Health Hazard Evaluation of Deepwater Horizon Response Workers

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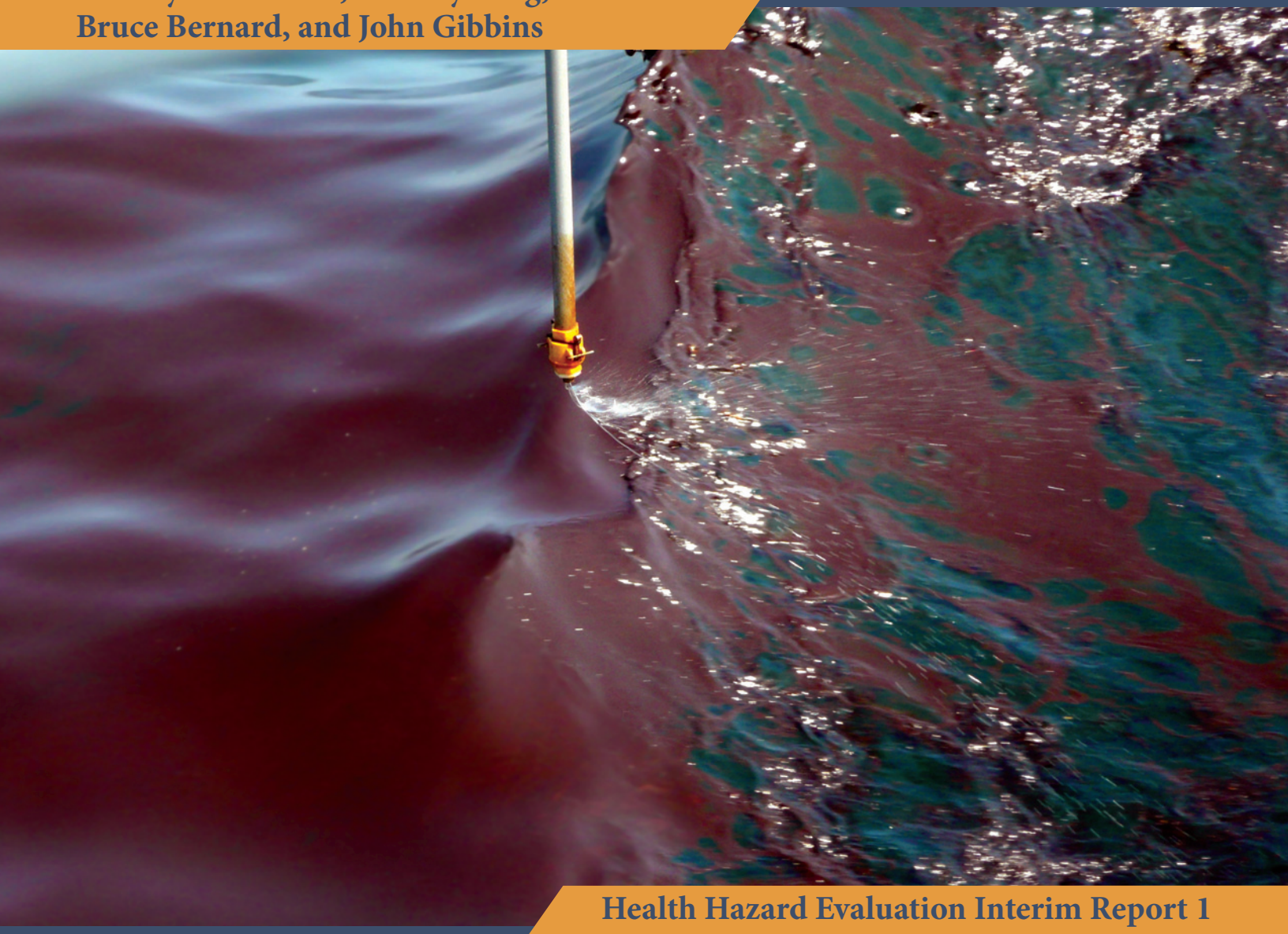

Health Hazard Evaluation Interim Report 1
June 23, 2010

DEPARTMENT OF HEALTH AND HUMAN SERVICES · USA
CDC Workplace Safety and Health
National Institute for Occupational Safety and Health NIOSH
HHE Health Hazard Evaluation Program

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 dispersant being applied to the surface of the ocean water in the Gulf of Mexico during the Deepwater Horizon response: June 2010.

DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service

National Institute for Occupational Safety and Health
Robert A. Taft Laboratories
4676 Columbia Parkway
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June 23, 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, followed by additional teams. To date, 14 HHE investigators have been on-scene; the investigation is continuing.

This letter is the first 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 #1) 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:

- 1A – Evaluation of May 26, 2010, Hospitalization of Seven Fishermen
- 1B – Evaluation of June 4-5, 2010 M/V International Peace/MV Warrior Dispersant Mission

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

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
Dr. Richard Heron, BP
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LT John Kaser, USCG
Mr. Clint Guidry, LA Shrimp Association
Ms. Cindy Coe, OSHA
Dr. Raoul Ratard, LA DHHS
Mr. Brock Lamont, CDC

Interim Report #1A
Evaluation of May 26, 2010, Hospitalization of Seven Fishermen

Lead Author: Melody Kawamoto

Sources of Information

- Hospital records from West Jefferson Medical Center (WJMC), Marrero, Louisiana
- BP Healthcare Provider Reporting Forms completed by nurse case managers
- OSHA preliminary Incident Report of Fishermen Evacuated Near Grand Isle Shipyard
- USCG investigator's report of the investigation of fishermen evacuated near Grand Isle Shipyard
- Preliminary Investigation of Vessel of Opportunity Worker Exposure Incident Occurring on May 26, 2010, by Center for Toxicology and Environmental Health (CTEH)
- Interview with captains of fishing vessels from Task Forces 1, 2, 3, and 4 by CTEH toxicologist
- NIOSH medical officer interviews with CTEH and OSHA investigators and nurse case managers

Summary

Initial investigations focused on exposure to dispersant based on patient reports. OSHA and CTEH reviewed dispersant application records from May 26, 2010; the patients' vessels were approximately 40–60 miles from the area of dispersant use. When oil was observed by the fishermen, the description was most consistent with emulsified crude oil, which, according to the CTEH report, does not contain free dispersant. All but one of the hospitalized fishermen reported extremely unpleasant odors. The reported odors included "concentrated soap" and "bad Clorox" as well as unspecified "chemical" odors. One patient reported a "Pine-Sol" taste. The sources of the unpleasant odors or taste could not be determined by investigators after the event. Captains of vessels from Task Forces 1, 2, 3, and 4 reported to a CTEH toxicologist that the symptoms began after Pentene Clean had been substituted for the usual citrus-based cleaner but this could not be confirmed in the review of other reports and records. Several of the patients had reported symptoms 3 to 7 days before hospitalization and one reported symptoms approximately 20 days before hospitalization. The most frequent signs and symptoms reported by the hospitalized fishermen were headache, upper respiratory irritation or congestion, nausea, elevated self-monitored blood pressure, fatigue, and chest pain or pressure. Two of the fishermen were hospitalized for evaluation of potentially serious medical problems that are common in the United States. The rest were hospitalized for observation because of their reported exposure to chemicals. Six patients were discharged within 1 day of admission; one was discharged after an additional day of testing.

Conclusions

Given the various descriptions and unspecified sources of the reported odors, the uncertain timing of the symptoms in relation to use of the substitute cleaner, and symptoms that could be related to a variety of causes, it is unlikely that a single specific trigger for the reported symptoms can be determined. Dispersant use appears unlikely to be the source of the symptoms based on the information reviewed by NIOSH investigators. The symptoms were more likely to have been aggravated by several contributing factors, including unpleasant odors, heat, and fatigue.

