

Health Hazard Evaluation of Deepwater Horizon Response Workers

Robert McCleery and Bradley King



Health Hazard Evaluation Interim Report 3
July 22, 2010



Interim report reissued December 2012: front and back covers, lead and contributing authors, and acknowledgments were added to the original interim report.

The photo on the front cover shows a skimming operation in the Gulf of Mexico during the Deepwater Horizon Response: June 2010.



National Institute for Occupational
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Robert A. Taft Laboratories
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22 July 2010

HETA 2010-0115

Fred Tremmel
Deepwater Horizon ICP
1597 Highway 311
Houma, LA 70395

Dear Mr. Tremmel:

On May 28, 2010, the National Institute for Occupational Safety and Health (NIOSH) received a request from BP for a health hazard evaluation (HHE). The request asked NIOSH to evaluate potential exposures and health effects among workers involved in Deepwater Horizon Response activities. NIOSH sent an initial team of HHE investigators on June 2, 2010, to begin the assessment of off-shore activities. To date, more than two dozen HHE investigators have been on-scene; the investigation is continuing with efforts to assess on-shore response activities.

This letter is the third in a series of interim reports. As this information is cleared for posting, we will make it available on the NIOSH website (www.cdc.gov/niosh/hhe). When all field activity and data analyses are complete we will compile the interim reports into a final report.

This report (Interim Report #3) includes several discrete components of our investigation. For each, we provide background, describe our methods, report the findings, and provide conclusions and, where appropriate, interim recommendations. The components included in this report are as follows:

- 3A – Evaluation of June 14-16, 2010 M/V Queen Bee Mission
- 3B – Evaluation of June 21-22, 2010 Dispersant Releases from the M/V International Peace

Thank you for your cooperation with this evaluation. If you have any questions, please do not hesitate to contact me at 513.841.4382 or atepper@cdc.gov.

Sincerely yours,



Allison Tepper, PhD

Chief

Hazard Evaluations and Technical

Assistance Branch

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2 Enclosures

cc:

Mr. David Dutton, BP

Mr. Mark Saperstein, BP

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Mr. Charles Huber, Manager, Dispersant Operations

CDR Laura Weems, USCG

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Ms. Cindy Coe, OSHA

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Interim Report #3A

Evaluation of June 14-16, 2010, M/V Queen Bee Mission

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Introduction

An industrial hygienist from the National Institute for Occupational Safety and Health (NIOSH) conducted an industrial hygiene survey during an offshore oil recovery mission involving the 234 foot M/V Queen Bee platform supply vessel on June 14–16, 2010. This vessel was retrofitted with a U.S. Coast Guard (USCG) operated weir skimmer, skimming control stand, high volume pumping unit (HVPU), boom system, three on-deck 500-barrel storage capacity tanks, and an industrial crane (to move boom and the skimmer). During this survey personnel on the Queen Bee who were skimming oil from the ocean surface included crew, contract personnel from Ameri-force, and the USCG. The USCG personnel were operating the skimming system and instructing and observing contract personnel's use of all components of the skimming system.

The vortex weir skimmer used on the Queen Bee consisted of a heavy-duty frame holding a central collection bowl and three floats. Underneath the bottom of the bowl are the hydraulic lines and the hose used to transport the oil/water mix to the on-deck storage tanks. The principal behind this type of skimmer is that the central bowl creates a void in the water into which an oil/water mix pours. The skimmer operator can remotely adjust the bowl depth in the water to optimize the amount of oil flowing into the bowl. Although the weir skimmer recovery rate is high, the recovery efficiency is relatively low. The skimmer tends to collect a substantial amount of water that then needs to be decanted from the storage tanks.

Six personnel operated the skimming system, four from Ameri-force and two from the USCG, for approximately 12-hour shifts (work shifts were not fixed). When skimming oil, one person operated the skimmer and one to two others remained on deck to assist the skimmer operator if necessary. Besides the skimming operation, other duties included ensuring adequate personal protective equipment (PPE) was on hand, cleaning oil impact areas on deck, decanting oil storage tanks (removing water from collected oil), checking the level of collected oil and water in the storage tanks, removing debris (seaweed, sticks, garbage), and removing the boom and skimmer from the water when moving to a new site or after the shift ended at night. Due to the high heat and humidity on deck, personnel not operating the skimmer or conducting other duties took breaks on deck under awnings or inside the air-conditioned galley. Smoking was allowed outdoors in a designated corner between the cabin and deck.

A crane was used to hoist the skimmer into and out of the water and personnel guided the skimmer using attached ropes. Other personnel adjusted hydraulic lines and the vacuum line to ensure that they were not crimped or catching on the vessel railing or other parts. To clean oil off the skimmer, contract and USCG personnel sprayed it with soap (Gorco Inc., Pro Strength Liquid Rig Wash, Houma, Louisiana) from a standard hand-held garden-type sprayer, followed by a high-pressure water rinse using a diesel-operated pressure washer. When placing and removing the skimmer from the water and cleaning the

skimmer, personnel wore Tyvek® coveralls, multiple layers of nitrile gloves, cotton gloves with beaded grips (if needed), rubber steel toe chemical boots, hardhats, and ear muffs when near the HVPU. The coveralls and nitrile gloves were discarded after use. For all other activities where possible dermal exposure to oil could occur, personnel continually wore nitrile gloves to protect their hands.

Evaluation

A NIOSH industrial hygienist conducted personal breathing zone (PBZ) and area air sampling on the Queen Bee on June 14–16, 2010. Shorter-term and longer-term air samples were collected when placing and removing the skimmer and boom from the water and during skimmer cleaning and storage tank decanting. The shorter-term samples represent exposure during specific work tasks and the longer-term samples represent full-shift occupational exposures.

On June 14, 2010, on arrival to the Queen Bee, area air monitoring and observation and documentation of work practices began as skimming operations were performed. Additionally, minor repairs to the skimming system were also carried out in the late morning hours. The skimmer was removed from the water at the end of the shift. Approximate location coordinates on arrival to the vessel were 29°02.0823N/88°20.8559W. The sea and wind were calm. On June 15, 2010, air samples were collected during skimming operations and storage tank decanting. At the end of the day, both the skimmer and boom were removed from the water prior to the vessel moving to another location with reports of heavier oil. Approximate location coordinates at the beginning of the shift were 29°02.1196N/88°27.4805W. On June 15, 2010, both the sea and wind were calm. On June 16, 2010, skimming operations did not begin until 10:00 a.m. as the vessel moved to a new location. Skimming operations were performed as well as storage tank decanting. Skimming was postponed in the late afternoon for 1.5 hours due to safety concerns stemming from lightning in an approaching storm. Skimming resumed until the end of the shift. Location coordinates at the beginning of the shift were 29°11.6741N/88°25.8641W. On June 16, 2010, both the sea and wind were calm until the storm arrived.

To evaluate exposures to volatile organic compounds (VOCs), a NIOSH investigator used integrated air sampling with a variety of sampling media, including multi-sorbent thermal desorption tubes followed by thermal desorption/gas chromatography-mass spectrometry (NIOSH Method 2549); and activated charcoal tubes [NIOSH 2010]. Results of the thermal desorption tubes were used to select specific VOCs for quantitation on PBZ and area air samples collected using charcoal tubes. Other chemicals measured in PBZ or area air samples using integrated air sampling techniques included propylene glycol (a component of the Corexit EC9500A dispersant), diesel exhaust, and the benzene soluble fraction of total particulate samples. Direct reading measurements were made for carbon monoxide (CO) and hydrogen sulfide (H₂S). See Table 1 for a complete listing of the sampling and analytical methods used.

Results and Discussion

Table 2 contains a summary of the relevant occupational exposure limits (OELs) to which results were compared. Table 3 presents temperature and relative humidity (RH) measurements made during the three days of the evaluation where sampling was conducted by the NIOSH industrial hygienist.

Volatile Organic Compounds

On June 15–16, 2010, one thermal desorption tube air sample was collected each day to screen for VOCs. On both sampling days, various C₅ to C₁₉ hydrocarbons (straight and branched alkanes) were

found with major peaks in the C₇ to C₁₃ range; some samples also contained naphthalene, benzene, toluene, xylenes, ethyl benzene, and other substances. Propylene glycol, a component of the dispersant (Corexit EC9500A), was not detected.

Based on the results of the thermal tube screening samples, the PBZ and area charcoal tube air samples were quantitated for benzene, ethyl benzene, toluene, xylenes, limonene, naphthalene, and total hydrocarbons (THC) (as hexane). Results are shown in Tables 4, 5, and 6. Some employees had charcoal tube samples collected side-by-side; the results of which were comparable. All air concentrations were well below the relevant OELs. Benzene was not detected in any PBZ or area air samples, all naphthalene results were below the minimum quantifiable concentration (MQC), and all toluene results were below the MQC except for an area air sample located inside the galley by the phone (0.0034 parts per million [ppm]). Ethyl benzene, limonene, xylenes, and THC were present above the minimum quantifiable concentrations. Ethyl benzene time weighted average (TWA) concentrations ranged from non-detectable to 0.086 ppm (PBZ – skimmer operator). Xylene TWA concentrations ranged from non-detectable to 0.046 ppm (PBZ – skimmer operator). Limonene TWA concentrations ranged from non-detectable to 0.053 ppm (area – inside the galley by the phone). Limonene is an ingredient in cleaning agents, which might explain its presence in the air samples. Total hydrocarbon TWA concentrations were all equal to or less than 5 milligrams per cubic meter (mg/m³). Although there is no OEL specifically for THCs, OELs for petroleum distillates and kerosene (two mixtures containing a similar range of hydrocarbons as was found on the initial thermal tube air samples) are 350 mg/m³ as a work shift TWA as shown in Table 2.

