Bakken Shale Crude Oil Spill Evaluation Pilot Study

April

2015

Project Duration: Week of February 9 2015

Project Participants:

- Several EPA regional Removal programs
- EPA's Environmental Response Team (ERT) and
- U.S. Department of Interior

Project Location:

Oil and Hazardous Materials Simulated Environmental Test Tank (OHMSETT),

National Oil Spill Response Test Facility,

Naval Weapons Station Earle Waterfront (NWSEW), Leonardo, NJ,

Bureau of Safety and Environmental Enforcement (BSEE) managed facility

Project Design:

Approximately 1675 gallons (11,280 pounds) of Bakken crude oil was transported from Eddystone Rail facility in Eddystone, PA to the OHMSETT facility. Based on Material Safety Data Sheet and supplier information, the product was consistent with standard Bakken oil that is shipped throughout the country.

The pilot study involved the discharge of known amounts of Bakken crude oil into specific areas of the OHMSETT tank. The oil was then periodically sampled as it weathered and was analyzed for chemical and physical parameters. Fate and behavior analysis was performed on the Bakken oil for viscosity, density, bottom solids, and water content. Fresh and weathered oil was recovered from the water to allow for an evaluation of standard oil recovery equipment (oleophilic drum skimmer).

ERT, supported by members of the US Coast Guard Atlantic Strike Team, performed air monitoring and sampling for evaluation of hydrocarbons. Monitoring parameters included:

- volatile organic compounds (VOCs),
- lower explosive limit (LEL),
- hydrogen sulfide (H_2S), and
- benzene.

Air samples were collected in Tedlar bags and charcoal tubes for time-weighted concentration data. The Trace Atmospheric Gas Analyzer (TAGA) bus, EPA's self-contained mobile laboratory, was onsite performing air analysis in downwind areas. Samples of fresh and weathered oil were also collected for flammability and finger print analysis.

The general study goals include:

1. Evaluate benzene and other VOC emissions from a discharge of Bakken oil to gain more information to support Health and Safety decisions for responders and the public;
2. Evaluate physical properties of Bakken oil, including as weathering progresses, in order to better predict the fate on the surface water;
3. Evaluate recoverability of fresh and weathered Bakken oil using standard methods.

Background:

While significant testing has been performed by different organizations on Bakken oil, the testing is generally comprised of standard petroleum characteristic analyses and characterization for proper U.S. Department of Transportation (DOT) classification for transportation. The DOT recently published its findings from an extensive sampling program focused on the Bakken oil that indicates that the oil contains a relatively high gas content and that, in some cases, it appears to be more volatile than many light crude oils. The data from these testing programs have provided critical knowledge of the properties of this light, "sweet" crude oil. However, many questions relating to spill response continue to be raised by the response community at all levels of government. Over 1.2 million barrels of crude oil were transported via rail and pipeline from the Bakken Formation's Williston Basin in 2013.

Oil analyses results from the DOT/PHMSA testing program in 2013 show the following range of characteristics associated with crude oil produced in the Williston Basin:

Flash Point	<32 to < 73 degrees F
Initial Boiling Point	85 to 104 degrees F
Butane	2.4 to 3 %
Propane	0.6 to 1.2 %
Hydrogen Sulfide	< 5 parts per million (ppm)
API Gravity	39.9 to 43.8
Reid Vapor Pressure	8.7 to 11.8 pounds per square inch absolute (psia)

(DOT: Operation Safe Delivery Update – Report, 7-23-14)

OHMSETT Test Conditions:

On February 11, 2015 approximately 660 gallons of oil were discharged into a 100x65 foot area of the test tank. The weather conditions were cold (34˚F maximum temperature during the study) with winds out of the northeast. The oil spread rapidly and then accumulated in the downwind area of the tank. Volatilization of lighter end hydrocarbons was noted during the release. The oil was then allowed to sit over a 24-hour period to allow for collection of samples and air emissions information. Air monitoring stations were located immediately surrounding and atop the test area as well as locations approximately 600 feet from the test tank.

Image 1: Release of ~ 660 gallons of Bakken Crude Oil at OHMSETT (2/11/2015).

Oil Chemistry:

Product samples were collected from the storage containers as follows:

- before oil was released onto the water,
- following the initial 24 hour period of weathering, and
- after about a week of weathering.

The samples were subjected to both fingerprint analysis and hydrocarbon analysis by GCMS. The fingerprint results showed a significant loss of the lighter compounds after 24 hours including a complete loss of benzene. The following results are representative of the benzene concentrations within the oil from the time of shipment through the weathering period. Flash point tests performed on two weathered oil samples showed after one day the flash point was 132 degrees F, and after seven days the flash point was 165 degrees F.

Benzene Concentrations in Weathered Oil Samples

Sample ID	Description	Date Collected	Time Collected	Benzene µg/g	% lost
OHM-004	at Eddystone, PA	2/4/15	08:48	**1720**	
OHM-001	Arrival OHMSETT	2/4/15	10:30	**1720**	**0.0**
54969	Prior to Release	2/11/15	10:09	**1700**	**1.2**
54980	~24hrs Post Release (weathered)	2/12/15	08:31	**U**	**100**
OHM-005	Extended weathering	2/18/15	08:00	**U**	**100**

Air Monitoring and Sampling:

Air monitoring and sampling was performed throughout the initial days of the testing. Monitoring and sampling equipment included:

- AreaRAEs were deployed to monitor for VOCs, LEL, and H_2S,
- 600-mg carbon tubes to collect samples for comparison to 8-hour time weighted average (TWA) benzene standards,
- Tedlar bags to collect 1-minute grab samples,
- UltraRAE 3000s with benzene-specific tubes to capture benzene readings concurrent with Tedlar bag sampling and
- TAGA to capture real-time benzene concentrations.