Interim Recommendations

BP should:

- Assure implementation of pre-placement medical screening to assess response workers' fitness for duty
- Provide training for response workers on the different types and appearances of oil they may encounter during the course of their duties, and provide regular communication to workers about the response activities in their area of operation
- Facilitate the reporting and investigation of the medical disposition of workers sent to hospitals by working with established systems (e.g., local healthcare providers and state and local health departments)
- Provide resources and assistance to continuing medical education programs to raise local physicians' awareness of occupational health issues related to occupational hazards in the oil industry (including spill response), particularly emphasizing the importance of a detailed exposure history

Interim Report #1B
Evaluation of June 4–5, 2010, M/V International Peace – M/V Warrior Dispersant Mission

Lead Authors: Bradley King, Bruce Bernard, and John Gibbins
Contributing Authors: Scott Brueck, Greg Burr, Nancy Burton, Chad Dowell, Kenny Fent, Charles Mueller, and Teresa Seitz

Introduction

NIOSH investigators conducted industrial hygiene surveys, health symptom surveys, and medical interviews during a small scale dispersant mission involving two motor vessels, International Peace (IP) and Warrior, on June 4 and 5, 2010. Prior to the April 20, 2010 well site explosion, these vessels transferred personnel and equipment to oil rigs and platforms. During this mission, the personnel on the IP applied dispersant to the water surface from the deck of the vessel and personnel on the Warrior monitored the dispersed oil under the surface using fluorometry and collected water samples. [Fluorometry is a method for characterizing the oil slick and the efficacy of the dispersant.] Personnel on both vessels included crew and contract personnel from Oil Spill Response Limited (OSR) and the U.S. Coast Guard (USCG). Other personnel from NIOSH, the Center for Toxicology and Environmental Health (CTEH), and Battelle also were present.

When applying dispersant from the IP, all non essential personnel remained in the cabin. The one contract employee who remained on deck wore disposable coveralls, nitrile gloves, steel toe boots, safety goggles, a hardhat, a personal floatation device, and a half-mask air purifying respirator with organic vapor cartridges. The coveralls and nitrile gloves were discarded after use.

When conducting fluorometry and collecting water samples on the Warrior, USCG personnel wore cloth coveralls, nitrile gloves, steel toe boots, hardhats, safety glasses, and personal floatation devices. During fluorometry, a flow-through fluorometer was lowered into the water to provide direct readings. These readings were recorded on a laptop before and after dispersants were applied. The USCG also collected water samples at various depths (e.g., 1 and 10 meters) using pole-mounted collection bottles. The water samples (a mixture of oil, water, and occasionally dispersants) were capped and saved for chemical analysis. After fluorometry and water sample collection, USCG personnel cleaned/decontaminated the collection equipment and rope lines with a standard hand-held garden-type sprayer and cleaning solution.

Evaluation

NIOSH investigators conducted personal breathing zone (PBZ) and area air sampling on the IP and Warrior on June 4 and 5, 2010. During various activities including preparing for dispersion, active dispersion, and fluorometry, short term and longer term air samples were collected. Longer term samples also were collected while travelling to the oil slick. The short term samples are intended to represent exposure during specific work tasks and the longer term samples more closely represent full-shift occupational exposures.

On June 4, 2010, no dispersants were applied so these air samples represent exposures in the vicinity of oil contaminated waters during dispersion preparation and routine activities (such as cleaning). On June 5, 2010, an OSR employee on the IP applied 50 gallons of Corexit® EC9500A dispersant (Nalco, Naperville, Illinois) using a mechanical delivery system. Afterwards, an additional aerial release of 125 gallons of this dispersant occurred from a support aircraft. Both applications required approval of the USCG since routine use of dispersant from vessels and aircraft had been suspended at the time of this NIOSH evaluation. Standard protocols were followed, as relayed to NIOSH personnel by USCG personnel on the vessels. This included relocating the vessels at least one nautical mile upwind of the release and waiting 30 minutes before re-entering the area.

To evaluate the presence of volatile organic compounds (VOCs), NIOSH investigators 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. Other chemicals measured in PBZ or area air samples using integrated air sampling techniques included propylene glycol (a component of the dispersant), diesel exhaust, mercury (a possible component of crude oil), and the benzene soluble fraction of total particulate samples. Direct reading measurements were made for carbon monoxide (CO) and hydrogen sulfide (H_2S). The sampling and analytical methods used are provided in Tables 2–5.

Because of concerns about acute health effects that have been reported with use of the dispersant, NIOSH medical officers conducted medical interviews and health surveys at the time of exposure monitoring by NIOSH industrial hygienists on two vessels involved in applying or monitoring dispersant. The workers were asked to report symptoms they experienced during this specific mission. All 10 crew, USCG members, and contractors on the IP were asked to complete a brief symptom survey within 30 minutes to 1 hour after dispersant application. Three to four hours later, each participant was interviewed about changes in their symptoms.