Propylene Glycol

Propylene glycol, a component of the dispersant (Corexit EC9500A), was not detected in any of the five area air samples collected on the Queen Bee, as shown in Tables 4, 5, and 6.

Diesel Exhaust

Emissions from diesel engines used to power the vessels are complex mixtures of gases and particulates. NIOSH uses elemental carbon (EC) as a surrogate index of exposure because the sampling and analytical method for EC is very sensitive, and a high percentage of diesel particulate (80%–90%) is EC. In comparison, tobacco smoke particulate (a potential interference when measuring diesel exhaust) is composed primarily of organic carbon (OC). Although OSHA and NIOSH have established OELs for some of the individual components of diesel exhaust (i.e., nitrogen dioxide, CO), neither agency has established an OEL for EC. However, the California Department of Health Services' Hazard Evaluation System & Information Service (HESIS) guideline for diesel exhaust particles (measured as EC) is 20 micrograms per cubic meter (µg/m³) for an 8-hour TWA. Six area air samples were collected for diesel exhaust and analyzed for the components described above. As shown in Tables 4, 5, and 6, EC concentrations during response tasks ranged from below the MQC to 2.3 µg/m³, below the HESIS guideline. Furthermore, diesel exhaust was not a substantial part of these sample results because the ratio of EC to total carbon (the sum of EC + OC) ranged from 3.7% to 8.6%, well below the expected 60% to 80% of EC to total carbon typically reported in diesel exhaust.

Benzene Soluble Total Particulate Fraction

Ten PBZ and six area air samples were collected for total particulates with the particulate fraction analyzed for benzene soluble components (to separate out contributions from substances such as salts from the sea water) as an indicator of oil mist exposures (Tables 4, 5, and 6). Total particulate TWA

concentrations ranged from non-detectable to 0.57 mg/m³ (PBZ – skimmer operator). None of the samples contained detectable concentrations of benzene soluble particulates.

Carbon Monoxide and Hydrogen Sulfide

Tables 4, 5, and 6 include a summary of the direct reading measurements for CO and H₂S. Carbon monoxide, a component of incomplete combustion, possibly from the diesel engines, was monitored for approximately 7 to 12 hours on the Queen Bee deck on June 14–16, 2010. Over the 3 days of measurements, CO concentrations from five area monitors ranged up to 3 ppm, with TWAs all less than 1 ppm, well below OELs. Hydrogen sulfide was not detected on four long term samples (approximately 7 to 12 hours) collected on the Queen Bee deck on June 14–16, 2010.

Summary

PBZ and area air concentrations of the contaminants measured were below OELs. The NIOSH investigator observed the potential for dermal contact with oil while placing and removing the skimmer and boom from the water and during cleaning activities on deck. However, contract and USCG personnel wore protective equipment during tasks where there was an increased potential for dermal exposure to oil. No symptoms were reported by Queen Bee personnel.

Because of the potential for dermal contact with oil on various parts of the skimming system, the NIOSH industrial hygienist recommends the protective steps observed during this evaluation be continued. This includes using eye protection, coveralls, rubber chemical boots, hardhats, and nitrile gloves for those on the deck during oil skimming operations with greater potential for dermal contact and using ear muffs when working on or near the HVPU. If skimming operations change, the NIOSH industrial hygienist recommends that additional monitoring be performed using integrated air sampling methods and direct reading measurements.

Skimming operations may require contract and USCG personnel to work extended work shifts in hot conditions that may lead to a heat-related illness. The NIOSH industrial hygienist recommends that personnel not involved in or taking a break from skimming operations continue the practice of cooling down under an awning or inside the cabin. All personnel should continue drinking plenty of fluids for hydration and taking frequent breaks to reduce the potential for a heat-related illness. NIOSH and OSHA have released an interim document providing guidance on protecting response workers and volunteers that among other topics includes information on heat stress and fatigue prevention. The document is available on the NIOSH website, <http://www.cdc.gov/niosh/topics/oilspillresponse/protecting/>.

Acknowledgments

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Table 1. Analytical methods used for substances evaluated during the June 14–16, 2010 Queen Bee evaluation

Analyte	Method
Benzene	NMAM* 1501†
Benzene soluble fraction	NMAM 5042
Carbon monoxide	Direct reading—GasAlert CO Extreme, BW Technologies Ltd., Calgary, Canada
Diesel exhaust (elemental carbon, organic carbon, total carbon)	NMAM 5040
Ethyl benzene	NMAM 1501†
Hydrogen sulfide	Direct reading—GasAlert H ₂ S Extreme, BW Technologies Ltd., Calgary, Canada
Limonene	NMAM 1501†
Naphthalene	NMAM 1501†
Propylene Glycol	NMAM 5523
Relative humidity	Direct reading—HOBO® H8 ProSeries, Onset Computer Corporation, Bourne, Massachusetts
Temperature	Direct reading—HOBO® H8 ProSeries, Onset Computer Corporation, Bourne, Massachusetts
Total Hydrocarbons	NMAM 1501†
Toluene	NMAM 1501†
Volatile organic compounds (Screening)	NMAM 2549
Xylene (Total)	NMAM 1501†

*National Institute for Occupational Safety and Health (NIOSH) Manual of Analytical Methods [NIOSH 2010]
†Analysis for selected volatile organic compounds by an adaptation of the method

Table 2. Occupational exposure limits for substances evaluated during the June 14–16, 2010 Queen Bee evaluation

Chemical	NIOSH REL^a	OSHA PEL^b	ACGIH TLV^c	AIHA WEEL^d
Benzene	0.1 ppm TWA ^e 1 ppm STEL ^f	1 ppm TWA 5 ppm STEL 0.5 ppm Action Level	0.5 ppm TWA 2.5 ppm STEL	N/A ^g
Benzene soluble fraction of total particulate	N/A	N/A	0.5 mg/m ³ TWA ^h	N/A
Carbon monoxide	35 ppm TWA 200 ppm Ceiling	50 ppm TWA [¶]	25 ppm TWA [¶]	N/A
Diesel exhaust (as elemental carbon) ⁱ	N/A	N/A	N/A	N/A
Ethyl benzene	100 ppm TWA (435 mg/m ³) 125 ppm STEL	100 ppm TWA	100 ppm TWA ^l 125 ppm STEL	N/A
Hydrogen sulfide	10 ppm Ceiling	20 ppm Ceiling ^k	1 ppm TWA 5 ppm STEL	N/A
Limonene	N/A	N/A	N/A	30 ppm
Naphthalene	10 ppm TWA (50 mg/m ³) 15 ppm STEL	10 ppm TWA	10 ppm TWA 15 ppm STEL	N/A
Propylene glycol	N/A	N/A	N/A	10 mg/m ³
Total Hydrocarbons	350 mg/m ³ TWA 1800 mg/m ³ Ceiling (Petroleum Distillates)	2000 mg/m ³ TWA (Petroleum Distillates)	200 mg/m ³ TWA (Kerosene as total hydrocarbon vapor)	N/A
Toluene	100 ppm TWA 150 ppm STEL	200 ppm TWA 300 ppm Ceiling 500 ppm Peak	20 ppm TWA	N/A
Xylene	100 ppm TWA 150 ppm STEL	100 ppm TWA	100 ppm TWA 150 ppm STEL	N/A

^aNational Institute for Occupational Safety and Health (NIOSH) recommended exposure limit (REL) [NIOSH 2005]

^bOccupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) [29 CFR 1910]

^cAmerican Conference of Governmental Industrial Hygienists® (ACGIH) threshold limit value® (TLV) [ACGIH 2010]

^dAmerican Industrial Hygiene Association (AIHA) Workplace Environmental Exposure Level (WEEL) [AIHA 2009]

^eTWA = time weighted average

^fSTEL = short term exposure limit

^gN/A = not applicable

^hThis OEL is for asphalt (bitumen) fume as benzene soluble aerosol but was considered appropriate because this sampling was intended to differentiate between petroleum associated particulate and background particulate.

ⁱCalifornia Department of Health Services' Hazard Evaluation System & Information Service (HESIS) guideline for diesel exhaust particles (measured as elemental carbon [EC]) is 20 µg/m³ for an 8-hour TWA [CDHS 2002]

^jProposed to be changed to 20 ppm TWA and STEL eliminated [ACGIH 2010]

^kExposures shall not exceed with the following exception: if no other measurable exposure occurs during the 8-hour work shift, exposures may exceed 20 ppm, but not more than 50 ppm (peak), for a single time period up to 10 minutes

Table 3. Environmental conditions during the June 14–16, 2010 Queen Bee evaluation

Vessel	Temperature (°F)*	Relative Humidity (%)*
June 14, 2010†		
Queen Bee (on crane – in the sun)	80–120; 103	16–66; 36
Queen Bee (on skimmer console – in the shade)	82–109; 99	26–56; 43
June 15, 2010†		
Queen Bee (on crane – in the sun)	73–110; 96	26–82; 48
Queen Bee (on skimmer console – in the shade)	72–121; 96	19–86; 50
June 16, 2010†		
Queen Bee (on crane – in the sun)	70–117; 95	18–73; 45
Queen Bee (on skimmer console – in the shade)	70–108; 91	33–71; 51

*Reported as range; average
†Hours of monitoring: approximately 7:00 AM – 8:00 PM

Table 4. Personal breathing zone and area air concentrations for substances measured on June 14, 2010 on the Queen Bee

