) SLC oil, (B) dispersed SLC at DOR=20, (C) dispersed SLC at DOR=50, and (D) dispersed SLC at DOR=100 using direct sampling and microFast GC method.

A

Time (min.)	0-15					15-30					30-45					45-60				
Replicate	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV
	Concentration (ppb)					Concentration (ppb)					Concentration (ppb)					Concentration (ppb)				
Benzene	21	18	9	16	6	13	14	14	13	1	11	5	11	9	3	5	6	9	7	2
Toluene	28	40	22	30	9	33	16	22	23	8	22	14	32	23	9	20	26	28	25	4
Ethyl Benzene	2	7	6	5	3	6	4	4	5	1	3	5	5	4	1	4	4	5	4	1
m,p-Xylene	12	16	13	14	2	14	11	13	13	1	4	6	9	7	3	4	1	2	2	1
o-Xylene	7	14	11	11	4	9	7	5	7	2	5	7	8	7	1	5	8	11	8	3

B

Time (min.)	0-15					15-30					30-45					45-60				
Replicate	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV
	Concentration (ppb)					Concentration (ppb)					Concentration (ppb)					Concentration (ppb)				
Benzene	20	20	20	20	0	14	12	13	13	1	12	14	6	11	4	14	12	9	12	3
Toluene	21	15	40	25	13	35	20	21	25	9	32	20	22	25	6	21	32	21	25	7
Ethyl Benzene	3	4	6	4	2	5	3	4	4	1	5	7	7	6	1	7	6	2	5	2
m,p-Xylene	2	1	4	2	1	4	2	3	3	1	2	2	3	2	1	2	1	5	3	2
o-Xylene	4	6	8	6	2	8	6	10	8	2	8	5	4	6	2	4	1	3	2	1

C

Time (min.)	0-15					15-30					30-45					45-60				
Replicate	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV
	Concentration (ppb)					Concentration (ppb)					Concentration (ppb)					Concentration (ppb)				
Benzene	11	10	10	10	1	10	8	8	9	1	4	4	3	4	1	4	6	4	5	1
Toluene	41	30	34	35	6	31	26	27	28	2	23	15	13	17	5	18	20	19	19	1
Ethyl Benzene	8	7	7	7	1	7	5	5	5	1	4	3	3	3	1	4	3	3	3	1
m,p-Xylene	23	14	17	18	5	17	12	15	14	3	13	11	8	11	2	10	7	7	8	2
o-Xylene	13	11	11	12	1	10	10	9	10	1	8	7	6	7	1	6	4	4	5	1

D

Time (min.)	0-15					15-30					30-45					45-60				
Replicate	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV
	Concentration (ppb)					Concentration (ppb)					Concentration (ppb)					Concentration (ppb)				
Benzene	16	16	13	15	2	15	10	10	12	3	10	9	9	9	0	8	9	8	8	1
Toluene	34	22	27	28	6	38	27	29	31	6	37	25	31	31	6	22	27	35	28	6
Ethyl Benzene	6	9	11	8	2	6	2	4	4	2	6	4	3	5	2	3	2	6	4	2
m,p-Xylene	10	2	3	5	4	1	2	3	2	1	15	2	3	7	7	4	3	14	7	6
o-Xylene	8	6	3	6	2	9	3	7	6	3	9	7	5	7	2	7	6	8	7	1

Table A5. Concentration of BTEX components in water from baffled-flask study at 21°C with (A) SLC oil, (B) dispersed SLC at DOR=20, (C) dispersed SLC at DOR=50, and (D) dispersed SLC at DOR=100 using headspace sampling and microFast GC method.

A

Time (min.)	0-15					15-30					30-45					45-60				
Replicate	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV
	Concentration (ppb)					Concentration (ppb)					Concentration (ppb)					Concentration (ppb)				
Benzene	274	228	220	241	30	192	169	154	172	19	81	73	66	73	8	59	53	48	54	6
Toluene	760	676	608	681	76	537	478	478	497	34	237	192	199	210	24	161	131	136	143	16
Ethyl Benzene	83	71	75	76	6	61	52	55	56	4	46	37	39	41	4	33	27	28	29	3
m,p-Xylene	151	126	126	134	14	213	190	171	191	21	97	87	78	87	9	67	60	54	60	6
o-Xylene	137	104	101	114	20	202	162	178	181	20	114	96	101	104	9	79	66	70	72	6

B

Time (min.)	0-15					15-30					30-45					45-60				
Replicate	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV
	Concentration (ppb)					Concentration (ppb)					Concentration (ppb)					Concentration (ppb)				
Benzene	313	303	334	317	16	266	256	265	262	6	169	156	136	153	17	111	105	109	108	3
Toluene	836	857	1017	903	99	696	622	630	649	40	362	343	294	333	35	270	218	283	257	34
Ethyl Benzene	114	113	129	118	9	86	82	104	91	12	55	57	0	37	32	45	54	46	48	5
m,p-Xylene	266	288	340	298	38	176	225	204	202	25	102	144	97	115	26	95	88	75	86	10
o-Xylene	200	205	232	212	17	180	162	191	178	15	116	128	113	119	8	0	0	0	0	0

C

Time (min.)	0-15					15-30					30-45					45-60				
Replicate	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV
	Concentration (ppb)					Concentration (ppb)					Concentration (ppb)					Concentration (ppb)				
Benzene	305	357	309	324	29	253	226	231	237	15	168	188	167	174	12	114	125	95	111	15
Toluene	749	852	700	767	78	553	488	548	530	36	414	428	341	394	47	298	276	227	267	36
Ethyl Benzene	99	85	105	96	10	56	53	59	56	3	46	49	42	45	4	40	42	34	39	4
m,p-Xylene	258	255	360	291	60	180	123	134	146	31	120	118	98	112	12	84	86	68	79	10
o-Xylene	252	234	253	246	11	123	144	133	133	11	101	117	99	105	10	103	88	83	91	11

D

Time (min.)	0-15					15-30					30-45					45-60				
Replicate	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV
	Concentration (ppb)					Concentration (ppb)					Concentration (ppb)					Concentration (ppb)				
Benzene	300	319	366	328	34	246	257	255	253	6	186	155	191	177	20	141	99	110	117	22
Toluene	682	730	652	688	39	511	558	553	541	26	358	342	395	365	27	330	258	295	294	36
Ethyl Benzene	124	111	92	109	16	65	59	66	63	4	54	40	45	47	7	51	37	36	41	8
m,p-Xylene	230	242	262	245	16	136	140	178	151	23	107	104	118	110	7	98	74	86	86	12
o-Xylene	273	217	240	243	28	142	136	170	149	18	121	111	135	122	12	115	90	103	103	13

Table A6. Concentration of BTEX components in water from baffled-flask study at 4°C with (A) SLC oil, (B) dispersed SLC at DOR=20, (C) dispersed SLC at DOR=50, and (D) dispersed SLC at DOR=100 using headspace sampling and microFast GC method.

A

Time (min.)	0-15					15-30					30-45					45-60				
Replicate	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV
	Concentration (ppb)					Concentration (ppb)					Concentration (ppb)					Concentration (ppb)				
Benzene	211	175	169	185	23	148	130	118	132	15	62	56	51	56	6	46	41	37	41	4
Toluene	578	514	462	518	58	408	363	363	378	26	180	146	152	159	18	123	99	103	108	13
Ethyl Benzene	54	46	49	50	4	40	34	36	36	3	30	24	25	26	3	21	18	18	19	2
m,p-Xylene	161	145	145	150	9	136	121	109	122	14	62	56	50	56	6	43	38	35	39	4
o-Xylene	182	157	155	165	15	156	125	137	139	16	88	74	78	80	7	61	51	54	55	5

B

Time (min.)	0-15					15-30					30-45					45-60				
Replicate	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV
	Concentration (ppb)					Concentration (ppb)					Concentration (ppb)					Concentration (ppb)				
Benzene	311	307	328	315	11	301	327	323	317	14	267	277	279	275	6	227	214	183	208	23
Toluene	829	853	925	869	50	658	979	1015	884	197	634	791	631	686	91	671	524	416	537	128
Ethyl Benzene	71	94	93	86	13	85	101	102	96	9	71	72	72	72	1	74	66	50	63	12
m,p-Xylene	169	199	273	214	53	222	261	266	250	24	181	162	149	164	16	145	142	114	134	17
o-Xylene	160	164	185	170	14	161	182	196	180	18	146	166	155	156	10	140	149	110	133	21

C

Time (min.)	0-15					15-30					30-45					45-60				
Replicate	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV
	Concentration (ppb)					Concentration (ppb)					Concentration (ppb)					Concentration (ppb)				
Benzene	386	367	390	381	12	418	361	349	376	37	177	294	269	247	61	257	214	210	227	26
Toluene	847	913	802	854	56	819	830	868	839	25	751	683	622	686	64	620	594	507	574	60
Ethyl Benzene	75	80	68	74	6	80	74	78	77	3	66	66	56	63	6	59	68	52	59	8
m,p-Xylene	525	553	392	490	86	441	444	463	450	12	477	477	491	481	8	516	534	319	456	119
o-Xylene	89	88	92	90	2	102	86	105	97	10	99	98	91	96	4	87	66	77	77	10

D

Time (min.)	0-15					15-30					30-45					45-60				
Replicate	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV
	Concentration (ppb)					Concentration (ppb)					Concentration (ppb)					Concentration (ppb)				
Benzene	315	299	334	316	17	225	259	243	243	17	243	227	246	239	10	190	208	195	197	9
Toluene	808	837	867	838	30	636	641	683	653	26	583	511	559	551	37	444	450	388	427	35
Ethyl Benzene	70	68	75	71	4	102	67	58	76	23	57	49	58	55	5	48	47	43	46	3
m,p-Xylene	246	225	248	240	13	213	210	185	203	15	185	129	176	164	30	150	146	121	139	16
o-Xylene	167	158	165	163	5	166	140	147	151	13	131	127	114	124	9	112	107	123	114	8

Table A7. Concentration of BTEX components in air from recirculating tank study (Run #1) at 21°C with (A) SLC oil, (B) dispersed SLC at DOR=20, and (C) dispersed SLC at DOR=100 using thermal desorption method.