On the Warrior, seven contractors and USCG personnel involved in monitoring the water for dispersant (using fluorometry) were interviewed about symptoms within 30 minutes to 1 hour after aerial application. Three to four hours later, they completed the symptom survey. Personnel on the Warrior who were not involved in water dispersant monitoring (e.g., the cook) did not complete the survey.

Results

Table 1 contains a summary of the relevant occupational exposure limits (OELs) for this evaluation.

Volatile Organic Compounds

On June 4, 2010, two long term area air samples and one short term sample were collected using Summa canisters. On June 5, 2010, two longer term area air samples and three shorter term samples were collected using Summa canisters. Individual VOC concentrations were well below applicable OELs. Acrolein was identified in the highest concentration relative to the OELs; however, the maximum levels were only 1% to 4% of full-shift, short term, or ceiling OELs. Concentrations of benzene and ethanol

were between 0.1% and 1% of their OELs. All other VOCs that were evaluated were at concentrations less than 0.1% of the OELs or were not detected.

On June 4, 2010, two thermal desorption tube air samples were collected to screen for VOCs and on June 5, 2010, three thermal desorption tubes samples were collected. The screening samples collected on June 5, 2010 contained a wider variety of substances than those collected on the previous day when no dispersant was applied. On June 5, 2010, various C_6 to C_{18} hydrocarbons (straight and branched alkanes) were found; some samples also contained naphthalene, benzene, alcohols (ethanol and isopropyl alcohol), limonene, 2-butoxyethanol, dipropylene glycol butyl ether isomers, and other substances.

Based on the results of the Summa canisters and thermal tube screening samples, the PBZ and area charcoal tube air samples were quantitated for acetone, benzene, ethanol, ethylbenzene, isopropyl alcohol, limonene, naphthalene, toluene, total hydrocarbons (THC) (as hexane), and xylenes. Results are shown in Tables 2–5. All air concentrations were well below the relevant OELs. In PBZ samples on the Warrior (Tables 3 and 5), only limonene and THC were present above the minimum quantifiable concentrations. Ethanol was present in the highest concentration at 5.6 parts per million (ppm) in one air sample taken on June 4, 2010 in the IP cabin. Ethanol and limonene are ingredients in cleaning agents, which might explain their presence in the air samples. Even on an additive basis, for any given exposure period, the mixtures of chemicals measured in the air are a fraction (<10%) of the acceptable levels. Total hydrocarbon concentrations were all less than 10 milligrams per cubic meter (mg/m^3). 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/m^3 as a work-shift time weighted average (TWA) as shown in Table 1.

A second set of charcoal tube air samples was quantitated for 2-butoxyethanol, dipropylene glycol butyl ether, and dipropylene glycol methyl ether. The concentrations of 2-butoxyethanol in five area air samples collected on June 4 and 5, 2010, were all below 0.01 ppm, well below the most protective OEL of 5 ppm. Dipropylene glycol butyl ether was detected on three samples at low concentrations. One sample had breakthrough indicating that more than 10% of the mass of dipropylene glycol butyl ether was present on the back section of the tube. Thus, the reported concentration may be underestimated. 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 on three of four air samples collected on the IP (which applied dispersant), but not on the two samples collected on the Warrior (which did not apply dispersant), as shown in Tables 2, 4, and 5. Both the IP and the Warrior were positioned at least one nautical mile from the aerial application on June 5 (following standard USCG protocol). The concentrations of propylene glycol measured on June 4, 2010, might have been associated with dispersant preparations made by the crew, because dispersant was not applied until June 5, 2010. The propylene glycol concentrations ranged up to 0.17 mg/m^3, below the OEL of 10 mg/m^3, with the highest concentration measured on the person involved in the dispersal on the IP. It should be noted, however, that this PBZ sample (and two area samples) contained more than 10% of the mass of propylene glycol on the back section of the XAD-7 sorbent tube, indicating significant breakthrough. The reported concentrations may be underestimated. 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.

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 ($\mu g/m^3$) for an 8-hour TWA. As shown in Tables 2, 4, and 5, EC concentrations during response tasks ranged from 2.6 to 6.2 $\mu g/m^3$, 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 6.7% to 19%, well below the expected 60% to 80% of EC to total carbon typically reported in diesel exhaust.