Activity/Location	Substance	Sampling Information*		Sample Concentration†‡
		Time (min)	Volume (Liters)	
Area Air Samples				
On skimmer console	Benzene	423	86.0	<0.0007 ppm
On skimmer console	Benzene	424	85.4	<0.0007 ppm
On skimmer console	Benzene soluble fraction	420	827	<0.05 mg/m ³
On skimmer console	Carbon monoxide	377	N/A	Range: 0–8 ppm; Avg: 0 ppm
On skimmer console	Diesel exhaust	421	846	EC: 2.3 µg/m ³ ; OC: 59 µg/m ³
On skimmer console	Ethyl benzene	423	86.0	<0.0005 ppm
On skimmer console	Ethyl benzene	424	85.4	<0.0005 ppm
On skimmer console	Hydrogen sulfide	377	N/A	0 ppm
On skimmer console	Limonene	423	86.0	<0.0004 ppm
On skimmer console	Limonene	424	85.4	<0.0004 ppm
On skimmer console	Naphthalene	423	86.0	<0.0004 ppm
On skimmer console	Naphthalene	424	85.4	<0.0004 ppm
On skimmer console	Toluene	423	86.0	<0.0006 ppm
On skimmer console	Toluene	424	85.4	<0.0006 ppm
On skimmer console	Total hydrocarbons	423	86.0	0.44 mg/m ³
On skimmer console	Total hydrocarbons	424	85.4	0.45 mg/m ³
On skimmer console	Xylenes	423	86.0	<0.001 ppm
On skimmer console	Xylenes	424	85.4	(0.0021 ppm)

*N/A = not applicable

†Concentrations reported as “<” were not detected; the given value is the minimum detectable concentration

‡Concentrations in parentheses were between the minimum detectable concentration and the minimum quantifiable concentration (parentheses are used to point out there is more uncertainty associated with these values than values above the minimum quantifiable concentration)

Table 5. Personal breathing zone and area air concentrations for substances measured on June 15, 2010 on the Queen Bee

Activity/Location	Substance	Sampling Information*		Sample Concentration†‡
		Time (min)	Volume (Liters)	
Personal Breathing Zone Air Samples (Worker A)				
Skimmer Operator	Benzene	728	144	<0.001 ppm
Skimmer Operator - Removing Skimmer and Boom	Benzene	78	15.4	<0.004 ppm
Skimmer Operator	Benzene soluble fraction	718	1420	<0.1 mg/m ³
Skimmer Operator	Ethyl benzene	728	144	0.0039 ppm
Skimmer Operator - Removing Skimmer and Boom	Ethyl benzene	78	15.4	<0.003 ppm
Skimmer Operator	Hydrogen sulfide	792	N/A	0 ppm
Skimmer Operator	Limonene	728	144	0.014 ppm
Skimmer Operator - Removing Skimmer and Boom	Limonene	78	15.4	<0.002 ppm
Skimmer Operator	Naphthalene	728	144	(0.0018 ppm)
Skimmer Operator - Removing Skimmer and Boom	Naphthalene	78	15.4	<0.003 ppm
Skimmer Operator	Total hydrocarbons	728	144	1.7 mg/m ³
Skimmer Operator - Removing Skimmer and Boom	Total hydrocarbons	78	15.4	0.038 mg/m ³
Skimmer Operator	Toluene	728	144	(0.0012 ppm)
Skimmer Operator - Removing Skimmer and Boom	Toluene	78	15.4	<0.003 ppm
Skimmer Operator	Xylenes	728	144	0.023 ppm
Skimmer Operator - Removing Skimmer and Boom	Xylenes	78	15.4	<0.006 ppm
Personal Breathing Zone Air Samples (Worker B§)				
Skimmer Operator	Benzene	717	145	<0.0009 ppm
Skimmer Operator	Ethyl benzene	717	145	0.0021 ppm
Skimmer Operator	Limonene	717	145	0.020 ppm
Skimmer Operator	Naphthalene	717	145	(0.00083 ppm)
Skimmer Operator	Total hydrocarbons	717	145	1.8 mg/m ³
Skimmer Operator	Toluene	717	145	(0.0015) ppm
Skimmer Operator	Xylenes	717	145	0.014 ppm
Personal Breathing Zone Air Samples (Worker C§)				
Skimmer Operator	Benzene	727	146	<0.001 ppm
Skimmer Operator	Ethyl benzene	727	146	(0.0017 ppm)
Skimmer Operator	Limonene	727	146	0.0080 ppm
Skimmer Operator	Naphthalene	727	146	<0.0008 ppm
Skimmer Operator	Total hydrocarbons	727	146	1.9 mg/m ³
Skimmer Operator	Toluene	727	146	<0.001 ppm
Skimmer Operator	Xylenes	727	146	0.010 ppm

Table 5. Personal breathing zone and area air concentrations for substances measured on June 15, 2010 on the Queen Bee (continued)

Activity/Location	Substance	Sampling Information*		Sample Concentration†‡
		Time (min)	Volume (Liters)	
Personal Breathing Zone Air Samples (Worker D§)				
Skimmer Operator	Benzene	697	138	<0.001 ppm
Skimmer Operator	Ethyl benzene	697	138	0.0086 ppm
Skimmer Operator	Limonene	697	138	0.012 ppm
Skimmer Operator	Naphthalene	697	138	(0.0010 ppm)
Skimmer Operator	Total hydrocarbons	697	138	1.9 mg/m ³
Skimmer Operator	Toluene	697	138	(0.0016 ppm)
Skimmer Operator	Xylenes	697	138	0.046 ppm
Personal Breathing Zone Air Samples (Worker E)				
Skimmer Operator	Benzene soluble fraction	727	1440	<0.1 mg/m ³
Personal Breathing Zone Air Samples (Worker F§)				
Skimmer Operator	Benzene soluble fraction	712	1430	<0.1 mg/m ³
Area Air Samples				
On skimmer console	Benzene	761	148	<0.001 ppm
Opening tank hatch	Benzene	3	0.592	<0.1 ppm
Outside-entrance to galley	Benzene	664	133	<0.0009 ppm
Inside galley by phone	Benzene	479	94.6	<0.0007 ppm
On skimmer console	Benzene	534	107	<0.001 ppm
On skimmer console	Benzene soluble fraction	757	1480	(0.20 mg/m ³)
Outside-entrance to galley	Benzene soluble fraction	664	1320	<0.06 mg/m ³
Outside-entrance to galley	Carbon monoxide	670	N/A	Range: 0–3 ppm; Avg: 0 ppm
On skimmer console	Carbon monoxide	758	N/A	Range: 0–3 ppm; Avg: 0 ppm
On skimmer console	Diesel exhaust	757	1520	EC: (1.7 µg/m ³); OC: (18 µg/m ³)
Outside-entrance to galley	Diesel exhaust	664	1320	EC: 1.3 µg/m ³ ; OC: (18 µg/m ³)
On skimmer console	Ethyl benzene	761	148	<0.0009 ppm
Opening tank hatch	Ethyl benzene	3	0.592	<0.08 ppm
Outside-entrance to galley	Ethyl benzene	664	133	0.0024 ppm
Inside galley by phone	Ethyl benzene	479	94.6	0.0046 ppm
On skimmer console	Ethyl benzene	534	107	<0.0009 ppm
On skimmer console	Hydrogen sulfide	758	N/A	0 ppm
On skimmer console	Limonene	761	148	<0.0007 ppm
Opening tank hatch	Limonene	3	0.592	<0.06 ppm
Outside-entrance to galley	Limonene	664	133	0.0019 ppm
Inside galley by phone	Limonene	479	94.6	0.053 ppm
On skimmer console	Limonene	534	107	<0.0007 ppm
On skimmer console	Naphthalene	761	148	(0.0016 ppm)
Opening tank hatch	Naphthalene	3	0.592	<0.06 ppm
Inside galley by phone	Naphthalene	479	94.6	(0.0010 ppm)
Outside-entrance to galley	Naphthalene	664	133	(0.00087 ppm)

Table 5. Personal breathing zone and area air concentrations for substances measured on June 15, 2010 on the Queen Bee (continued)

Activity/Location	Substance	Sampling Information*		Sample Concentration†‡
		Time (min)	Volume (Liters)	
Area Air Samples (continued)				
On skimmer console	Naphthalene	534	107	<0.0007 ppm
On skimmer console	Propylene glycol	762	1510	<0.01 mg/m ³
On skimmer console	Total hydrocarbons	761	148	0.55 mg/m ³
Opening tank hatch	Total hydrocarbons	3	0.592	4.1 mg/m ³
Outside-entrance to galley	Total hydrocarbons	664	133	0.62 mg/m ³
Inside galley by phone	Total hydrocarbons	479	94.6	5.0 mg/m ³
On skimmer console	Total hydrocarbons	534	107	0.38 mg/m ³
On skimmer console	Toluene	761	148	<0.001 ppm
Opening tank hatch	Toluene	3	0.592	<0.09 ppm
Outside-entrance to galley	Toluene	664	133	<0.0008 ppm
Inside galley by phone	Toluene	479	94.6	0.0034 ppm
On skimmer console	Toluene	534	107	<0.001 ppm
On skimmer console	Xylenes	761	148	(0.0023 ppm)
Opening tank hatch	Xylenes	3	0.592	<0.2 ppm
Outside-entrance to galley	Xylenes	664	133	0.014 ppm
Inside galley by phone	Xylenes	479	94.6	0.029 ppm
On skimmer console	Xylenes	534	107	(0.0023 ppm)

*N/A = not applicable

†Concentrations reported as "<" were not detected; the given value is the minimum detectable concentration

‡Concentrations in parentheses were between the minimum detectable concentration and the minimum quantifiable concentration (parentheses are used to point out there is more uncertainty associated with these values than values above the minimum quantifiable concentration)