A

Time (min.)	0-15					15-30					30-45					45-60				
Replicate	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV
	Concentration (ppb)					Concentration (ppb)					Concentration (ppb)					Concentration (ppb)				
Benzene	9.12	5.08	4.14	6.11	2.65	1.55	1.93	2.89	2.12	0.70	0.74	1.02	1.07	0.94	0.18	0.89	1.28	0.97	1.05	0.20
Toluene	7.14	8.71	6.23	7.36	1.25	3.70	7.09	4.92	5.24	1.72	2.60	4.15	5.30	4.02	1.35	1.65	1.32	4.94	2.64	2.00
Ethyl Benzene	4.06	2.91	3.02	3.33	0.64	2.57	2.89	2.86	2.77	0.17	1.60	3.71	2.35	2.55	1.07	2.33	1.64	4.16	2.71	1.30
m,p-Xylene	2.19	3.22	2.48	2.63	0.53	5.51	4.68	3.68	4.62	0.92	3.44	6.31	4.12	4.62	1.50	2.48	2.57	6.00	3.68	2.01
o-Xylene	0.99	0.77	1.21	0.99	0.22	1.21	1.69	2.83	1.91	0.83	2.21	1.50	1.22	1.64	0.51	1.25	1.59	1.45	1.43	0.17

B

Time (min.)	0-15					15-30					30-45					45-60				
Replicate	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV
	Concentration (ppb)					Concentration (ppb)					Concentration (ppb)					Concentration (ppb)				
Benzene	3.72	2.60	2.97	3.10	0.57	1.97	2.30	1.45	1.91	0.43	1.18	1.02	1.04	1.08	0.08	1.33	1.04	1.01	1.13	0.18
Toluene	5.71	4.14	5.68	5.18	0.90	2.89	1.22	1.58	1.90	0.88	3.29	1.25	4.76	3.10	1.76	3.36	2.12	1.16	2.21	1.10
Ethyl Benzene	4.10	2.29	2.25	2.88	1.06	3.42	2.54	1.50	2.49	0.96	1.42	1.29	2.73	1.81	0.80	2.43	1.66	2.24	2.11	0.40
m,p-Xylene	5.43	2.74	2.43	3.53	1.65	5.40	3.01	2.56	3.66	1.53	3.22	2.29	4.72	3.41	1.23	3.46	1.10	2.33	2.30	1.18
o-Xylene	1.16	0.89	1.35	1.13	0.23	1.12	0.94	1.34	1.13	0.20	0.76	1.32	0.87	0.98	0.29	1.64	1.02	0.99	1.21	0.37

C

Time (min.)	0-15					15-30					30-45					45-60				
Replicate	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV
	Concentration (ppb)					Concentration (ppb)					Concentration (ppb)					Concentration (ppb)				
Benzene	5.02	3.68	4.09	4.26	0.68	2.65	3.33	2.24	2.74	0.55	1.41	1.22	1.07	1.23	0.17	1.43	1.29	1.11	1.27	0.16
Toluene	7.67	5.36	6.90	6.64	1.18	3.47	1.65	1.78	2.30	1.01	3.94	1.75	6.32	4.00	2.29	4.51	2.74	1.38	2.88	1.57
Ethyl Benzene	5.04	2.85	2.64	3.51	1.33	3.82	3.09	1.85	2.92	0.99	1.75	1.42	3.67	2.28	1.21	3.07	1.94	2.37	2.46	0.57
m,p-Xylene	3.55	3.38	2.79	3.24	0.40	6.43	3.86	3.36	4.55	1.65	4.13	2.97	5.55	4.22	1.30	4.72	1.31	2.96	3.00	1.71
o-Xylene	1.03	1.37	1.46	1.29	0.23	1.48	1.47	0.84	1.26	0.37	1.22	1.51	1.41	1.38	0.14	1.17	1.67	1.41	1.42	0.25

Table A8. Concentration of BTEX components in air from recirculating tank study (Run #2) at 21°C with (A) SLC oil, (B) dispersed SLC at DOR=20, and (C) dispersed SLC at DOR=100 using thermal desorption method.

A

Time (min.)	0-15					15-30					30-45					45-60				
Replicate	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV
	Concentration (ppb)					Concentration (ppb)					Concentration (ppb)					Concentration (ppb)				
Benzene	7.85	5.03	3.60	5.49	2.16	1.51	1.77	3.24	2.18	0.93	0.77	1.12	0.92	0.93	0.17	0.96	1.47	1.02	1.15	0.28
Toluene	6.49	7.40	6.23	6.71	0.62	3.92	7.23	5.51	5.56	1.66	2.42	4.15	4.98	3.85	1.31	1.40	1.19	4.50	2.36	1.85
Ethyl Benzene	4.47	2.71	2.63	3.27	1.04	2.83	3.20	2.43	2.82	0.39	1.53	3.27	2.16	2.32	0.88	2.24	1.40	4.20	2.61	1.44
m,p-Xylene	2.30	3.06	2.51	2.62	0.39	5.45	4.07	3.27	4.26	1.10	3.88	7.14	3.58	4.87	1.97	2.15	2.80	6.60	3.85	2.40
o-Xylene	1.12	0.66	1.34	1.04	0.35	1.35	1.47	2.52	1.78	0.64	2.43	1.57	1.23	1.75	0.62	1.40	1.78	1.35	1.51	0.24

B

Time (min.)	0-15					15-30					30-45					45-60				
Replicate	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV
	Concentration (ppb)					Concentration (ppb)					Concentration (ppb)					Concentration (ppb)				
Benzene	3.31	2.70	2.97	2.99	0.31	2.07	2.64	1.48	2.07	0.58	1.16	0.95	0.90	1.00	0.14	1.15	0.98	1.12	1.08	0.09
Toluene	5.82	4.10	5.74	5.22	0.97	2.63	1.19	1.74	1.85	0.73	3.29	1.25	4.71	3.08	1.74	3.79	1.99	1.16	2.32	1.35
Ethyl Benzene	4.10	2.22	2.14	2.82	1.11	3.90	2.67	1.62	2.73	1.14	1.55	1.47	2.89	1.97	0.80	2.58	1.78	2.20	2.18	0.40
m,p-Xylene	4.67	2.98	2.21	3.29	1.26	5.19	3.43	2.71	3.78	1.27	3.64	2.29	4.39	3.44	1.07	3.94	1.04	2.61	2.53	1.45
o-Xylene	0.99	0.76	1.34	1.03	0.29	0.96	0.85	1.15	0.99	0.15	0.79	1.16	0.80	0.92	0.21	1.70	0.98	0.97	1.22	0.42

C

Time (min.)	0-15					15-30					30-45					45-60				
Replicate	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV
	Concentration (ppb)					Concentration (ppb)					Concentration (ppb)					Concentration (ppb)				
Benzene	4.56	3.49	4.46	4.17	0.59	2.44	3.10	2.13	2.56	0.50	1.20	1.36	1.21	1.26	0.09	1.30	1.25	1.17	1.24	0.07
Toluene	6.83	5.68	5.86	6.12	0.62	3.26	1.42	1.80	2.16	0.97	4.46	1.61	5.37	3.81	1.96	4.46	3.07	1.54	3.03	1.46
Ethyl Benzene	5.80	2.94	2.59	3.77	1.76	3.24	2.75	1.78	2.59	0.75	1.78	1.41	3.56	2.25	1.15	3.16	1.85	2.04	2.35	0.71
m,p-Xylene	4.05	3.79	2.76	3.53	0.68	5.66	3.47	3.63	4.25	1.22	3.84	2.61	5.94	4.13	1.68	4.25	1.15	3.37	2.93	1.60
o-Xylene	0.87	1.33	1.62	1.27	0.37	1.27	1.39	0.75	1.14	0.34	1.04	1.51	1.53	1.36	0.28	1.01	1.47	1.59	1.36	0.31

Table A9. Concentration of BTEX components in air from recirculating tank study (Run #3) at 21°C with (A) SLC oil, (B) dispersed SLC at DOR=20, and (C) dispersed SLC at DOR=100 using thermal desorption method.