Mercury

No mercury was detected on three area air samples collected on June 5, 2010 as shown in Tables 4 and 5. The minimum detectable concentrations ranged up to 0.00007 mg/m^3, well below the most protective OEL of 0.025 mg/m^3.

Benzene Soluble Total Particulate Fraction

Three PBZ and one area air sample were collected for total particulates with the particulate fraction analyzed for benzene soluble components (to separate out contributions from substances like salts from the sea water) as an indicator of oil mist exposures (Tables 2, 4, and 5). None of the samples contained detectable concentrations of benzene soluble particulates.

Carbon Monoxide and Hydrogen Sulfide

Tables 2–5 include a summary of the direct reading measurements for CO and H_2S. Carbon monoxide, a component of incomplete combustion, possibly from the diesel engines, was monitored for approximately 6 to 8 hours on the IP and Warrior decks on June 4 and June 5, 2010. Area concentrations of CO ranged up to 13 ppm, with TWAs all less than 5 ppm, well below OELs. Hydrogen sulfide was not detected on two long term samples (approximately 6 and 8 hours) collected on the deck of the IP on June 4 and 5, 2010.

Health Symptom Surveys and Medical Interviews

Seventeen persons on the two vessels (10 from IP and 7 from Warrior) completed the symptom survey. Demographically, the workers on the two vessels were similar (Table 6). Reported symptoms, grouped by type, are presented in Table 7. This table includes symptoms for workers surveyed on the two vessels and 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.

Very few workers on either vessel reported upper or lower respiratory, gastrointestinal, musculoskeletal, or psychological symptoms; or injuries. Some workers on the Warrior reported constitutional (i.e., headaches and fatigue) and skin symptoms. Those on the IP reported very few

symptoms. On the IP, only 1 person, who used personal protective equipment, was on deck during dispersant activities; the others were in the enclosed vessel cabin.

The symptoms reported by personnel on the Warrior were similar to those reported by the comparison group (Table 7).

Summary

Very few symptoms were reported by personnel on the IP, where the dispersant operator was using personal protective equipment and others on the vessel were in the cabin. Personnel working on the deck of the Warrior had more constitutional and skin symptoms than those on the IP. Their symptoms were similar to surveyed response workers not exposed to chemical hazards, but because the sample of exposed workers was very small it is not possible to make statistical comparisons between the groups. It also is not appropriate to generalize these findings to workers on other vessels due to the specialized nature of this mission. Some reported symptoms might have been related to a combination of several factors, including heat and humidity, sun exposure, and contact with water contaminated with the oil/dispersant mix. Although PBZ and area air concentrations of the measured contaminants measured were all well below OELs, NIOSH investigators did observe the potential for dermal contact with the dispersant while preparing for dispersion and during active dispersion from the vessel.

Because of the potential for inhalation and dermal contact with the dispersant, NIOSH investigators recommend the protective steps observed during this evaluation be continued. This includes keeping non-essential personnel inside the cabin and using respiratory protection, eye protection, coveralls, and nitrile gloves for those on the deck during dispersant application. Personnel conducting fluorometry and water sampling and preparing for dispersion should continue to wear cloth coveralls, eye protection, and nitrile gloves along with other needed safety equipment when handling the dispersant. If the widespread use of aerial or vessel release of dispersant resumes or usage patterns change, NIOSH investigators recommend that additional monitoring be performed using integrated air sampling methods in addition to the direct reading measurements. With regard to propylene glycol monitoring, NIOSH investigators recommend that future monitoring 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.

Acknowledgments

Field assistance and logistical support were provided by Donald Booher and Karl Feldmann. Analytical support was provided by Ardith Grote, Bureau Veritas North America, and Columbia Analytical Services, Inc.