§Worker smoked

Table 6. Personal breathing zone and area air concentrations for substances measured on June 16, 2010 on the Queen Bee

Activity/Location	Substance	Sampling Information*		Sample Concentration†‡
		Time (min)	Volume (Liters)	
Personal Breathing Zone Air Samples (Worker A)				
Skimmer Operator	Benzene	420	82.3	<0.002 ppm
Skimmer Operator	Benzene	408	81.9	<0.002 ppm
Skimmer Operator	Ethyl benzene	420	82.3	0.0046 ppm
Skimmer Operator	Ethyl benzene	408	81.9	0.0040 ppm
Skimmer Operator	Limonene	420	82.3	0.0087 ppm
Skimmer Operator	Limonene	408	81.9	0.0037 ppm
Skimmer Operator	Naphthalene	420	82.3	(0.0015 ppm)
Skimmer Operator	Naphthalene	408	81.9	<0.0009 ppm
Skimmer Operator	Total hydrocarbons	420	82.3	1.5 mg/m ³
Skimmer Operator	Total hydrocarbons	408	81.9	1.2 mg/m ³
Skimmer Operator	Toluene	420	82.3	<0.001 ppm
Skimmer Operator	Toluene	408	81.9	<0.001 ppm
Skimmer Operator	Xylenes	420	82.3	0.026 ppm
Skimmer Operator	Xylenes	408	81.9	0.022 ppm
Personal Breathing Zone Air Samples (Worker B§)				
Skimmer Operator	Benzene	464	93.6	<0.001 ppm
Skimmer Operator	Ethyl benzene	464	93.6	0.0039 ppm
Skimmer Operator	Limonene	464	93.6	0.016 ppm
Skimmer Operator	Naphthalene	464	93.6	<0.0008 ppm
Skimmer Operator	Total hydrocarbons	464	93.6	2.2 mg/m ³
Skimmer Operator	Toluene	464	93.6	(0.0013 ppm)
Skimmer Operator	Xylenes	464	93.6	0.025 ppm
Personal Breathing Zone Air Samples (Worker C§)				
Skimmer Operator	Benzene soluble fraction	463	920	<0.2 mg/m ³
Personal Breathing Zone Air Samples (Worker D§)				
Skimmer Operator	Benzene	468	91.9	<0.001 ppm
Skimmer Operator	Ethyl benzene	468	91.9	0.0052 ppm
Skimmer Operator	Limonene	468	91.9	0.044 ppm
Skimmer Operator	Naphthalene	468	91.9	(0.0021 ppm)
Skimmer Operator	Total hydrocarbons	468	91.9	2.6 mg/m ³
Skimmer Operator	Toluene	468	91.9	(0.0015 ppm)
Skimmer Operator	Xylenes	468	91.9	0.031 ppm
Personal Breathing Zone Air Samples (Worker E)				
Skimmer Operator	Benzene	462	91.0	<0.001 ppm
Skimmer Operator	Ethyl benzene	462	91.0	0.0038 ppm
Skimmer Operator	Limonene	462	91.0	0.018 ppm
Skimmer Operator	Naphthalene	462	91.0	(0.0020 ppm)
Skimmer Operator	Total hydrocarbons	462	91.0	2.3 mg/m ³
Skimmer Operator	Toluene	462	91.0	(0.0015 ppm)
Skimmer Operator	Xylenes	462	91.0	0.025 ppm
Personal Breathing Zone Air Samples (Worker F§)				
Skimmer Operator	Benzene soluble fraction	464	917	<0.2 mg/m ³

Table 6. Personal breathing zone and area air concentrations for substances measured on June 16, 2010 on the Queen Bee (continued)

Activity/Location	Substance	Sampling Information*		Sample Concentration†‡
		Time (min)	Volume (Liters)	
Area Air Samples				
On skimmer console	Benzene	390	77.8	<0.002 ppm
Outside-entrance to galley	Benzene	399	77.8	<0.0008 ppm
On skimmer console	Benzene	389	75.2	<0.002 ppm
On skimmer console	Benzene soluble fraction	389	758	<0.1 mg/m ³
Outside-entrance to galley	Benzene soluble fraction	397	794	<0.1 mg/m ³
Outside-entrance to galley	Carbon monoxide	399	N/A	0 ppm
On skimmer console	Carbon monoxide	373	N/A	0 ppm
On skimmer console	Diesel exhaust	390	779	EC: (0.87 µg/m ³); OC: (17 µg/m ³)
Outside-entrance to galley	Diesel exhaust	397	798	EC: (1.5 µg/m ³); OC: (21 µg/m ³)
On skimmer console	Ethyl benzene	390	77.8	(0.0015 ppm)
Outside-entrance to galley	Ethyl benzene	399	77.8	0.0059 ppm
On skimmer console	Ethyl benzene	389	75.2	(0.0015 ppm)
On skimmer console	Hydrogen sulfide	373	N/A	0 ppm
On skimmer console	Limonene	390	77.8	<0.0009 ppm
Outside-entrance to galley	Limonene	399	77.8	<0.0005 ppm
On skimmer console	Limonene	389	75.2	<0.001 ppm
On skimmer console	Naphthalene	390	77.8	(0.0017 ppm)
Outside-entrance to galley	Naphthalene	399	77.8	<0.0005 ppm
On skimmer console	Naphthalene	389	75.2	(0.0010 ppm)
On skimmer console	Propylene glycol	386	762	<0.02 mg/m ³
On skimmer console	Total hydrocarbons	390	77.8	0.73 mg/m ³
Outside-entrance to galley	Total hydrocarbons	399	77.8	0.64 mg/m ³
On skimmer console	Total hydrocarbons	389	75.2	0.72 mg/m ³
On skimmer console	Toluene	390	77.8	<0.001 ppm
Outside-entrance to galley	Toluene	399	77.8	<0.0007 ppm
On skimmer console	Toluene	389	75.2	<0.001 ppm
On skimmer console	Xylenes	390	77.8	(0.0041 ppm)
Outside-entrance to galley	Xylenes	399	77.8	(0.036 ppm)
On skimmer console	Xylenes	389	75.2	(0.0038 ppm)

*N/A = not applicable

†Concentrations reported as "<" were not detected; the given value is the minimum detectable concentration

‡Concentrations in parentheses were between the minimum detectable concentration and the minimum quantifiable concentration (parentheses are used to point out there is more uncertainty associated with these values than values above the minimum quantifiable concentration)

§Worker smoked

Interim Report #3B

Evaluation of June 21-22, 2010, Dispersant Releases from the M/V International Peace

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Introduction

A NIOSH industrial hygienist conducted industrial hygiene assessments and administered health symptom surveys during small-area dispersant releases involving the motor vessel International Peace (IP) on June 21–22, 2010 (see Figure 1). As a utility vessel, the IP transferred personnel and equipment to oil rigs and platforms prior to the April 20, 2010, Deepwater Horizon explosion and collapse. As part of the response to the resultant oil spill, the IP was chartered by Oil Spill Response, Ltd., [OSR, Ltd., London, UK]. Wholly owned by a number of oil and energy industry companies, OSR provides oil spill response and preparedness services to its shareholders and members. OSR deployed Special Monitoring of Applied Response Technologies (SMART) Team personnel to the IP specifically to conduct monitoring of the effectiveness of dispersant applied to the spilled oil in the Gulf of Mexico.

As part of these monitoring efforts, the IP was outfitted with six dispersant-holding tanks (each with an approximate volume of 1 cubic meter [m³]) on its deck and two dispersant spray arms, each of which extended from either side of the IP (see Figure 2). Each spray arm had three tubes descending from the main arm through which dispersant was pumped from one of the tanks. The tubes extended to within several feet of the surface of the water and allowed dispersant to be applied as a mist. At the time of the June 21–22, 2010, NIOSH evaluation, the dispersant being used and evaluated by the SMART Team was Corexit® EC9500A (Nalco, Naperville, Illinois). The tanks on the IP had previously held Corexit® EC9527A, a dispersant that was discontinued in early May.



Figure 1. M/V International Peace



Figure 2. Dispersant spray arm

The effectiveness of Corexit® EC9500A in dispersing the spilled oil was evaluated by the SMART Team following a protocol in which both pre- and post-dispersant application water sampling was conducted by fluorometry and the collection of bulk water samples. A direct-reading fluorometer was lowered from the side of the vessel into the water to provide real-time measurements regarding dispersed oil concentrations. The bulk water samples were collected at both 1 meter and 10 meters below the water surface. These samples were held for toxicity, oil content, and chemistry analyses to be conducted by an on-shore laboratory.

During this evaluation, two OSR team members conducted the fluorometry sampling while two team members from BP contractors (i.e., Exponent and Battelle) collected bulk water samples with the hands-on assistance of a U.S. Environmental Protection Agency (EPA) on-scene coordinator. The protocol that was followed during dispersant release and sample collection began with on-board personnel directing the vessel to a pre-identified location in the Gulf to look for areas of fresh oil suitable for dispersal. Aerial spotters were also called in to assist in identifying the most suitable oil to spray. Once oil was identified, the team members conducted fluorometry and collected bulk samples of clean water near the oil spill area. The vessel was then directed to the edge of the oil slick and additional water samples were collected prior to dispersant application. Preparations for dispersant release followed. According to protocol, only the two OSR team members who were directly involved in dispersant spraying were allowed on deck during the spray operation. During spraying, these personnel wore Microgard® 2500 Plus coveralls, chemical resistant gloves, and either a 3M™ 4277 half-mask respirator with combined organic vapor/acid gas/P100 particulate cartridges and goggles, or a 3M™ 6001 full-facepiece respirator. After donning this personal protective equipment (PPE), the two OSR team members worked on the deck of the IP, connecting tubing from a dispersant tank to the dispersant spray arms. Approximately 50 gallons of the Corexit EC9500A was pumped through the spray arms over a period of 5–10 minutes, misting the surface oil. The length of time during which these personnel conducted the spray operations and remained in the PPE was approximately 30 minutes. After completing the spray operations, the OSR team members doffed their PPE and returned to the air-conditioned cabin to rest and rehydrate. The coveralls and gloves were discarded after use. The vessel was then directed outside of the area where dispersant was released to allow wave action to mix the dispersant, oil, and water. After a period of time, the vessel was redirected back into the area of dispersant release to conduct a final round of fluorometry and bulk water sampling. The activities typically lasted several hours and only one dispersant application was allowed to be conducted on any given day. This operation was repeated on both days of the NIOSH evaluation.