A

Time (min.)	0-15					15-30					30-45					45-60				
Replicate	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV
	Concentration (ppb)					Concentration (ppb)					Concentration (ppb)					Concentration (ppb)				
Benzene	7.22	4.17	2.92	4.77	2.21	1.39	1.44	2.98	1.94	0.91	0.74	1.05	0.78	0.86	0.17	0.78	1.47	0.82	1.02	0.39
Toluene	6.75	7.18	6.17	6.70	0.51	3.88	6.44	5.07	5.13	1.28	2.35	4.32	4.08	3.58	1.08	1.20	1.01	3.96	2.06	1.65
Ethyl Benzene	4.11	2.19	2.21	2.84	1.10	2.89	2.66	1.99	2.51	0.47	1.53	2.97	2.12	2.21	0.72	1.95	1.31	3.40	2.22	1.07
m,p-Xylene	2.02	2.63	2.16	2.27	0.32	5.40	4.03	2.88	4.10	1.26	3.11	6.35	3.76	4.41	1.72	1.85	2.30	6.73	3.63	2.69
o-Xylene	1.10	0.58	1.13	0.94	0.31	1.19	1.18	2.22	1.53	0.60	2.19	1.40	1.13	1.58	0.55	1.14	1.69	1.41	1.41	0.28

B

Time (min.)	0-15					15-30					30-45					45-60				
Replicate	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV
	Concentration (ppb)					Concentration (ppb)					Concentration (ppb)					Concentration (ppb)				
Benzene	2.85	2.66	3.26	2.93	0.31	2.20	2.27	1.32	1.93	0.53	1.00	0.93	0.73	0.89	0.14	0.98	0.92	1.21	1.03	0.15
Toluene	5.48	3.74	3.91	4.38	0.96	2.89	1.21	1.50	1.87	0.90	2.92	1.28	3.77	2.66	1.27	4.17	1.77	1.13	2.36	1.61
Ethyl Benzene	3.84	2.09	2.14	2.69	1.00	3.51	2.56	1.32	2.46	1.10	1.70	1.28	2.60	1.86	0.68	2.47	1.42	2.33	2.07	0.57
m,p-Xylene	4.41	2.75	2.27	3.14	1.12	5.50	3.60	2.55	3.88	1.49	2.95	2.08	4.39	3.14	1.17	3.19	0.99	2.51	2.23	1.13
o-Xylene	0.98	0.75	1.24	0.99	0.24	0.81	0.82	1.16	0.93	0.20	0.68	0.94	0.80	0.81	0.13	1.55	0.84	0.77	1.05	0.43

C

Time (min.)	0-15					15-30					30-45					45-60				
Replicate	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV
	Concentration (ppb)					Concentration (ppb)					Concentration (ppb)					Concentration (ppb)				
Benzene	4.79	2.93	4.24	3.99	0.95	2.44	3.10	2.13	2.56	0.50	1.15	1.35	1.30	1.27	0.10	1.23	1.31	0.95	1.16	0.19
Toluene	7.51	5.85	5.10	6.15	1.23	3.26	1.42	1.80	2.16	0.97	4.06	1.57	4.40	3.34	1.54	4.55	2.67	1.43	2.89	1.57
Ethyl Benzene	5.86	2.53	2.33	3.57	1.98	3.24	2.75	1.78	2.59	0.75	1.76	1.30	3.17	2.08	0.97	3.32	1.68	1.76	2.25	0.93
m,p-Xylene	3.93	3.41	2.24	3.19	0.86	5.66	3.47	3.63	4.25	1.22	3.72	2.66	6.48	4.29	1.97	3.53	1.04	3.67	2.75	1.48
o-Xylene	0.72	1.24	1.58	1.18	0.44	1.27	1.39	0.75	1.14	0.34	0.93	1.24	1.61	1.26	0.34	0.94	1.40	1.62	1.32	0.35

Table A10. Concentration of BTEX components in air from recirculating tank study (Run #1) at 21°C with (A) SLC oil, (B) dispersed SLC at DOR=20, and (C) dispersed SLC at DOR=100 using direct sampling and microFast GC method.

A

Time (min.)	0-15					15-30					30-45					45-60				
Replicate	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV
	Concentration (ppb)					Concentration (ppb)					Concentration (ppb)					Concentration (ppb)				
Benzene	11.85	5.97	5.44	7.76	3.55	1.86	2.50	3.86	2.74	1.02	0.97	1.30	1.35	1.21	0.20	1.12	1.64	1.30	1.35	0.27
Toluene	8.70	10.37	7.42	8.83	1.48	4.68	8.86	6.31	6.62	2.11	3.29	5.40	7.06	5.25	1.89	1.98	1.71	5.96	3.22	2.37
Ethyl Benzene	5.35	3.46	3.59	4.13	1.05	3.43	3.61	3.62	3.55	0.10	1.95	4.37	3.05	3.12	1.21	2.75	1.98	5.33	3.35	1.75
m,p-Xylene	2.74	4.13	3.23	3.36	0.71	6.72	6.24	4.65	5.87	1.08	4.46	8.10	5.35	5.97	1.89	3.30	3.14	7.49	4.64	2.47
o-Xylene	1.17	1.01	1.61	1.26	0.31	1.55	2.02	3.77	2.45	1.17	2.63	1.83	1.45	1.97	0.60	1.55	1.87	1.86	1.76	0.18

B

Time (min.)	0-15					15-30					30-45					45-60				
Replicate	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV
	Concentration (ppb)					Concentration (ppb)					Concentration (ppb)					Concentration (ppb)				
Benzene	4.54	3.21	3.85	3.87	0.67	2.50	2.84	1.86	2.40	0.50	1.51	1.33	1.27	1.37	0.12	1.61	1.39	1.26	1.42	0.18
Toluene	7.32	5.24	7.28	6.62	1.19	3.61	1.59	1.88	2.36	1.09	4.06	1.65	6.10	3.94	2.23	4.25	2.82	1.45	2.84	1.40
Ethyl Benzene	5.12	2.90	2.68	3.57	1.35	4.08	3.17	1.81	3.02	1.14	1.80	1.54	3.64	2.32	1.15	3.20	2.00	2.64	2.61	0.60
m,p-Xylene	7.05	3.65	2.90	4.53	2.22	6.43	3.76	3.32	4.50	1.68	4.07	2.86	5.69	4.21	1.42	4.61	1.30	3.03	2.98	1.66
o-Xylene	1.47	1.07	1.62	1.39	0.28	1.31	1.18	1.69	1.39	0.27	1.00	1.60	1.15	1.25	0.31	1.97	1.36	1.25	1.53	0.39

C

Time (min.)	0-15					15-30					30-45					45-60				
Replicate	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV
	Concentration (ppb)					Concentration (ppb)					Concentration (ppb)					Concentration (ppb)				
Benzene	6.43	4.54	5.46	5.48	0.94	3.54	4.02	2.64	3.40	0.70	1.72	1.47	1.38	1.52	0.18	1.86	1.55	1.37	1.59	0.25
Toluene	9.24	6.62	9.20	8.35	1.50	4.56	2.01	2.38	2.98	1.38	5.12	2.08	7.70	4.97	2.82	5.37	3.56	1.84	3.59	1.77
Ethyl Benzene	6.15	3.48	3.22	4.28	1.62	4.89	3.81	2.18	3.63	1.37	2.16	1.85	4.37	2.79	1.37	3.84	2.40	3.17	3.13	0.72
m,p-Xylene	4.61	4.45	3.53	4.20	0.58	7.85	4.59	4.05	5.50	2.05	4.97	3.49	6.94	5.13	1.73	5.62	1.58	3.70	3.63	2.02
o-Xylene	1.21	1.62	1.94	1.59	0.37	1.98	1.78	1.04	1.60	0.49	1.51	1.91	1.74	1.72	0.20	1.46	2.04	1.88	1.80	0.30

Table A11. Concentration of BTEX components in air from recirculating tank study (Run #2) at 21°C with (A) SLC oil, (B) dispersed SLC at DOR=20, and (C) dispersed SLC at DOR=100 using direct sampling and microFast GC method.