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Table 1. Occupational exposure limits for substances evaluated during the June 4–5, 2010 dispersant mission

Chemical	NIOSH REL*	OSHA PEL†	ACGIH TLV‡	AIHA WEEL§
Acetone	250 ppm TWA¶	1000 ppm TWA	500 ppm TWA 750 ppm STEL**	N/A††
Acrolein	0.1 ppm TWA 0.3 ppm STEL	0.1 ppm TWA	0.1 ppm Ceiling	N/A
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
Benzene-soluble fraction of total particulate	N/A	N/A	0.5 mg/m^3 TWA††	N/A
2-Butoxyethanol	5 ppm TWA	50 ppm TWA	20 ppm TWA	N/A
Carbon monoxide	35 ppm TWA 200 ppm Ceiling	50 ppm TWA	25 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
Diesel exhaust (as elemental carbon)‡‡	N/A	N/A	N/A	N/A
Ethanol	1000 ppm TWA 1900 mg/m^3	1000 ppm TWA	1000 ppm STEL	N/A
Ethyl benzene	100 ppm TWA (435 mg/m^3) 125 ppm STEL	100 ppm TWA	100 ppm TWA 125 ppm STEL 20 ppm TWA-proposed	N/A
Hydrogen sulfide	10 ppm Ceiling	20 ppm Ceiling 50 ppm Peak	1 ppm TWA 5 ppm STEL	N/A
Isopropyl Alcohol	400 ppm TWA 500 ppm STEL	400 ppm TWA	200 ppm TWA 400 ppm STEL	N/A
Limonene	N/A	N/A	N/A	30 ppm
Mercury	0.05 mg/m^3 TWA	0.1 mg/m^3 Ceiling	0.025 mg/m^3 TWA	N/A
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

Table 1. Occupational exposure limits for substances evaluated during the June 4–5, 2010 dispersant mission (continued)

Chemical	NIOSH REL*	OSHA PEL†	ACGIH TLV‡	AIHA WEEL§
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

*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
††This 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.
‡‡California Department of Health Services' Hazard Evaluation System & Information Service (HESIS) guideline for diesel exhaust particles (measured as elemental carbon [EC]) is 20 µg/m^3 for an 8-hour TWA [CDHS 2002]

Table 2. Personal breathing zone and area air concentrations for substances measured on June 4, 2010 on The International Peace

Activity/Location	Substance	Sampling Information		Sample Concentration*†
		Time (min)	Volume (Liters)	
No Dispersant Applied—Personal Breathing Zone Air Samples				
Dispersant prep	Benzene soluble fraction	27	54.0	<1 mg/m^3
Dispersant prep	Propylene glycol	27	53.8	0.099 mg/m^3§
No Dispersant Applied—Area Air Samples				
Deck	Acetone	61	12.2	(0.052 ppm)
Deck	Acetone	379	75.9	(0.011 ppm)
Cabin	Acetone	330	66.1	0.083 ppm
Deck	Benzene	61	12.2	<0.005 ppm
Deck	Benzene	379	75.9	<0.0008 ppm
Cabin	Benzene	330	66.1	(0.0018 ppm)
Deck	Benzene soluble fraction	50	101	<0.6 mg/m^3
Deck	2-Butoxyethanol	50	10.0	(0.0043 ppm)
Deck	2-Butoxyethanol	379	76.0	0.0030 ppm
Deck	Carbon monoxide	343	N/A‡	Range: 0–3 ppm; Avg: 0.1 ppm
Deck	Diesel exhaust	351	706	EC: 2.6 µg/m^3; OC: (35 µg/m^3)
Deck	Dipropylene glycol butyl ether	50	10.0	<0.05 mg/m^3
Deck	Dipropylene glycol butyl ether	379	76.0	(0.0020 mg/m^3)
Deck	Dipropylene glycol methyl ether	50	10.0	<0.03 mg/m^3
Deck	Dipropylene glycol methyl ether	379	76.0	<0.004 mg/m^3
Deck	Ethanol	61	12.2	(3.8 ppm)
Deck	Ethanol	379	75.9	(0.50 ppm)
Cabin	Ethanol	330	66.1	5.6 ppm
Deck	Ethylbenzene	61	12.2	<0.004 ppm
Deck	Ethylbenzene	379	75.9	(0.0011 ppm)
Cabin	Ethylbenzene	330	66.1	0.0052 ppm
Deck	Hydrogen sulfide	343	N/A	0 ppm
Deck	Isopropyl alcohol	61	12.2	(0.080 ppm)
Deck	Isopropyl alcohol	379	75.9	(0.013 ppm)
Cabin	Isopropyl alcohol	330	66.1	0.15 ppm
Deck	Limonene	61	12.2	0.016 ppm
Deck	Limonene	379	75.9	0.0033 ppm
Cabin	Limonene	330	66.1	0.035 ppm
Deck	Naphthalene	61	12.2	<0.003 ppm
Deck	Naphthalene	379	75.9	<0.0005 ppm
Cabin	Naphthalene	330	66.1	(0.0052 ppm)