Evaluation

The NIOSH industrial hygienist conducted personal breathing zone (PBZ) and area air sampling on the IP on June 21 and 22, 2010. Longer-term PBZ air samples started during oil locating activities and continued through the collection of the last water sample, a period of approximately 5–6 hours. Longer-term area air samples were also collected inside the vessel's cabin on June 21, 2010. Shorter-term area air samples were collected using Summa canisters during specific tasks on June 21 and 22, 2010. In general, the shorter-term air samples were intended to represent airborne concentrations during specific work tasks and the longer-term samples more closely represented full-shift occupational exposures.

Volatile organic compounds (VOCs) and propylene glycol were sampled for in this evaluation because of their presence in the dispersant as described in the product's material safety data sheet (MSDS). To

evaluate the presence of VOCs, the NIOSH industrial hygienist used integrated air sampling with a variety of sampling media, including multi-sorbent thermal desorption tubes followed by thermal desorption/gas chromatography-mass spectrometry (NIOSH Method 2549); Summa canisters analyzed for selected contaminants by gas chromatography-mass spectrometry (EPA Method TO-15); and activated charcoal tubes [EPA 1999; NIOSH 2010]. Results of the thermal desorption tubes and Summa canister area air samples were used to select specific VOCs for quantitation on PBZ and area air samples collected using charcoal tubes. Propylene glycol was also measured in PBZ and area air samples using integrated air sampling techniques. At the end of each of the two days of sampling, the NIOSH industrial hygienist performed post-calibration of sampling pumps. See Table 1 for a complete listing of sampling and analytical methods used during the NIOSH evaluation.

In addition to conducting integrated air sampling for the collection of PBZ and area air samples, a number of bulk samples were collected on June 21, 2010. These included a Corexit® EC9500A dispersant sample collected from the tank of dispersant used during spraying operations, samples of the water from 1 meter depth prior to dispersant application, samples of the surface oil to be dispersed, and samples of the oil/water/dispersant mix after dispersant had been applied. Samples were collected in 60 milliliter (mL) amber glass wide-mouth bottles. All bulk and industrial hygiene samples (with the exception of Summa canisters) were maintained cold by the NIOSH industrial hygienist until and during shipment to the lab for analysis.

Initial analysis of the dispersant bulk sample from the IP was conducted using gas chromatography/mass spectroscopy (GC/MS) to aid in determining if components identified in air samples could be present as a result of their presence in the dispersant. Independent of this particular dispersant bulk sample, two bulk samples of Corexit® EC9500A dispersant were also supplied directly to NIOSH by BP contractor Exponent for similar analysis. These two samples supplied to NIOSH had been dispensed on June 19, 2010 into 40 mL glass vials from a tote in the field and reportedly originated with Clean Islands Cooperative stock [Seitz 2010].

The NIOSH industrial hygienist also distributed health surveys at the time of exposure monitoring to the five SMART team members involved in spraying or water sample collection activities. The workers were asked to report any symptoms they had experienced while working during oil spill response activities.

Results and Discussion

Table 2 contains a summary of the relevant occupational exposure limits (OELs) for this evaluation. Table 3 presents temperature and relative humidity (RH) measurements made during the two days of the evaluation on the IP. The temperature on the deck ranged from 74°F–99°F and RH ranged from 37%–78%. The temperature in the vessel cabin ranged from 71°F–75°F and RH ranged from 41%–61%.

Volatile Organic Compounds

On June 21, 2010, two thermal desorption tube PBZ air samples on Workers D (involved in dispersant spraying operations) and E (involved in water sampling operations) and one area air sample were collected to screen for VOCs. On June 22, 2010, a thermal desorption tube PBZ air sample was collected during each of two back-to-back time periods during the day on Worker C (involved in water sampling operations). On both days, various C₆ to C₁₈ hydrocarbons (straight and branched alkanes) were found; some samples also contained naphthalene, alcohols (i.e., ethanol), limonene, 2-butoxyethanol, dipropylene glycol butyl ether isomers, and other substances.

On June 21, 2010, one shorter-term (1 hour) area air sample was collected using a Summa canister during water sampling activities after dispersant spraying. On June 22, 2010, one shorter-term (2 hour) area air sample was collected using a Summa canister during dispersant spraying and subsequent water sampling activities. Both air samples were compared to work-shift OELs and short-term exposure limits (STELs). Individual VOC concentrations were well below applicable OELs. Acrolein was measured in the highest concentration relative to both the work-shift OELs and STELs. However, the maximum concentration of acrolein was <4% of the NIOSH recommended exposure limit (REL) and the American Conference of Governmental Industrial Hygienists' (ACGIH) threshold limit value (TLV) STEL (0.25 mg/m³). Even on an additive basis, for any given exposure period, the mixtures of VOCs measured in the air were a fraction (<4%) of the acceptable levels.

During the 2 days of the NIOSH evaluation, longer-term PBZ air samples were collected on the five team members involved in the dispersant release and water sampling activities to quantify exposure to VOCs. These samples were collected using two charcoal tubes side-by-side on each worker sampled. One charcoal tube was used to quantify certain VOCs (e.g., benzene, toluene, and xylenes) identified using thermal desorption tubes and Summa canisters; the second charcoal tube was used to quantify airborne levels of other VOCs (i.e., 2-butoxyethanol, dipropylene glycol butyl ether, and dipropylene glycol methyl ether) that required a different analytic method than that used on the first charcoal tube.

On June 21, 2010, one pair of charcoal tubes was used to collect a longer-term PBZ air sample on Worker A, one of the two team members directly involved in dispersant spraying operations. A pair of charcoal tube samples was also collected on each of the two team members (Workers B and C) involved in water sample collection before and after dispersant spray activities. A longer-term area air sample was also collected using a pair of charcoal tubes in the cabin of the vessel. On June 22, 2010, pairs of charcoal tubes were used to collect longer-term PBZ samples on Workers A and D, the two team members directly involved in spraying operations. Pairs of charcoal tubes were also used to collect longer-term PBZ samples on Workers B and E, two team members involved in water sample collection.

Based on the results of the Summa canisters and thermal tube screening samples, the first charcoal tube of each PBZ and area air sample pair were quantitated for benzene, ethanol, ethyl benzene, limonene, naphthalene, toluene, total hydrocarbons (THC) (as hexane), and xylenes. Results are shown in Tables 4–5. In the PBZ air samples collected on June 21, 2010, limonene, THC, and xylenes were the only compounds present on this set of charcoal tubes above the minimum quantifiable concentrations (MQC). In addition to these three compounds, toluene and ethanol were also found in concentrations above the MQC in the area air sample collected inside the cabin. Ethanol was present in the highest concentration at 5.7 parts per million (ppm). Ethanol and limonene are ingredients in cleaning agents, which might explain their presence in the air samples. While both indoor and outdoor concentrations of these VOCs were low, all the indoor concentrations were higher than those found from samples collected on individuals working outside. On June 22, 2010, similarly low concentrations of limonene, THC, toluene, and xylenes were measured in the PBZ air samples.

All air concentrations of these compounds were well below the relevant individual OELs. Even on an additive basis, for any given exposure period, the mixtures of chemicals measured in the air were a fraction (<10%) of the acceptable levels. Total hydrocarbon concentrations ranged from 0.94 milligrams per cubic meter (mg/m³), collected on Worker A, who conducted spray operations, to 8.4 mg/m³, collected inside the vessel cabin. Although there is no OEL specifically for THCs, OELs for petroleum

distillates and kerosene (two mixtures containing a similar range of hydrocarbons as was found on the thermal tube air samples) are 350 mg/m³ as a work-shift time weighted average as shown in Table 2.

As described previously, the second charcoal tube from each air sample pair was analyzed for 2-butoxyethanol, dipropylene glycol butyl ether, and dipropylene glycol methyl ether. Results are shown in Tables 4–5. For 2-butoxyethanol, three PBZ and one area air samples were collected on June 21, 2010. The PBZ samples were collected on Worker A, who was involved in dispersant spraying operations, and Workers B and C, who collected the bulk water samples before and after spraying. The area sample was collected inside the vessel cabin. Of these, the only sample result above the MQC for 2-butoxyethanol was the PBZ air sample collected on the worker conducting dispersant spraying (Worker A) at a concentration of 0.0031 ppm, well below the most protective OEL of 5 ppm. On June 22, 2010, four PBZ air samples were collected for 2-butoxyethanol. These were collected on Workers A and D while conducting spraying operations and on workers B and C while conducting water sampling before and after spraying. Only Worker A (0.0049 ppm) and Worker D (0.0033 ppm) had results that were above the MQC for 2-butoxyethanol. These results were well below the most protective OEL of 5 ppm.