A

Time (min.)	0-15					15-30					30-45					45-60				
Replicate	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV
	Concentration (ppb)					Concentration (ppb)					Concentration (ppb)					Concentration (ppb)				
Benzene	12.56	6.39	4.85	7.93	4.08	1.96	2.13	3.55	2.54	0.88	0.99	1.28	1.46	1.24	0.24	1.01	1.56	1.08	1.21	0.30
Toluene	7.40	10.47	5.93	7.93	2.32	3.93	9.75	5.93	6.54	2.95	2.99	4.59	6.21	4.60	1.61	1.96	1.66	6.19	3.27	2.53
Ethyl Benzene	5.08	3.71	3.20	3.99	0.97	2.78	3.07	3.18	3.01	0.21	1.70	4.02	2.50	2.74	1.18	2.99	2.18	4.42	3.20	1.14
m,p-Xylene	2.38	3.51	2.93	2.94	0.56	6.18	6.61	4.05	5.61	1.37	4.91	7.77	5.78	6.15	1.47	3.10	3.17	8.09	4.79	2.86
o-Xylene	0.99	1.10	1.68	1.26	0.37	1.39	1.61	3.47	2.16	1.14	2.32	1.99	1.21	1.84	0.57	1.34	1.57	1.82	1.58	0.24

B

Time (min.)	0-15					15-30					30-45					45-60				
Replicate	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV
	Concentration (ppb)					Concentration (ppb)					Concentration (ppb)					Concentration (ppb)				
Benzene	3.72	2.69	3.08	3.17	0.52	2.12	2.41	1.82	2.12	0.29	1.43	1.42	1.13	1.33	0.17	1.75	1.17	1.13	1.35	0.35
Toluene	6.66	4.93	5.97	5.85	0.87	3.61	1.67	1.62	2.30	1.14	3.57	1.71	5.06	3.45	1.68	4.08	2.37	1.19	2.55	1.45
Ethyl Benzene	4.56	2.49	2.31	3.12	1.25	4.16	3.08	1.70	2.98	1.23	1.71	1.29	3.89	2.30	1.40	3.10	1.98	2.32	2.47	0.58
m,p-Xylene	7.05	3.39	2.63	4.36	2.36	6.82	3.16	3.12	4.37	2.12	3.46	3.00	5.23	3.90	1.18	4.29	1.30	3.00	2.86	1.50
o-Xylene	1.54	1.10	1.74	1.46	0.33	1.25	1.09	1.85	1.39	0.40	1.08	1.41	1.11	1.20	0.18	1.81	1.15	1.01	1.33	0.43

C

Time (min.)	0-15					15-30					30-45					45-60				
Replicate	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV
	Concentration (ppb)					Concentration (ppb)					Concentration (ppb)					Concentration (ppb)				
Benzene	6.82	4.99	5.46	5.76	0.95	3.82	3.45	2.72	3.33	0.56	1.81	1.39	1.52	1.57	0.21	1.93	1.36	1.13	1.48	0.41
Toluene	10.17	6.82	8.19	8.39	1.68	4.15	1.69	2.16	2.67	1.31	4.81	1.91	6.24	4.32	2.21	5.90	3.53	1.51	3.65	2.20
Ethyl Benzene	5.29	2.95	3.16	3.80	1.29	5.29	3.39	2.20	3.62	1.56	1.96	1.81	4.59	2.79	1.56	3.99	2.57	3.32	3.29	0.71
m,p-Xylene	3.92	4.18	3.07	3.73	0.58	6.36	4.82	3.36	4.85	1.50	5.12	2.93	7.15	5.07	2.11	5.17	1.66	3.81	3.55	1.77
o-Xylene	1.22	1.34	2.02	1.53	0.43	2.13	1.56	1.06	1.59	0.53	1.31	1.58	1.63	1.51	0.17	1.42	2.19	1.62	1.74	0.40

Table A12. Concentration of BTEX components in air from recirculating tank study (Run #3) at 21°C with (A) SLC oil, (B) dispersed SLC at DOR=20, and (C) dispersed SLC at DOR=100 using direct sampling and microFast GC method.

A

Time (min.)	0-15					15-30					30-45					45-60				
Replicate	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV
	Concentration (ppb)					Concentration (ppb)					Concentration (ppb)					Concentration (ppb)				
Benzene	10.07	5.80	4.90	6.92	2.76	2.09	2.13	4.28	2.83	1.26	1.24	1.89	1.55	1.56	0.33	1.20	1.69	1.44	1.44	0.25
Toluene	9.66	11.72	7.71	9.70	2.00	5.06	9.57	6.18	6.94	2.35	1.96	1.50	6.17	3.21	2.58	2.18	1.56	6.49	3.41	2.69
Ethyl Benzene	5.24	3.08	3.38	3.90	1.17	3.36	3.90	4.09	3.78	0.37	2.64	2.22	5.27	3.38	1.66	2.88	1.82	5.43	3.38	1.86
m,p-Xylene	2.76	4.13	3.26	3.38	0.69	5.98	5.86	5.21	5.68	0.41	2.88	2.43	6.84	4.05	2.42	2.84	2.92	6.82	4.19	2.28
o-Xylene	1.07	0.93	1.60	1.20	0.35	1.53	1.88	3.36	2.25	0.97	1.32	2.01	1.99	1.77	0.39	1.36	1.61	2.01	1.66	0.33

B

Time (min.)	0-15					15-30					30-45					45-60				
Replicate	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV
	Concentration (ppb)					Concentration (ppb)					Concentration (ppb)					Concentration (ppb)				
Benzene	4.22	3.01	3.51	3.58	0.61	2.80	2.92	1.79	2.50	0.62	1.52	1.29	1.35	1.39	0.12	1.82	1.24	1.07	1.37	0.39
Toluene	6.59	5.87	8.16	6.87	1.17	3.14	1.38	1.79	2.11	0.92	4.10	1.76	6.71	4.19	2.48	4.63	2.91	1.58	3.04	1.53
Ethyl Benzene	5.38	3.10	2.66	3.71	1.46	4.04	2.98	1.79	2.94	1.12	1.96	1.62	3.93	2.50	1.25	3.42	2.12	2.40	2.65	0.69
m,p-Xylene	7.83	3.39	2.66	4.63	2.80	6.88	3.88	3.55	4.77	1.84	3.75	3.29	5.69	4.24	1.27	5.21	1.24	3.09	3.18	1.98
o-Xylene	1.57	1.17	1.82	1.52	0.33	1.27	1.29	1.68	1.41	0.23	1.03	1.40	1.04	1.16	0.21	1.85	1.18	1.10	1.38	0.41

C

Time (min.)	0-15					15-30					30-45					45-60				
Replicate	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV
	Concentration (ppb)					Concentration (ppb)					Concentration (ppb)					Concentration (ppb)				
Benzene	4.77	3.41	4.03	4.07	0.68	3.25	3.39	1.98	2.87	0.77	1.69	1.44	1.60	1.58	0.13	2.14	1.38	1.22	1.58	0.49
Toluene	7.38	6.69	9.55	7.87	1.49	3.65	1.55	1.97	2.39	1.11	4.71	1.97	7.65	4.78	2.84	5.47	3.20	1.90	3.52	1.80
Ethyl Benzene	6.13	3.53	3.11	4.26	1.64	4.68	3.52	2.05	3.42	1.32	2.15	1.83	4.60	2.86	1.51	3.87	2.35	2.71	2.98	0.79
m,p-Xylene	9.16	3.77	3.17	5.37	3.30	7.64	4.61	4.09	5.45	1.92	4.27	3.85	6.49	4.87	1.42	6.20	1.38	3.55	3.71	2.41
o-Xylene	1.79	1.40	2.09	1.76	0.34	1.40	1.50	1.88	1.59	0.25	1.14	1.56	1.15	1.28	0.24	2.08	1.30	1.30	1.56	0.45

Table A13. Concentration of BTEX components in water from recirculating tank study (Run #1) at 21°C with (A) SLC oil, (B) dispersed SLC at DOR=20, and (C) dispersed SLC at DOR=100 using headspace sampling and microFast GC method.

A

Time (min.)	0-15					15-30					30-45					45-60				
Replicate	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV
	Concentration (ppb)					Concentration (ppb)					Concentration (ppb)					Concentration (ppb)				
Benzene	97	62	65	75	16	75	45	18	46	23	35	30	7	24	12	20	38	66	41	19
Toluene	441	422	434	433	8	392	375	353	373	16	348	383	350	360	16	363	362	389	371	13
Ethyl Benzene	90	78	72	80	7	70	59	64	64	4	66	63	71	66	3	68	64	69	67	2
m,p-Xylene	321	247	243	271	36	245	235	226	235	8	215	219	229	221	6	246	233	233	237	6
o-Xylene	131	128	118	126	5	119	111	107	112	5	111	114	107	111	3	118	109	110	112	4

B

Time (min.)	0-15					15-30					30-45					45-60				
Replicate	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV
	Concentration (ppb)					Concentration (ppb)					Concentration (ppb)					Concentration (ppb)				
Benzene	221	143	150	171	35	171	103	142	139	28	89	118	97	101	12	126	115	152	131	15
Toluene	1363	1303	1342	1336	25	1210	1158	1091	1153	48	1076	1184	1080	1113	50	1121	1119	1203	1148	39
Ethyl Benzene	126	189	172	162	27	165	132	123	140	18	152	161	168	160	7	161	146	162	156	7
m,p-Xylene	780	601	591	657	87	596	571	550	572	19	523	532	555	537	13	598	565	567	576	15
o-Xylene	376	364	330	357	19	332	304	290	309	17	304	314	289	302	10	329	294	299	307	15

C

Time (min.)	0-15					15-30					30-45					45-60				
Replicate	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV
	Concentration (ppb)					Concentration (ppb)					Concentration (ppb)					Concentration (ppb)				
Benzene	228	123	129	160	48	164	89	146	133	32	89	104	88	94	7	110	78	138	108	25
Toluene	1213	1134	1302	1216	69	1210	1181	1004	1132	91	990	1078	1026	1031	36	1177	1007	1155	1113	75
Ethyl Benzene	121	183	157	154	26	158	112	129	133	19	157	153	176	162	10	166	150	168	162	8
m,p-Xylene	748	541	544	611	97	578	553	533	555	18	481	490	516	496	15	622	582	487	564	56
o-Xylene	335	324	287	315	20	302	271	302	291	15	313	283	251	282	25	293	262	266	274	14

Table A14. Concentration of BTEX components in water from recirculating tank study (Run #2) at 21°C with (A) SLC oil, (B) dispersed SLC at DOR=20, and (C) dispersed SLC at DOR=100 using headspace sampling and microFast GC method.