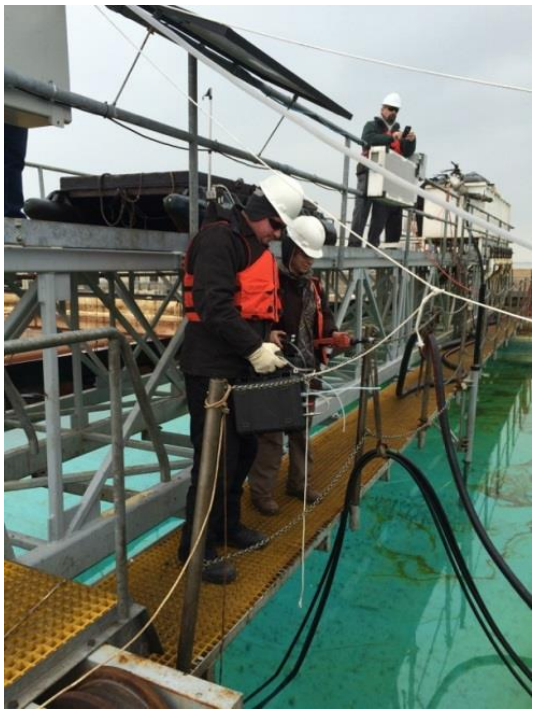

Image 2: AreaRAE deployment for air monitoring (2/11/2015).

AreaRAE monitoring stations were deployed at 9 locations, with the 4 closest stations being located on the deck <10' from the 100x65 ft. test area. Benzene sampling with charcoal tubes was conducted at 8 of the 9 monitoring stations. Tedlar bag grab samples were collected immediately adjacent (<5') to the tote releasing the oil and then, post-release, at the monitoring stations indicating the highest VOC concentration at specific post-release sample intervals. Benzene specific UltraRAE readings were collected concurrently and collocated with Tedlar bag grab samples. The highest readings were all within 5 feet of test area or within the breathing zones.

Key air monitoring and sampling information included:

- No LEL exceedances above 10 percent. A maximum of 4.7% was observed at the location of release after 4 minutes.
- Hydrogen Sulfide was detected at a maximum concentration of 0.2 ppm. One minute averages were normally below 0.04 ppm.
- Maximum verifiable VOC concentration of 138 ppm (west side of tank located within 5 feet of study area). The highest verifiable one minute average was 67 ppm. Both were recorded within 5 minutes of the release.
- A maximum benzene concentration of 5500 ppbv was detected using an UltraRAE located 5 feet above the release point, during the release.
- A maximum benzene concentration of 2700 ppbv was detected in a Tedlar bag sample collected 5 feet above the release point, during the release.
- Charcoal tube results suggested a possible maximum concentration for an 8 hour TWA of 75.1 ppbv benzene.
- The TAGA detected a maximum benzene concentration of 550 ppbv in downwind locations.
- About six hours after the initial release, verifiable VOC readings (1-minute average) were all below 5 ppm.

Oil Recovery Results:

Oil recovery tests were performed using an Elastec TDS 118G grooved drum skimmer. Initially, the oil spilled on February 11 into the 100x65 ft area was herded and then recovered during the morning of February 12, approximately 24 hour later. At that time, approximately 30% of the oil was estimated to have been lost (mostly through evaporation). The recovered weathered oil was then re-released into a 10x10 ft area for the recovery tests.

Image 3: Oil slick on 100x65 ft area (2/11/2015).

Image 4: Recovered oil- (10x10 ft) for recovery test (2/11/2015).

Oil Recovery Tests

Recovery Test	Weathering Period	Oil Layer Thickness	Recovery Rate	Recovery Efficiency
1	24-hour	1-inch	20-23 gpm	>97%
2	24-hour	1-inch	20-23 gpm	>97%
3	unweathered	1-inch	5.62 gpm	100%

Oil Loss over Time

Time Period	Percent Lost*
1 hour	10
2 hours	15
5 hours	20
24 hours	27
7 days	40

*The majority of the oil volume lost was due to evaporation. A smaller percentage is assumed to be lost by dissolution into the water column.

The mechanisms for dissolution and chemical impacts to the water column are yet to be evaluated. Recent 2015 spills in MT and ND involving Bakken oil have shown concentrations of hydrocarbons dissolved in the water column may be significant. In one case, the surface water intake 14 feet below surface carried BTEX compounds into the Water Treatment Plant resulting in a Treatment Plant shutdown. Benzene was above the EPA's National Primary Drinking Water Standard Maximum Contaminant Level (MCL). The oil appears to readily disperse as observed during both test conditions and these incidents.

Conclusion

- Concentrations of volatile organic compounds may be greater under warmer weather conditions with probable elevated LEL percentages.
- Rapid dispersion in flowing water is likely to occur under turbulent conditions.
- Skimming operations are possible, more so after some loss of light end hydrocarbons.
- Additional studies are likely appropriate to build on these findings.

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