On June 21, 2010, dipropylene glycol butyl ether was measured above the MQC on all three PBZ samples but not on the indoor area air sample. The highest dipropylene glycol butyl ether concentration (0.027 ppm) was collected on a worker involved in the dispersant spraying operations (Worker A). Of these three samples, the two with the highest concentrations had breakthrough indicating 6% of the mass of dipropylene glycol butyl ether was present on the back sections of the respective samples' tube. A breakthrough of greater than 10% would suggest the reported concentration may be underestimated. On June 22, 2010, dipropylene glycol butyl ether was measured above the MQC on three of four PBZ air samples. The two highest concentrations were found on the samples collected on the two workers involved in dispersant spraying operations (Workers A and D), at 0.063 and 0.046 ppm, respectively. As with the previous day, two samples had breakthrough indicating 2%–3% of the mass of dipropylene glycol butyl ether was present on the back section of the tube. For both June 21 and 22, 2010, dipropylene glycol methyl ether was not present on any of the air samples.

Propylene Glycol

Propylene glycol, a component of the dispersant, was detected in low concentrations above the MQC on the three PBZ and one area air samples collected on the IP on June 21, 2010, as shown in Table 4. The samples collected on the two workers involved in dispersant spray operations (Workers A and D) returned the highest results of 0.047 and 0.11 mg/m³, respectively, all well below the OEL of 10 mg/m³. The PBZ sample on a worker involved in water sampling activities (Worker B) and the area air sample inside the cabin both returned results of 0.017 mg/m³. As shown in Table 5, propylene glycol was detected in low concentrations above the MQC on three of four PBZ air samples collected on June 22, 2010. As with the previous day, the samples collected on the workers involved in dispersant spraying operations (Workers A and D) returned the highest results of 0.078 and 0.076 mg/m³, with the sample collected on a worker involved in water sampling activities (Worker C) returning a result of 0.011 mg/m³.

On June 4–5, 2010, NIOSH evaluated propylene glycol exposures during dispersant releases on board the IP and the Warrior as described in NIOSH Health Hazard Evaluation 2010-0115 Interim Report #1B [NIOSH 2010a]. The sampling method for propylene glycol used in that evaluation included a single XAD-7 tube per sample as described in the NIOSH Manual of Analytical Methods (NMAM), Method 5523 [NIOSH 2010b]. However, several of these samples contained more than 10% of the mass of propylene glycol on the back section of the XAD-7 sorbent tube, indicating significant breakthrough and, therefore,

potential underestimation of the true exposure concentration. It was speculated that this breakthrough may be a result of the high relative humidity in the environment, as this is a potential problem with this type of sampling media. Because of the breakthrough seen on those samples, propylene glycol sampling on the June 21–22, 2010, evaluation included two XAD-7 sorbent tubes in series per sample so that the second tube could capture any propylene glycol that broke through the media in the first tube. The PBZ samples collected on both June 21 and 22, 2010, from Workers A and D showed breakthrough of greater than 10% of the mass of propylene glycol on the back section of the first XAD-7 tube per sample. Despite finding breakthroughs of greater than 10% on the back section of the first tube of these samples, only trace amounts of the compound were found on the second tubes for all samples analyzed suggesting little of the compound actually passed through the media of the first tube entirely. The results reported are the combination of the first and second tubes for each sample.

Bulk Samples

Initial analyses of the three dispersant bulk samples identified the following compounds: dipropylene glycol butyl ether [also known as 1-(2-butoxy-1-methylethoxy)-2-propanol], various aliphatic hydrocarbons (mostly branched C₁₀–C₁₂ alkanes), acid esters, propylene glycol, and ethyl hexanol. Traces of 2-butoxyethanol and dipropylene glycol were also detected in the three samples. While the analyses of the three samples showed similar chemical constituents, 2-butoxyethanol was detected at a higher concentration (as evidenced by a greater peak area in the GC/MS chromatogram) in the sample collected from the IP as compared to the other two bulk samples provided by the BP contractor.

The Corexit® EC9500A material safety data sheet (MSDS) does not list 2-butoxyethanol as a component of the 9500 dispersant [Nalco 2008a]. It is possible that the compound is present as a contaminant in one of the reagents used in the formulation of the dispersant. It is also possible that the higher presence of 2-butoxyethanol in the sample collected on the IP may be a result of contamination from the re-use of dispersant-holding tanks that previously held Corexit® EC9527A (which was published as containing 30%–60% 2-butoxyethanol) [Nalco 2008b]. The tanks on the IP had originally been identified with labeling for the 9527 dispersant. The original labeling on these tanks identifying the contents as Corexit® EC9527A had been marked or covered over when the change to the 9500 dispersant was made (see Figure 3). However, new labeling specifically for the Corexit® EC9500A dispersant had not been applied to the tanks at that time. Additionally, labels of '2-butoxyethanol' (a dispersant component identified on the MSDS of the Corexit® EC9527A but not for the 9500A) had not been removed from the tanks (see Figure 4). It is not known whether the tote from which the BP contractor collected their samples had previously contained other products such as Corexit® EC9527A.



Figure 3. Labeling on dispersant-holding tank



Figure 4. Dispersant-holding tanks on the deck of the International Peace

Health Symptom Surveys

Five personnel on the IP completed the symptom survey during this evaluation (see Table 6). Reported symptoms, grouped by type, are presented in Table 7. This table also includes symptoms for a comparison group of workers recruited at the Venice Field Operations Branch and the Venice Commanders' Camp, who reported that they had not worked on boats and had no exposures to oil, dispersant, cleaner, or other chemicals.

The symptoms reported by the five workers during this dispersant mission included exhaustion, itchy eyes, musculoskeletal complaints, and feeling pressured. One worker reported feeling worried or stressed.

Summary

During this evaluation on the IP, workers who completed the health survey were asked to report symptoms experienced over the course of their response activities. Two workers reported having itching eyes (the only irritative symptom mentioned) which could be related to non-specific eye irritation, to sweat, sunscreen, other lotions or insect repellants, or to exposure to the dispersant or salt water contaminated with the dispersant/oil mix. The other symptoms (exhaustion and musculoskeletal pain) were likely related to a combination of factors, including heat and humidity, sun exposure, bending and extreme postures, and long working hours. Three workers reported experiencing “work pressure,” which speaks to both the demands that these workers are under, and other contributing factors, both occupational and non-occupational.

The NIOSH industrial hygiene evaluation found that PBZ and area air concentrations of the compounds measured were all well below OELs. Higher concentrations of propylene glycol, dipropylene glycol butyl ether, and 2-butoxyethanol were measured in the PBZ of the two workers involved in dispersant spraying operations as compared to the three workers only involved in water sampling or to the air of the indoor cabin. This suggests that exposures to these compounds may be a result of dispersant spraying operations and is consistent with the facts that these compounds were identified as present in the dispersant bulk sample collected and there were no other known sources of this exposure during this evaluation. In contrast, the highest concentrations for other VOCs quantitated such as ethanol, limonene, toluene, xylene, and total hydrocarbons were recorded from area air samples taken inside the vessel cabin. The presence of these substances may be a result of contaminants found in building materials, furnishings, and cleaning products, as similar substances often are found at low levels in the air of indoor environments.

Recommendations

The use of the specific PPE described was OSR policy for their employees and has been used in their operations in this type of dispersant release at oil spills around the world. The NIOSH industrial hygienist did not find an exposure approaching an OEL for this activity on the days sampling was conducted. However, the potential that the results of this evaluation may not reflect conditions on a continual basis is recognized. Because of the potential for inhalation and dermal contact with the dispersant, NIOSH recommends that protective steps observed during this evaluation be continued. This includes keeping non-essential personnel inside the cabin during dispersant spray operations and using respiratory protection, eye protection, coveralls, and gloves for those on the deck during dispersant spraying. Personnel conducting fluorometry and water sampling and preparing for dispersion should continue to wear cloth coveralls, eye protection, and nitrile gloves when handling items or samples potentially contaminated with oil or dispersant. If dispersant usage patterns change, NIOSH investigators recommend that additional monitoring be performed using integrated air sampling methods.

The NIOSH industrial hygienist observed heat stress as a significant issue for workers in this environment, particularly those wearing PPE. Work practices that were observed showed that employees recognized the potential hazard and took the appropriate steps needed, such as a rest/cooling period and hydration after wearing PPE. It is recommended that new employees tasked to conduct spraying operations in PPE continue to be trained in the recognition of the heat stress hazard, potential symptoms associated with heat stress, and the importance of hydration. NIOSH and OSHA

have released an interim document providing guidance on protecting response workers and volunteers that, among other topics, includes information on heat stress and fatigue prevention. The document is available on the NIOSH website, <http://www.cdc.gov/niosh/topics/oilspillresponse/protecting/>.

Further evaluation is needed regarding the identification of trace quantities of 2-butoxyethanol in the bulk dispersant samples. NIOSH has contacted the manufacturer to obtain additional information and may conduct additional testing on a neat sample obtained directly from the manufacturer. To prevent cross-contamination, it is recommended that new totes be used if a chemical product such as the dispersant is changed rather than refilling totes previously used. If totes or tanks such as those on the deck of the IP are reused, it is recommended that they be cleaned before they are used with a new product and new identifying labels be added. Labels associated with the previous chemical should be removed to ensure proper identification of the tanks' current contents.

With regard to propylene glycol monitoring, NIOSH recommends that future monitoring in this environment using XAD-7 media include the collection of two sorbent tubes in series until further work can be done to identify the cause of breakthrough in these samples.