A

Time (min.)	0-15					15-30					30-45					45-60				
Replicate	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV
	Concentration (ppb)					Concentration (ppb)					Concentration (ppb)					Concentration (ppb)				
Benzene	92	64	62	73	14	73	48	19	47	22	75	51	17	48	24	19	37	71	42	22
Toluene	433	380	474	429	38	337	386	350	358	21	320	359	339	339	16	312	348	339	333	15
Ethyl Benzene	83	73	79	78	4	64	65	61	63	2	68	64	58	64	4	75	70	69	71	3
m,p-Xylene	318	257	256	277	29	238	251	240	243	6	231	254	225	237	12	256	212	205	224	23
o-Xylene	142	127	107	125	14	101	94	101	99	3	91	100	100	97	4	117	115	102	111	7

B

Time (min.)	0-15					15-30					30-45					45-60				
Replicate	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV
	Concentration (ppb)					Concentration (ppb)					Concentration (ppb)					Concentration (ppb)				
Benzene	253	123	140	172	58	171	100	167	146	32	92	112	101	101	8	117	82	155	118	30
Toluene	1383	1134	1445	1321	134	1149	1181	1044	1125	58	1009	1164	985	1053	79	1224	987	1259	1157	121
Ethyl Benzene	116	205	171	164	37	158	120	139	139	16	161	148	187	166	16	177	158	163	166	8
m,p-Xylene	741	563	582	629	80	647	548	587	594	41	496	538	589	541	38	671	559	551	593	55
o-Xylene	368	314	307	330	27	320	265	323	303	27	354	283	282	306	34	302	249	255	269	24

C

Time (min.)	0-15					15-30					30-45					45-60				
Replicate	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV
	Concentration (ppb)					Concentration (ppb)					Concentration (ppb)					Concentration (ppb)				
Benzene	221	137	172	177	35	190	110	160	154	33	101	132	105	112	14	129	94	171	131	32
Toluene	1295	1408	1517	1406	90	1161	1123	1168	1151	20	1183	1184	1178	1182	3	1244	1276	1167	1229	46
Ethyl Benzene	122	191	163	159	28	182	147	118	149	26	167	164	161	164	2	167	155	173	165	8
m,p-Xylene	787	637	609	678	78	620	645	533	599	48	544	553	527	542	11	657	599	612	623	25
o-Xylene	406	375	320	367	36	339	334	313	329	11	334	308	309	317	12	313	285	317	305	14

Table A15. Concentration of BTEX components in water from recirculating tank study (Run #3) at 21°C with (A) SLC oil, (B) dispersed SLC at DOR=20, and (C) dispersed SLC at DOR=100 using headspace sampling and microFast GC method.

A

Time (min.)	0-15					15-30					30-45					45-60				
Replicate	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV
	Concentration (ppb)					Concentration (ppb)					Concentration (ppb)					Concentration (ppb)				
Benzene	105	55	66	75	21	83	44	17	48	27	76	43	15	45	25	16	42	74	44	24
Toluene	428	421	526	458	48	340	405	395	380	29	333	341	316	330	11	343	383	349	358	17
Ethyl Benzene	78	81	69	76	5	58	64	66	63	4	67	58	54	60	6	79	59	77	72	9
m,p-Xylene	276	265	279	273	6	231	224	261	239	16	196	231	248	225	22	269	182	232	227	36
o-Xylene	161	143	91	132	30	94	99	99	97	2	88	90	89	89	1	99	104	108	104	4

B

Time (min.)	0-15					15-30					30-45					45-60				
Replicate	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV
	Concentration (ppb)					Concentration (ppb)					Concentration (ppb)					Concentration (ppb)				
Benzene	273	135	154	188	61	184	110	182	159	34	96	122	106	108	11	124	136	165	142	17
Toluene	1453	1247	1561	1420	130	1252	1288	1117	1219	73	1080	1269	1044	1131	99	1285	1056	1360	1234	129
Ethyl Benzene	122	220	184	175	40	171	126	152	150	18	174	157	198	177	17	192	171	180	181	9
m,p-Xylene	793	608	635	678	82	692	597	628	639	40	545	571	618	578	30	712	603	584	633	56
o-Xylene	390	330	338	353	27	339	281	345	322	29	382	305	301	330	37	317	268	271	285	22

C

Time (min.)	0-15					15-30					30-45					45-60				
Replicate	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV
	Concentration (ppb)					Concentration (ppb)					Concentration (ppb)					Concentration (ppb)				
Benzene	243	170	194	203	31	232	134	185	183	40	112	155	129	132	18	154	104	206	154	42
Toluene	1593	1675	1896	1721	128	1347	1393	1331	1357	26	1349	1421	1448	1406	42	1543	1441	1284	1423	107
Ethyl Benzene	152	221	180	184	29	221	174	148	181	31	186	186	177	183	4	206	178	201	195	12
m,p-Xylene	976	745	707	809	119	681	761	656	699	45	599	625	622	615	12	795	725	722	747	34
o-Xylene	491	420	375	429	48	413	401	357	390	24	381	372	359	371	9	381	334	361	359	20

Table A16. Desorption tube air results for Ohmsett field test (Oil Control Run #1) using SLC oil.

Time (min.)	0					2					5				
Replicate	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV
	Concentration (ppb)					Concentration (ppb)					Concentration (ppb)				
Benzene	ND	ND	ND	—	—	ND	ND	ND	—	—	BDL	BDL	BDL	—	—
Toluene	BDL	BDL	BDL	—	—	BDL	BDL	BDL	—	—	BDL	BDL	BDL	—	—
Ethyl Benzene	ND	ND	ND	—	—	ND	ND	ND	—	—	ND	ND	ND	—	—
m,p-Xylene	ND	ND	ND	—	—	ND	ND	ND	—	—	ND	ND	ND	—	—
o-Xylene	ND	ND	ND	—	—	ND	ND	ND	—	—	ND	ND	ND	—	—

Time (min.)	7					13				
Replicate	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV
	Concentration (ppb)					Concentration (ppb)				
Benzene	ND	ND	ND	—	—	ND	ND	ND	—	—
Toluene	BDL	BDL	BDL	—	—	BDL	BDL	BDL	—	—
Ethyl Benzene	ND	ND	ND	—	—	ND	ND	ND	—	—
m,p-Xylene	ND	ND	ND	—	—	ND	ND	ND	—	—
o-Xylene	ND	ND	ND	—	—	ND	ND	ND	—	—

ND= non detect, BDL= below detection limit

Table A17. Desorption tube air results for Ohmsett field test (Oil Control Run #2) using SLC oil.

Time (min.)	0					2					5				
Replicate	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV
	Concentration (ppb)					Concentration (ppb)					Concentration (ppb)				
Benzene	ND	ND	ND	—	—	ND	ND	ND	—	—	26	55	46	42	15
Toluene	BDL	BDL	BDL	—	—	BDL	BDL	BDL	—	—	10	17	19	15	5
Ethyl Benzene	ND	ND	ND	—	—	ND	ND	ND	—	—	ND	ND	ND	—	—
m,p-Xylene	ND	ND	ND	—	—	ND	ND	ND	—	—	ND	ND	ND	—	—
o-Xylene	ND	ND	ND	—	—	ND	ND	ND	—	—	ND	ND	ND	—	—

Time (min.)	7					13				
Replicate	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV
	Concentration (ppb)					Concentration (ppb)				
Benzene	30	45	37	37	8	BDL	ND	ND	—	—
Toluene	45	62	59	55	9	20	35	44	33	12
Ethyl Benzene	ND	ND	ND	—	—	ND	ND	ND	—	—
m,p-Xylene	ND	ND	ND	—	—	ND	ND	ND	—	—
o-Xylene	ND	ND	ND	—	—	ND	ND	ND	—	—

ND= non detect, BDL= below detection limit

Table A18. Desorption tube air results for Ohmsett field test (Oil Control Run #3) using SLC oil.