Table 2. Personal breathing zone and area air concentrations for substances measured on June 4, 2010 on The International Peace (continued)

Activity/Location	Substance	Sampling Information		Sample Concentration*†
		Time (min)	Volume (Liters)	
No Dispersant Applied—Area Air Samples (continued)				
Deck	Propylene glycol	48	95.7	0.17 mg/m^3§
Deck	Total Hydrocarbons	61	12.2	3.3 mg/m^3
Deck	Total Hydrocarbons	379	75.9	0.80 mg/m^3
Cabin	Total Hydrocarbons	330	66.1	8.5 mg/m^3
Deck	Toluene	61	12.2	0.026 ppm
Deck	Toluene	379	75.9	0.0059 ppm
Cabin	Toluene	330	66.1	0.092 ppm
Deck	Xylenes	61	12.2	<0.008 ppm
Deck	Xylenes	379	75.9	0.0052 ppm
Cabin	Xylenes	330	66.1	0.021 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)
‡N/A = not applicable
§Sample had breakthrough (>10% of the mass was on the back section of the sorbent tube; concentrations may be underestimated)

Analytical methods:

Acetone, Benzene, Ethanol, Ethylbenzene, Isopropyl alcohol, Limonene, Naphthalene, Toluene, Xylene: NIOSH Manual of Analytical Methods (NMAM) 1501 with modifications
Benzene soluble fraction: NMAM 5042
2-Butoxyethanol: NMAM 1403 with modifications
Carbon monoxide and hydrogen sulfide: Direct reading, BW Technologies Ltd., Calgary, Canada
Diesel exhaust: NMAM 5040
Dipropylene glycol butyl ether: NMAM 1403 with modifications
Dipropylene glycol methyl ether: NMAM 1403 with modifications
Propylene glycol: NMAM 5523
Total hydrocarbons (as n-hexane): NMAM 1501 with modifications

Table 3. Personal breathing zone and area air concentrations for substances measured on June 4, 2010 on The Warrior

Activity/Location	Substance	Sampling Information		Sample Concentration*†
		Time (min)	Volume (Liters)	
No Dispersant Applied—Personal Breathing Zone Air Samples				
Prep for fluorometry	Acetone	87	17.5	(0.053 ppm)
Prep for fluorometry	Benzene	87	17.5	<0.004 ppm
Prep for fluorometry	Diesel exhaust	105	210	EC: (6.2 μg/m^3); OC: (72 μg/m^3)
Prep for fluorometry	Ethanol	87	17.5	(0.15 ppm)
Prep for fluorometry	Ethylbenzene	87	17.5	<0.003 ppm
Prep for fluorometry	Isopropyl alcohol	87	17.5	<0.005 ppm
Prep for fluorometry	Limonene	87	17.5	<0.002 ppm
Prep for fluorometry	Naphthalene	87	17.5	<0.002 ppm
Prep for fluorometry	Total hydrocarbons	87	17.5	0.52 mg/m^3
Prep for fluorometry	Toluene	87	17.5	<0.003 ppm
Prep for fluorometry	Xylenes	87	17.5	<0.003 ppm
No Dispersant Applied—Area Air Samples				
Deck	Carbon monoxide	355	N/A‡	Range: 0–7 ppm; Avg: 0.53 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)
‡N/A = not applicable

Analytical methods:
Acetone, Benzene, Ethanol, Ethylbenzene, Isopropyl alcohol, Limonene, Naphthalene, Toluene, Xylene: NMAM 1501 with modifications
Diesel exhaust: NMAM 5040
Mercury: NMAM 6009
Total hydrocarbons (as n-hexane): NMAM 1501 with modifications

Table 4. Personal breathing zone and area air concentrations for substances measured on June 5, 2010 on The International Peace