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Table 1. Analytical methods used for substances evaluated during June 21–22, 2010 on the International Peace

Analyte	Method
Benzene	NMAM 1501*†
2-Butoxyethanol	NMAM1403†
Dipropylene glycol butyl ether	NMAM1403†
Dipropylene glycol methyl ether	NMAM1403†
Ethanol	NMAM 1501†
Ethyl benzene	NMAM 1501†
Limonene	NMAM 1501†
Naphthalene	NMAM 1501†
Propylene glycol	NMAM 5523‡
Relative humidity	Direct reading—HOBO® H8 ProSeries, Onset Computer Corporation, Bourne, Massachusetts
Temperature	Direct reading—HOBO® H8 ProSeries, Onset Computer Corporation, Bourne, Massachusetts
Toluene	NMAM 1501†
Total Hydrocarbons	NMAM 1501†
Volatile organic compounds (Screening)	NMAM 2549 and EPA TO-15§
Xylene (Total)	NMAM 1501†

*National Institute for Occupational Safety and Health (NIOSH) Manual of Analytical Methods [NIOSH 2010b]

†Analysis by an adaptation of the method

‡Method was modified to include two XAD-7 sorbent tubes in series

§Environmental Protection Agency [EPA 1999]

Table 2. Table 2. Occupational exposure limits for substances evaluated during June 21-22, 2010 on the International Peace

Chemical	NIOSH REL*	OSHA PEL†	ACGIH TLV‡	AIHA WEEL§
Benzene	0.1 ppm TWA¶ 1 ppm STEL**	1 ppm TWA 5 ppm STEL 0.5 ppm Action Level	0.5 ppm TWA 2.5 ppm STEL	N/A††
2-Butoxyethanol	5 ppm TWA	50 ppm TWA	20 ppm TWA	N/A
Dipropylene glycol butyl ether	N/A	N/A	N/A	N/A
Dipropylene glycol methyl ether	100 ppm TWA 150 ppm STEL	100 ppm TWA	100 ppm TWA 150 ppm STEL	N/A
Ethanol	1000 ppm TWA	1000 ppm TWA	1000 ppm STEL	N/A
Ethyl benzene	100 ppm TWA 125 ppm STEL	100 ppm TWA	100 ppm TWA ^{‡‡} 125 ppm STEL	N/A
Limonene	N/A	N/A	N/A	30 ppm
Naphthalene	10 ppm TWA 15 ppm STEL	10 ppm TWA	10 ppm TWA 15 ppm STEL	N/A
Propylene glycol	N/A	N/A	N/A	10 mg/m ³
Total hydrocarbons	350 mg/m ³ TWA 1800 mg/m ³ Ceiling (Petroleum distillates)	2000 mg/m ³ TWA (Petroleum distillates as naphtha)	200 mg/m ³ TWA (Kerosene as total hydrocarbon vapor)	N/A
Toluene	100 ppm TWA 150 ppm STEL	200 ppm TWA 300 ppm Ceiling 500 ppm Peak	20 ppm TWA	N/A
Xylene	100 ppm TWA 150 ppm STEL	100 ppm TWA	100 ppm TWA 150 ppm STEL	N/A

*National Institute for Occupational Safety and Health (NIOSH) recommended exposure limit (REL) [NIOSH 2005]

†Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) [29 CFR 1910]

‡American Conference of Governmental Industrial Hygienists® (ACGIH) threshold limit value® (TLV) [ACGIH 2010]

§American Industrial Hygiene Association (AIHA) Workplace Environmental Exposure Level (WEEL) [AIHA 2009]

¶TWA = time weighted average

**STEL = short term exposure limit

††N/A = not applicable

‡‡Proposed to be changed to 20 ppm TWA and STEL eliminated [ACGIH 2010]

Table 3. Environmental conditions on June 21–22, 2010 on the International Peace

Vessel	Temperature (°F)*	Relative Humidity (%)*
June 21, 2010†		
Cabin	71–75; 73	41–56; 47
Deck	74–94; 90	44–78; 60
June 22, 2010‡		
Cabin	73–75; 74	42–61; 47
Deck	85–99; 93	37–78; 53

*Reported as range; average

†Hours of monitoring approximately 8:00 AM–7:00 PM

‡Hours of monitoring approximately 9:30 AM–3:00 PM

Table 4. Personal breathing zone and area air concentrations for substances measured on June 21, 2010 on the International Peace

Activity/Location	Substance	Sampling Information		Sample Concentration*†
		Time (min)	Volume (Liters)	
Personal Breathing Zone Air Samples—Worker A				
Conducted fluorometry and applied dispersant	Benzene	291	57.5	<0.001 ppm
Conducted fluorometry and applied dispersant	2-Butoxyethanol	290	57.6	0.0031 ppm
Conducted fluorometry and applied dispersant	Dipropylene glycol butyl ether	290	57.6	0.027 ppm‡
Conducted fluorometry and applied dispersant	Dipropylene glycol methyl ether	290	57.6	<0.0006 ppm
Conducted fluorometry and applied dispersant	Ethanol	291	57.5	(0.34 ppm)
Conducted fluorometry and applied dispersant	Ethyl benzene	291	57.5	(0.0012 ppm)
Conducted fluorometry and applied dispersant	Limonene	291	57.5	0.0075 ppm
Conducted fluorometry and applied dispersant	Naphthalene	291	57.5	<0.0007 ppm
Conducted fluorometry and applied dispersant	Propylene glycol	290	57.8	0.047 mg/m ³ §
Conducted fluorometry and applied dispersant	Toluene	291	57.5	(0.0014 ppm)
Conducted fluorometry and applied dispersant	Total hydrocarbons	291	57.5	1.2 mg/m ³
Conducted fluorometry and applied dispersant	Xylenes	291	57.5	0.0056 ppm
Personal Breathing Zone Air Samples—Worker B				
On Scene Coordinator, assisted with sampling	Benzene	85¶	16.8	<0.004 ppm
On Scene Coordinator, assisted with sampling	2-Butoxyethanol	343	68.6	(0.0015 ppm)
On Scene Coordinator, assisted with sampling	Dipropylene glycol butyl ether	343	68.6	0.015 ppm‡
On Scene Coordinator, assisted with sampling	Dipropylene glycol methyl ether	343	68.6	<0.0005 ppm
On Scene Coordinator, assisted with sampling	Ethanol	85¶	16.8	(0.91 ppm)
On Scene Coordinator, assisted with sampling	Ethyl benzene	85¶	16.8	<0.003 ppm
On Scene Coordinator, assisted with sampling	Limonene	85¶	16.8	(0.0060 ppm)
On Scene Coordinator, assisted with sampling	Naphthalene	85¶	16.8	<0.002 ppm

Table 4. Personal breathing zone and area air concentrations for substances measured on June 21, 2010 on the International Peace (continued)

Activity/Location	Substance	Sampling Information		Sample Concentration*†
		Time (min)	Volume (Liters)	
Personal Breathing Zone Air Samples—Worker B (continued)				
On Scene Coordinator, assisted with sampling	Propylene glycol	340	665	0.017 mg/m ³
On Scene Coordinator, assisted with sampling	Toluene	85¶	16.8	<0.003 ppm
On Scene Coordinator, assisted with sampling	Total hydrocarbons	85¶	16.8	1.3 mg/m ³
On Scene Coordinator, assisted with sampling	Xylenes	85¶	16.8	<0.006 ppm
Personal Breathing Zone Air Samples—Worker C				
Contractor, collected 10 meter water samples	Benzene	358	71.2	<0.0009 ppm
Contractor, collected 10 meter water samples	2-Butoxyethanol	356	71.2	(0.0014 ppm)
Contractor, collected 10 meter water samples	Dipropylene glycol butyl ether	356	71.2	0.0078 ppm
Contractor, collected 10 meter water samples	Dipropylene glycol methyl ether	356	71.2	<0.0005 ppm
Contractor, collected 10 meter water samples	Ethanol	358	71.2	(0.70 ppm)
Contractor, collected 10 meter water samples	Ethyl benzene	358	71.2	(0.00074 ppm)
Contractor, collected 10 meter water samples	Limonene	358	71.2	0.0071 ppm
Contractor, collected 10 meter water samples	Naphthalene	358	71.2	<0.0005 ppm
Contractor, collected 10 meter water samples	Toluene	358	71.2	(0.0022 ppm)
Contractor, collected 10 meter water samples	Total hydrocarbons	358	71.2	4.1 mg/m ³
Contractor, collected 10 meter water samples	Xylenes	358	71.2	(0.0042 ppm)
Personal Breathing Zone Air Samples—Worker D				
Conducted fluorometry and applied dispersant	Propylene glycol	337	666	0.11 mg/m ^{3**}
Area Air Samples				
Inside cabin	Benzene	296	58.8	<0.001 ppm
Inside cabin	2-Butoxyethanol	296	58.9	(0.0022 ppm)
Inside cabin	Dipropylene glycol butyl ether	296	58.9	(0.0028 ppm)
Inside cabin	Dipropylene glycol methyl ether	296	58.9	<0.0006 ppm
Inside cabin	Ethanol	296	58.8	5.7 ppm

Table 4. Personal breathing zone and area air concentrations for substances measured on June 21, 2010 on the International Peace (continued)

Activity/Location	Substance	Sampling Information		Sample Concentration*†
		Time (min)	Volume (Liters)	
Area Air Samples (continued)				
Inside cabin	Ethyl benzene	296	58.8	(0.0024 ppm)
Inside cabin	Limonene	296	58.8	0.037 ppm
Inside cabin	Naphthalene	296	58.8	<0.0006 ppm
Inside cabin	Propylene glycol	296	592	0.017 mg/m ³
Inside cabin	Toluene	296	58.8	0.0099 ppm
Inside cabin	Total hydrocarbons	296	58.8	8.4 mg/m ³
Inside cabin	Xylenes	296	58.8	0.015 ppm