Time (min.)	0					2					3				
	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV
Replicate	Concentration (ppb)					Concentration (ppb)					Concentration (ppb)				
Benzene	300	190	234	241	—	175	120	265	187	73	375	581	492	483	103
Toluene	BDL	BDL	BDL	—	—	BDL	BDL	BDL	—	—	521	684	444	550	123
Ethyl Benzene	ND	ND	ND	—	—	ND	ND	ND	—	—	ND	ND	ND	—	—
m,p-Xylene	ND	ND	ND	—	—	ND	ND	ND	—	—	ND	ND	ND	—	—
o-Xylene	ND	ND	ND	—	—	ND	ND	ND	—	—	ND	ND	ND	—	—

Time (min.)	7					10					13				
	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV
Replicate	Concentration (ppb)					Concentration (ppb)					Concentration (ppb)				
Benzene	181	201	225	202	22	50	39	43	44	—	33	25	42	—	—
Toluene	61	42	66	56	13	105	132	91	109	21	75	69	124	97	39
Ethyl Benzene	ND	ND	ND	—	—	ND	ND	ND	—	—	ND	ND	ND	—	—
m,p-Xylene	ND	ND	ND	—	—	ND	ND	ND	—	—	ND	ND	ND	—	—
o-Xylene	ND	ND	ND	—	—	ND	ND	ND	—	—	ND	ND	ND	—	—

ND= non detect, BDL= below detection limit

Table A19. Desorption tube air results for Ohmsett field test (Oil Dispersant Run #1) using SLC oil.

Time (min.)	0					2					3				
	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV
Replicate	Concentration (ppb)					Concentration (ppb)					Concentration (ppb)				
Benzene	ND	ND	ND	—	—	ND	ND	ND	—	—	ND	ND	ND	—	—
Toluene	BDL	BDL	BDL	—	—	BDL	BDL	BDL	—	—	BDL	BDL	BDL	—	—
Ethyl Benzene	ND	ND	ND	—	—	ND	ND	ND	—	—	ND	ND	ND	—	—
m,p-Xylene	BDL	BDL	BDL	—	—	BDL	BDL	BDL	—	—	BDL	BDL	BDL	—	—
o-Xylene	BDL	BDL	BDL	—	—	BDL	BDL	BDL	—	—	BDL	BDL	BDL	—	—

Time (min.)	5					7					10				
	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV
Replicate	Concentration (ppb)					Concentration (ppb)					Concentration (ppb)				
Benzene	ND	ND	ND	—	—	ND	ND	ND	—	—	ND	ND	ND	—	—
Toluene	BDL	BDL	BDL	—	—	BDL	BDL	BDL	—	—	BDL	BDL	BDL	—	—
Ethyl Benzene	ND	ND	ND	—	—	ND	ND	ND	—	—	ND	ND	ND	—	—
m,p-Xylene	BDL	BDL	BDL	—	—	BDL	BDL	BDL	—	—	BDL	BDL	BDL	—	—
o-Xylene	BDL	BDL	BDL	—	—	BDL	BDL	BDL	—	—	BDL	BDL	BDL	—	—

ND= non detect, BDL= below detection limit

Table A20. Desorption tube air results for Ohmsett field test (Oil Dispersant Run #2) using SLC oil.

Time (min.)	0					2					3				
Replicate	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV
	Concentration (ppb)					Concentration (ppb)					Concentration (ppb)				
Benzene	ND	ND	ND	—	—	BDL	BDL	BDL	—	—	124	118	162	135	24
Toluene	ND	BDL	BDL	—	—	BDL	BDL	BDL	—	—	211	188	158	186	27
Ethyl Benzene	ND	ND	ND	—	—	ND	ND	ND	—	—	ND	ND	ND	—	—
m,p-Xylene	BDL	BDL	BDL	—	—	BDL	BDL	BDL	—	—	BDL	BDL	BDL	—	—
o-Xylene	ND	ND	ND	—	—	ND	ND	BDL	—	—	BDL	BDL	BDL	—	—

Time (min.)	5					7					10				
Replicate	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV
	Concentration (ppb)					Concentration (ppb)					Concentration (ppb)				
Benzene	15	10	11	12	3	15	11	21	16	5	19	22	14	18	4
Toluene	BDL	BDL	BDL	—	—	BDL	BDL	BDL	—	—	BDL	BDL	BDL	—	—
Ethyl Benzene	ND	ND	ND	—	—	ND	ND	ND	—	—	ND	ND	ND	—	—
m,p-Xylene	BDL	BDL	BDL	—	—	BDL	BDL	BDL	—	—	BDL	BDL	BDL	—	—
o-Xylene	BDL	BDL	BDL	—	—	BDL	BDL	BDL	—	—	BDL	BDL	BDL	—	—

Time (min.)	13				
Replicate	1	2	3	AVG	STDEV
	Concentration (ppb)				
Benzene	BDL	BDL	BDL	—	—
Toluene	BDL	BDL	BDL	—	—
Ethyl Benzene	ND	ND	ND	—	—
m,p-Xylene	BDL	BDL	BDL	—	—
o-Xylene	BDL	BDL	BDL	—	—

ND= non detect, BDL= below detection limit

Table A21. Desorption tube air results for Ohmsett field test (Oil Dispersant Run #3) using SLC oil.

Time (min.)	0					2					3				
Replicate	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV
	Concentration (ppb)					Concentration (ppb)					Concentration (ppb)				
Benzene	ND	ND	ND	—	—	BDL	ND	ND	—	—	ND	ND	BDL	—	—
Toluene	BDL	BDL	BDL	—	—	BDL	BDL	BDL	—	—	BDL	ND	BDL	—	—
Ethyl Benzene	ND	ND	ND	—	—	ND	ND	BDL	—	—	ND	ND	BDL	—	—
m,p-Xylene	BDL	BDL	BDL	—	—	BDL	BDL	BDL	—	—	BDL	ND	BDL	—	—
o-Xylene	ND	ND	ND	—	—	ND	ND	BDL	—	—	BDL	ND	BDL	—	—

Time (min.)	5					7					10				
Replicate	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV
	Concentration (ppb)					Concentration (ppb)					Concentration (ppb)				
Benzene	11	17	13	14	3	ND	ND	ND	—	—	ND	ND	ND	—	—
Toluene	51	43	39	44	6	36	45	50	44	7	43	55	20	39	18
Ethyl Benzene	ND	BDL	BDL	—	—	BDL	BDL	BDL	—	—	ND	ND	ND	—	—
m,p-Xylene	BDL	BDL	BDL	—	—	BDL	BDL	BDL	—	—	ND	ND	BDL	—	—
o-Xylene	ND	BDL	BDL	—	—	BDL	BDL	BDL	—	—	ND	ND	BDL	—	—

Time (min.)	13				
Replicate	1	2	3	AVG	STDEV
	Concentration (ppb)				
Benzene	ND	BDL	BDL	—	—
Toluene	BDL	BDL	BDL	—	—
Ethyl Benzene	ND	BDL	BDL	—	—
m,p-Xylene	BDL	BDL	BDL	—	—
o-Xylene	BDL	BDL	BDL	—	—

ND= non detect, BDL= below detection limit

Table A22. Direct air sampling results for Ohmsett field test (Oil Control Run #1) using SLC oil.

Time (min.)	0					2					5				
Replicate	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV
	Concentration (ppb)					Concentration (ppb)					Concentration (ppb)				
Benzene	ND	ND	ND	—	—	ND	ND	ND	—	—	BDL	BDL	BDL	—	—
Toluene	BDL	BDL	BDL	—	—	BDL	BDL	BDL	—	—	BDL	BDL	BDL	—	—
Ethyl Benzene	ND	ND	ND	—	—	ND	ND	ND	—	—	ND	ND	ND	—	—
m,p-Xylene	ND	ND	ND	—	—	ND	ND	ND	—	—	ND	ND	ND	—	—
o-Xylene	ND	ND	ND	—	—	ND	ND	ND	—	—	ND	ND	ND	—	—

Time (min.)	7					13				
Replicate	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV
	Concentration (ppb)					Concentration (ppb)				
Benzene	ND	ND	ND	—	—	ND	ND	ND	—	—
Toluene	BDL	BDL	BDL	—	—	BDL	BDL	BDL	—	—
Ethyl Benzene	ND	ND	ND	—	—	ND	ND	ND	—	—
m,p-Xylene	ND	ND	ND	—	—	ND	ND	ND	—	—
o-Xylene	ND	ND	ND	—	—	ND	ND	ND	—	—

ND= non detect, BDL= below detection limit

Table A23. Direct air sampling results for Ohmsett field test (Oil Control Run #2) using SLC oil.