*Concentrations reported as "<" were not detected; the given value is the minimum detectable concentration

†Concentrations in parentheses were between the minimum detectable concentration and the minimum quantifiable concentration (parentheses are used to point out there is more uncertainty associated with these values than values above the minimum quantifiable concentration)

‡Sample had breakthrough

§Sample had breakthrough on first of two tubes in series, second tube was not detected

¶Pump failed after 85 minutes

**Sample had breakthrough on first of two tubes in series, second tube had concentrations between the minimum detectable concentration and the minimum quantifiable concentration

Table 5. Personal breathing zone air concentrations for substances measured on June 22, 2010 on the International Peace

Activity/Location	Substance	Sampling Information		Sample Concentration*†
		Time (min)	Volume (Liters)	
Personal Breathing Zone Air Samples—Worker A				
Conducted fluorometry and applied dispersant	Benzene	299	58.6	<0.001 ppm
Conducted fluorometry and applied dispersant	2-Butoxyethanol	298	58.9	0.0049 ppm
Conducted fluorometry and applied dispersant	Dipropylene glycol butyl ether	298	58.9	0.063 ppm‡
Conducted fluorometry and applied dispersant	Dipropylene glycol methyl ether	298	58.9	<0.0006 ppm
Conducted fluorometry and applied dispersant	Ethanol	299	58.6	(0.21 ppm)
Conducted fluorometry and applied dispersant	Ethyl benzene	299	58.6	(0.0008 ppm)
Conducted fluorometry and applied dispersant	Limonene	299	58.6	0.0037 ppm
Conducted fluorometry and applied dispersant	Naphthalene	299	58.6	<0.0007 ppm
Conduct fluorometry and apply dispersant	Propylene glycol	298	58.4	0.078 mg/m ³ §
Conducted fluorometry and applied dispersant	Toluene	299	58.6	(0.0013 ppm)
Conducted fluorometry and applied dispersant	Total hydrocarbons	299	58.6	0.94 mg/m ³
Conducted fluorometry and applied dispersant	Xylenes	299	58.6	(0.0039 ppm)
Personal Breathing Zone Air Samples—Worker B				
On Scene Coordinator, assisted with sampling	Benzene	296	58.5	<0.001 ppm
On Scene Coordinator, assisted with sampling	2-Butoxyethanol	295	58.8	(0.0021 ppm)
On Scene Coordinator, assisted with sampling	Dipropylene glycol butyl ether	295	58.8	0.0074 ppm
On Scene Coordinator, assisted with sampling	Dipropylene glycol methyl ether	295	58.8	<0.0006 ppm
On Scene Coordinator, assisted with sampling	Ethanol	296	58.5	(1.6 ppm)
On Scene Coordinator, assisted with sampling	Ethyl benzene	296	58.5	(0.0011 ppm)
On Scene Coordinator, assisted with sampling	Limonene	296	58.5	0.012 ppm
On Scene Coordinator, assisted with sampling	Naphthalene	296	58.5	<0.0007 ppm

Table 5. Personal breathing zone air concentrations for substances measured on June 22, 2010 on the International Peace (continued)

Activity/Location	Substance	Sampling Information		Sample Concentration*†
		Time (min)	Volume (Liters)	
Personal Breathing Zone Air Samples—Worker B (continued)				
On Scene Coordinator, assisted with sampling	Propylene glycol	295	580	(0.012 mg/m ³)
On Scene Coordinator, assisted with sampling	Toluene	296	58.5	0.0050 ppm
On Scene Coordinator, assisted with sampling	Total hydrocarbons	296	58.5	2.0 mg/m ³
On Scene Coordinator, assisted with sampling	Xylenes	296	58.5	0.0059 ppm
Personal Breathing Zone Air Samples—Worker C				
Contractor, collected 10 meter water samples	Propylene glycol	269	536	0.011 mg/m ³
Personal Breathing Zone Air Samples—Worker D				
Conducted fluorometry and applied dispersant	Benzene	304	61.0	<0.001 ppm
Conducted fluorometry and applied dispersant	2-Butoxyethanol	304	61.0	0.0033 ppm
Conducted fluorometry and applied dispersant	Dipropylene glycol butyl ether	304	61.0	0.046 ppm‡
Conducted fluorometry and applied dispersant	Dipropylene glycol methyl ether	304	61.0	<0.0005 ppm
Conducted fluorometry and applied dispersant	Ethanol	304	61.0	(0.76 ppm)
Conducted fluorometry and applied dispersant	Ethyl benzene	304	61.0	(0.0012 ppm)
Conducted fluorometry and applied dispersant	Limonene	304	61.0	0.0071 ppm
Conducted fluorometry and applied dispersant	Naphthalene	304	61.0	<0.0006 ppm
Conducted fluorometry and applied dispersant	Propylene glycol	298	586	0.076 mg/m ³ §
Conducted fluorometry and applied dispersant	Toluene	304	61.0	0.0034 ppm
Conducted fluorometry and applied dispersant	Total hydrocarbons	304	61.0	1.6 mg/m ³
Conducted fluorometry and applied dispersant	Xylenes	304	61.0	0.0064 ppm
Personal Breathing Zone Air Samples—Worker E				
Contractor, collected 1 meter water samples	Benzene	277	56.0	<0.001 ppm
Contractor, collected 1 meter water samples	2-Butoxyethanol	276	54.3	(0.0021 ppm)

Table 5. Personal breathing zone air concentrations for substances measured on June 22, 2010 on the International Peace (continued)

Activity/Location	Substance	Sampling Information		Sample Concentration*†
		Time (min)	Volume (Liters)	
Personal Breathing Zone Air Samples—Worker E (continued)				
Contractor, collected 1 meter water samples	Dipropylene glycol butyl ether	276	54.3	(0.013 ppm)
Contractor, collected 1 meter water samples	Dipropylene glycol methyl ether	276	54.3	<0.0006 ppm
Contractor, collected 1 meter water samples	Ethanol	277	56.0	(1.1 ppm)
Contractor, collected 1 meter water samples	Ethyl benzene	277	56.0	(0.00091 ppm)
Contractor, collected 1 meter water samples	Limonene	277	56.0	0.011 ppm
Contractor, collected 1 meter water samples	Naphthalene	277	56.0	<0.0007ppm
Contractor, collected 1 meter water samples	Toluene	277	56.0	0.0046 ppm
Contractor, collected 1 meter water samples	Total hydrocarbons	277	56.0	2.0 mg/m ³
Contractor, collected 1 meter water samples	Xylenes	277	56.0	(0.0054 ppm)

*Concentrations reported as "<" were not detected; the given value is the minimum detectable concentration

†Concentrations in parentheses were between the minimum detectable concentration and the minimum quantifiable concentration (parentheses are used to point out there is more uncertainty associated with these values than values above the minimum quantifiable concentration)

‡Sample had breakthrough

§Sample had breakthrough on first of two tubes in series, second tube had concentrations between the minimum detectable concentration and the minimum quantifiable concentration

Table 6. Health symptom survey—demographics

	International Peace*	Unexposed†
Number of participants	5	103
Age range	26–41	18–70
Race		
White	100%	40%
Hispanic	0%	29%
Asian	0%	9%
Black	0%	19%
Other	0%	3%
Male	100%	96%
Days worked oil spill	6–30	0–45
Days worked boat	6–25	0

*This dispersant mission was conducted on June 21–22, 2010.

†Participants were recruited from the Venice Field Operations Branch and the Venice Commanders' Camp. Those who reported that they had not worked on boats and had no exposures to oil, dispersant, cleaner, or other chemicals were included in this group.

Table 7. Health symptom survey—reported injuries and symptoms

	International Peace*	Unexposed†
Number of participants	5	103
Injuries		
Scrapes or cuts	1	11 (11%)
Burns by fire	0	1 (1%)
Chemical burns	0	0
Bad Sunburn	0	8 (8%)
Constitutional symptoms		
Headaches	0	5 (14%)
Feeling faint, dizziness, fatigue or exhaustion, or weakness	2	13 (13%)
Eye and upper respiratory symptoms		
Itchy eyes	2	5 (5%)
Nose irritation, sinus problems, or sore throat	0	16 (16%)
Metallic taste	0	0
Lower respiratory symptoms		
Coughing	0	8 (8%)
Trouble breathing, short of breath, chest tightness, wheezing	0	4 (4%)
Cardiovascular symptoms		
Fast heart beat	0	1 (1%)
Chest pressure	0	0
Gastrointestinal symptoms		
Nausea or vomiting	0	3 (3%)
Stomach cramps or diarrhea	0	7 (7%)
Skin symptoms		
Itchy skin, red skin, or rash	0	8 (8%)
Musculoskeletal symptoms		
Hand, shoulder, or back pain	2	6 (6%)
Psychosocial symptoms		
Feeling worried or stressed	1	4 (4%)
Feeling pressured	3	2 (2%)
Feeling depressed or hopeless	0	1 (1%)
Feeling short tempered	0	4 (4%)
Frequent changes in mood	0	3 (3%)
Heat stress symptoms‡		
Any	2	21 (20%)
4 or more symptoms	0	3 (3%)

*This mission of the International Peace was the application and monitoring of dispersant from the vessel to surface water. All 5 individuals returned their completed survey on June 22, 2010 after operations were concluded.

†Participants were recruited from the Venice Field Operations Branch and the Venice Commanders' Camp. Those who reported that they had not worked on boats and had no exposures to oil, dispersant, cleaner, or other chemicals were included in this group.

‡Headache, dizziness, feeling faint, fatigue or exhaustion, weakness, fast heartbeat, nausea, red skin, or hot and dry skin.

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