Time (min.)	0					2					5				
Replicate	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV
	Concentration (ppb)					Concentration (ppb)					Concentration (ppb)				
Benzene	ND	ND	ND	—	—	ND	ND	ND	—	—	35	99	41	58	35
Toluene	BDL	BDL	BDL	—	—	BDL	BDL	BDL	—	—	BDL	BDL	BDL	—	—
Ethyl Benzene	ND	ND	ND	—	—	ND	ND	ND	—	—	ND	ND	ND	—	—
m,p-Xylene	ND	ND	ND	—	—	ND	ND	ND	—	—	ND	ND	ND	—	—
o-Xylene	ND	ND	ND	—	—	ND	ND	ND	—	—	ND	ND	ND	—	—

Time (min.)	7					13				
Replicate	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV
	Concentration (ppb)					Concentration (ppb)				
Benzene	34	59	49	47	13	BDL	ND	ND	—	—
Toluene	BDL	BDL	BDL	—	—	24	BDL	BDL	24	—
Ethyl Benzene	ND	ND	ND	—	—	ND	ND	ND	—	—
m,p-Xylene	ND	ND	ND	—	—	ND	ND	ND	—	—
o-Xylene	ND	ND	ND	—	—	ND	ND	ND	—	—

ND= non detect, BDL= below detection limit

Table A24. Direct air sampling results for Ohmsett field test (Oil Control Run #3) using SLC oil.

Time (min.)	0					2					3				
Replicate	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV
	Concentration (ppb)					Concentration (ppb)					Concentration (ppb)				
Benzene	ND	ND	216	216	—	190	1020	492	567	420	448	784	580	604	169
Toluene	BDL	BDL	BDL	—	—	BDL	BDL	BDL	—	—	BDL	BDL	BDL	—	—
Ethyl Benzene	ND	ND	ND	—	—	ND	ND	ND	—	—	ND	ND	ND	—	—
m,p-Xylene	ND	ND	ND	—	—	ND	ND	ND	—	—	ND	ND	ND	—	—
o-Xylene	ND	ND	ND	—	—	ND	ND	ND	—	—	ND	ND	ND	—	—
Time (min.)	7					10					13				
Replicate	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV
	Concentration (ppb)					Concentration (ppb)					Concentration (ppb)				
Benzene	208	232	319	253	58	57	BDL	BDL	57	—	BDL	BDL	BDL	—	—
Toluene	54	54	61	56	4	135	116	114	122	12	82	95	111	103	11
Ethyl Benzene	ND	ND	ND	—	—	ND	ND	ND	—	—	ND	ND	ND	—	—
m,p-Xylene	ND	ND	ND	—	—	ND	ND	ND	—	—	ND	ND	ND	—	—
o-Xylene	ND	ND	ND	—	—	ND	ND	ND	—	—	ND	ND	ND	—	—

ND= non detect, BDL= below detection limit

Table A25. Direct air sampling results for Ohmsett field test (Oil Dispersant Run #1) using SLC oil.

Time (min.)	0					2					3				
Replicate	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV
	Concentration (ppb)					Concentration (ppb)					Concentration (ppb)				
Benzene	ND	ND	ND	—	—	ND	ND	ND	—	—	ND	ND	ND	—	—
Toluene	BDL	BDL	BDL	—	—	BDL	BDL	BDL	—	—	BDL	BDL	BDL	—	—
Ethyl Benzene	ND	ND	ND	—	—	ND	ND	ND	—	—	ND	ND	ND	—	—
m,p-Xylene	BDL	BDL	BDL	—	—	BDL	BDL	BDL	—	—	BDL	BDL	BDL	—	—
o-Xylene	BDL	BDL	BDL	—	—	BDL	BDL	BDL	—	—	BDL	BDL	BDL	—	—
Time (min.)	5					7					10				
Replicate	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV
	Concentration (ppb)					Concentration (ppb)					Concentration (ppb)				
Benzene	ND	ND	ND	—	—	ND	ND	ND	—	—	ND	ND	ND	—	—
Toluene	BDL	BDL	BDL	—	—	BDL	BDL	BDL	—	—	BDL	BDL	BDL	—	—
Ethyl Benzene	ND	ND	ND	—	—	ND	ND	ND	—	—	ND	ND	ND	—	—
m,p-Xylene	BDL	BDL	BDL	—	—	BDL	BDL	BDL	—	—	BDL	BDL	BDL	—	—
o-Xylene	BDL	BDL	BDL	—	—	BDL	BDL	BDL	—	—	BDL	BDL	BDL	—	—

ND= non detect, BDL= below detection limit

Table A26. Direct air sampling results for Ohmsett field test (Oil Dispersant Run #2) using SLC oil.

Time (min.)	0					2					3				
Replicate	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV
	Concentration (ppb)					Concentration (ppb)					Concentration (ppb)				
Benzene	ND	ND	ND	—	—	BDL	BDL	BDL	—	—	198	206	143	182	34
Toluene	ND	BDL	BDL	—	—	BDL	BDL	BDL	—	—	BDL	BDL	BDL	—	—
Ethyl Benzene	ND	ND	ND	—	—	ND	ND	ND	—	—	ND	ND	ND	—	—
m,p-Xylene	BDL	BDL	BDL	—	—	BDL	BDL	BDL	—	—	BDL	BDL	BDL	—	—
o-Xylene	ND	ND	ND	—	—	ND	ND	BDL	—	—	BDL	BDL	BDL	—	—

Time (min.)	5					7					10				
Replicate	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV
	Concentration (ppb)					Concentration (ppb)					Concentration (ppb)				
Benzene	19	14	10	14	5	17	BDL	BDL	17	—	14	BDL	BDL	14	—
Toluene	BDL	BDL	BDL	—	—	BDL	BDL	BDL	—	—	BDL	BDL	BDL	—	—
Ethyl Benzene	ND	ND	ND	—	—	ND	ND	ND	—	—	ND	ND	ND	—	—
m,p-Xylene	BDL	BDL	BDL	—	—	BDL	BDL	BDL	—	—	BDL	BDL	BDL	—	—
o-Xylene	BDL	BDL	BDL	—	—	BDL	BDL	BDL	—	—	BDL	BDL	BDL	—	—

Time (min.)	13				
Replicate	1	2	3	AVG	STDEV
	Concentration (ppb)				
Benzene	BDL	BDL	BDL	—	—
Toluene	BDL	BDL	BDL	—	—
Ethyl Benzene	ND	ND	ND	—	—
m,p-Xylene	BDL	BDL	BDL	—	—
o-Xylene	BDL	BDL	BDL	—	—

ND= non detect, BDL= below detection limit

Table A27. Direct air sampling results for Ohmsett field test (Oil Dispersant Run #3) using SLC oil.

Time (min.)	0					2					3				
Replicate	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV
	Concentration (ppb)					Concentration (ppb)					Concentration (ppb)				
Benzene	ND	ND	ND	—	—	BDL	ND	ND	—	—	ND	ND	BDL	—	—
Toluene	BDL	BDL	BDL	—	—	BDL	BDL	BDL	—	—	BDL	ND	BDL	—	—
Ethyl Benzene	ND	ND	ND	—	—	ND	ND	BDL	—	—	ND	ND	BDL	—	—
m,p-Xylene	BDL	BDL	BDL	—	—	BDL	BDL	BDL	—	—	BDL	ND	BDL	—	—
o-Xylene	ND	ND	ND	—	—	ND	ND	BDL	—	—	BDL	ND	BDL	—	—

Time (min.)	5					7					10				
Replicate	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV
	Concentration (ppb)					Concentration (ppb)					Concentration (ppb)				
Benzene	ND	BDL	BDL	—	—	ND	ND	ND	—	—	ND	ND	ND	—	—
Toluene	BDL	BDL	BDL	—	—	BDL	BDL	BDL	—	—	BDL	BDL	BDL	—	—
Ethyl Benzene	ND	BDL	BDL	—	—	BDL	BDL	BDL	—	—	ND	ND	ND	—	—
m,p-Xylene	BDL	BDL	BDL	—	—	BDL	BDL	BDL	—	—	ND	ND	BDL	—	—
o-Xylene	ND	BDL	BDL	—	—	BDL	BDL	BDL	—	—	ND	ND	BDL	—	—

Time (min.)	13				
Replicate	1	2	3	AVG	STDEV
	Concentration (ppb)				
Benzene	ND	BDL	BDL	—	—
Toluene	BDL	BDL	BDL	—	—
Ethyl Benzene	ND	BDL	BDL	—	—
m,p-Xylene	BDL	BDL	BDL	—	—
o-Xylene	BDL	BDL	BDL	—	—

ND= non detect, BDL= below detection limit

Table A28. Water sampling results for Ohmsett field test (Oil Control Run #2) using SLC oil.

Time (min.)	0					2					5				
Replicate	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV
	Concentration (ppb)					Concentration (ppb)					Concentration (ppb)				
Benzene	ND	ND	ND	—	—	BDL	BDL	44	44	—	ND	ND	ND	—	—
Toluene	BDL	BDL	BDL	—	—	25	94	199	106	88	15	21	47	28	17
Ethyl Benzene	ND	ND	ND	—	—	BDL	BDL	BDL	—	—	ND	ND	ND	—	—
m,p-Xylene	BDL	BDL	BDL	—	—	BDL	12	65	39	38	BDL	BDL	BDL	—	—
o-Xylene	ND	ND	ND	—	—	BDL	BDL	29	29	—	ND	ND	BDL	—	—

Time (min.)	7					13				
Replicate	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV
	Concentration (ppb)					Concentration (ppb)				
Benzene	ND	ND	11	11	—	BDL	BDL	BDL	—	—
Toluene	24	101	195	107	85	52	130	42	75	48
Ethyl Benzene	ND	BDL	BDL	—	—	BDL	BDL	ND	—	—
m,p-Xylene	BDL	BDL	0	0	—	BDL	17	BDL	17	—
o-Xylene	BDL	13	61	37	34	BDL	BDL	BDL	—	—

ND= non detect, BDL= below detection limit

Table A29. Water sampling results for Ohmsett field test (Oil Control Run #3) using SLC oil.

Time (min.)	0					2					5				
Replicate	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV
	Concentration (ppb)					Concentration (ppb)					Concentration (ppb)				
Benzene	ND	BDL	BDL	—	—	BDL	BDL	ND	—	—	ND	ND	ND	—	—
Toluene	BDL	BDL	BDL	—	—	15	55	162	77	76	10	29	81	40	37
Ethyl Benzene	ND	ND	ND	—	—	BDL	BDL	BDL	—	—	ND	ND	ND	—	—
m,p-Xylene	BDL	BDL	BDL	—	—	BDL	18	12	15	4	BDL	BDL	BDL	—	—
o-Xylene	ND	ND	ND	—	—	BDL	BDL	11	11	—	ND	ND	BDL	—	—

Time (min.)	7					13				
Replicate	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV
	Concentration (ppb)					Concentration (ppb)				
Benzene	ND	ND	18	18	—	BDL	BDL	BDL	—	—
Toluene	36	84	11	44	37	37	11	33	27	14
Ethyl Benzene	ND	BDL	BDL	—	—	BDL	BDL	25	25	—
m,p-Xylene	BDL	BDL	91	91	—	BDL	11	BDL	11	—
o-Xylene	BDL	14	41	28	19	BDL	BDL	BDL	—	—

ND= non detect, BDL= below detection limit

Table A30. Water sampling results for Ohmsett field test (Oil Dispersant Run #1) using SLC oil.

Time (min.)	0					2					3				
Replicate	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV
	Concentration (ppb)					Concentration (ppb)					Concentration (ppb)				
Benzene	BDL	ND	ND	—	—	ND	161	656	408	350	21	BDL	BDL	21	—
Toluene	58	42	29	43	14	53	469	2096	873	1079	152	82	57	97	49
Ethyl Benzene	ND	ND	ND	—	—	ND	BDL	0	0	—	BDL	BDL	ND	—	—
m,p-Xylene	BDL	BDL	BDL	—	—	BDL	115	665	390	388	48	14	BDL	31	24
o-Xylene	BDL	ND	ND	—	—	ND	53	282	167	161	15	BDL	BDL	15	—

Time (min.)	5					7					13				
Replicate	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV
	Concentration (ppb)					Concentration (ppb)					Concentration (ppb)				
Benzene	1744	4199	785	2243	1760	1966	758	12218	4981	6297	507	1376	3846	3846	1732
Toluene	7382	19211	2826	9806	8457	6320	2548	44528	17799	23225	1478	5037	11836	11836	5263
Ethyl Benzene	367	991	128	495	446	274	73	1472	606	756	54	218	520	520	236
m,p-Xylene	3576	9136	1178	4630	4082	2386	681	17455	6841	9232	513	1649	4583	4583	2100
o-Xylene	1143	3545	467	1718	1617	850	294	5912	2352	3096	226	750	2026	2026	926

ND= non detect, BDL= below detection limit

Table A31. Water sampling results for Ohmsett field test (Oil Dispersant Run #2) using SLC oil.

Time (min.)	0					2					3				
Replicate	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV
	Concentration (ppb)					Concentration (ppb)					Concentration (ppb)				
Benzene	29	49	26	35	13	35	31	90	52	33	89	81	117	96	19
Toluene	170	241	165	192	43	201	191	327	240	76	290	333	418	347	65
Ethyl Benzene	BDL	BDL	BDL	—	—	BDL	BDL	0	0	—	10	10	14	11	2
m,p-Xylene	36	61	33	43	15	49	41	90	60	26	80	101	152	111	37
o-Xylene	19	30	14	21	8	24	19	47	30	15	50	50	67	56	9

Time (min.)	5					7					10				
Replicate	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV
	Concentration (ppb)					Concentration (ppb)					Concentration (ppb)				
Benzene	232	108	576	305	242	992	ND	ND	992	—	ND	29	294	161	187
Toluene	813	445	2159	1139	902	3118	23	35	1059	1784	14	210	1564	596	844
Ethyl Benzene	31	13	94	46	42	145	ND	ND	145	—	ND	BDL	0	0	—
m,p-Xylene	282	148	810	413	350	1457	BDL	BDL	1457	—	BDL	56	756	406	495
o-Xylene	156	65	355	192	148	629	ND	BDL	629	—	BDL	28	334	181	216

ND= non detect, BDL= below detection limit

Table A32. Water sampling results for Ohmsett field test (Oil Dispersant Run #3) using SLC oil.

Time (min.)	0					2					3				
Replicate	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV
	Concentration (ppb)					Concentration (ppb)					Concentration (ppb)				
Benzene	89	117	180	129	47	217	310	173	234	70	151	290	487	309	169
Toluene	258	320	579	386	170	617	897	489	668	208	531	891	1549	990	516
Ethyl Benzene	11	10	23	15	7	19	35	16	23	10	18	29	47	31	15
m,p-Xylene	98	109	216	141	65	213	287	190	230	51	179	281	487	316	157
o-Xylene	43	52	114	69	39	104	149	90	114	31	98	158	243	166	73

Time (min.)	5					7					10				
Replicate	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV
	Concentration (ppb)					Concentration (ppb)					Concentration (ppb)				
Benzene	1327	884	1184	1132	226	1188	1645	1401	1412	229	718	2610	612	1313	1124
Toluene	3396	2499	1486	2460	955	3385	4932	3505	3941	861	2342	7258	1792	3798	3010
Ethyl Benzene	52	93	50	65	24	127	183	135	148	30	80	319	65	155	143
m,p-Xylene	1247	787	533	856	362	1169	1601	1136	1302	259	814	2720	661	1398	1147
o-Xylene	547	446	202	399	177	606	735	630	657	69	337	1055	310	567	422

Time (min.)	13				
Replicate	1	2	3	AVG	STDEV
	Concentration (ppb)				
Benzene	981	663	613	752	199
Toluene	2295	1897	1783	1991	269
Ethyl Benzene	97	77	51	75	23
m,p-Xylene	876	809	710	798	84
o-Xylene	438	354	312	368	64

Table A33. TPH water sampling results from Ohmsett field tests.

Time (min.)	0					2					3				
Replicate	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV
	Concentration (ppb)					Concentration (ppb)					Concentration (ppb)				
Oil Control Run #2	12	14	24	17	6	8	10	21	13	7	51	66	84	67	17
Oil Control Run #3	15	17	39	24	13	21	29	41	30	10	46	59	64	56	9
Oil Dispersed Run #1	49	54	56	53	4	48	61	72	60	12	1817	2108	2284	2070	236
Oil Dispersed Run #2	503	589	583	558	48	463	537	621	540	79	526	635	721	627	98
Oil Dispersed Run #3	538	597	613	583	40	538	624	701	621	82	504	708	688	633	112

Time (min.)	5					7					10				
Replicate	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV	1	2	3	AVG	STDEV
	Concentration (ppb)					Concentration (ppb)					Concentration (ppb)				
Oil Control Run #2	44	54	74	57	15	36	40	45	40	5	NC	NC	NC	NC	NC
Oil Control Run #3	51	62	88	67	19	62	91	132	95	35	NC	NC	NC	NC	NC
Oil Dispersed Run #1	217	304	422	314	103	2620	3118	3710	3149	546	6335	7095	7665	7032	667
Oil Dispersed Run #2	708	648	731	696	43	2233	2456	2702	2464	235	1935	2187	2129	2083	132
Oil Dispersed Run #3	1342	1197	1487	1342	145	1529	1758	2022	1770	247	1293	1435	1435	1388	82

Time (min.)	13				
Replicate	1	2	3	AVG	STDEV
	Concentration (ppb)				
Oil Control Run #2	532	697	782	670	127
Oil Control Run #3	451	559	573	528	67
Oil Dispersed Run #1	5641	6318	6995	6318	677
Oil Dispersed Run #2	1129	1298	1242	1223	86
Oil Dispersed Run #3	1327	1460	1553	1446	113