Activity / Location	Substance	Sampling Information		Sample Concentration*†
		Time (min)	Volume (Liters)	
Dispersant Applied by IP and Aircraft—Personal Breathing Zone Air Samples				
Boat dispersal	Acetone	78	15.7	<0.005 ppm
Boat dispersal	Benzene	78	15.7	<0.004 ppm
Boat dispersal	Benzene soluble fraction	78	156	<0.4 mg/m^3
Boat dispersal	Ethanol	78	15.7	(2.0 ppm)
Boat dispersal	Ethylbenzene	78	15.7	<0.003 ppm
Boat dispersal	Isopropyl alcohol	78	15.7	(0.11 ppm)
Boat dispersal	Limonene	78	15.7	0.022 ppm
Boat dispersal	Naphthalene	78	15.7	<0.002 ppm
Boat dispersal	Propylene glycol	77	151	0.17 mg/m^3§
Boat dispersal	Toluene	78	15.7	0.074 ppm
Boat dispersal	Xylenes	78	15.7	(0.011 ppm)
Boat dispersal	Total hydrocarbons	78	15.7	4.0 mg/m^3
Dispersant Applied by IP and Aircraft—Area Air Samples				
Deck¶	Acetone	43	8.69	<0.01 ppm
Deck	Acetone	498	100	(0.0015 ppm)
Cabin	Acetone	533	107	0.10 ppm
Deck¶	Benzene	43	8.69	<0.007 ppm
Deck	Benzene	498	100	<0.0006 ppm
Cabin	Benzene	533	107	<0.0006 ppm
Deck¶	2-Butoxyethanol	43	8.64	(0.0079 ppm)
Deck	2-Butoxyethanol	498	99.9	0.0023 ppm
Deck	Carbon monoxide	510	N/A‡	Range: 0–13 ppm; Avg: 4.2 ppm
Deck	Diesel exhaust	502	994	EC: 4.1 µg/m^3; OC: (30 µg/m^3)
Deck¶	Dipropylene glycol butyl ether	43	8.64	0.28 mg/m^3
Deck	Dipropylene glycol butyl ether	498	99.9	0.11 mg/m^3§
Deck¶	Dipropylene glycol methyl ether	43	8.64	<0.03 mg/m^3
Deck	Dipropylene glycol methyl ether	498	99.9	<0.003 mg/m^3
Deck¶	Ethanol	43	8.69	(0.12 ppm)
Deck	Ethanol	498	100	(0.015 ppm)
Cabin	Ethanol	533	107	3.2 ppm
Deck¶	Ethylbenzene	43	8.69	<0.005 ppm
Deck	Ethylbenzene	498	100	(0.00048 ppm)
Cabin	Ethylbenzene	533	107	0.0050 ppm
Deck	Hydrogen sulfide	510	N/A	0 ppm
Deck¶	Isopropyl alcohol	43	8.69	<0.009 ppm
Deck	Isopropyl alcohol	498	100	(0.0073 ppm)

Table 4. Personal breathing zone and area air concentrations for substances measured on June 5, 2010 on The International Peace (continued)

Activity / Location	Substance	Sampling Information		Sample Concentration*†
		Time (min)	Volume (Liters)	
Dispersant Applied by IP and Aircraft—Area Air Samples (continued)				
Cabin	Isopropyl alcohol	533	107	0.21 ppm
Deck¶	Limonene	43	8.69	<0.004 ppm
Deck	Limonene	498	100	(0.0012 ppm)
Cabin	Limonene	533	107	0.035 ppm
Deck**	Mercury	66	13.3	<0.00007 mg/m^3
Deck	Mercury	474	94.8	<0.00001 mg/m^3
Deck¶	Naphthalene	43	8.69	(0.031 ppm)
Deck	Naphthalene	498	100	(0.0030 ppm)
Cabin	Naphthalene	533	107	(0.0039 ppm)
Deck¶	Propylene glycol	41	80.4	(0.019 mg/m^3)§
Deck**	Propylene glycol	66	129	<0.007 mg/m^3
Deck¶	Total Hydrocarbons	43	8.69	0.52 mg/m^3
Deck	Total Hydrocarbons	498	100	0.50 mg/m^3
Cabin	Total Hydrocarbons	533	107	8.8 mg/m^3
Deck¶	Toluene	43	8.69	<0.006 ppm
Deck	Toluene	498	100	0.0098 ppm
Cabin	Toluene	533	107	0.18 ppm
Deck¶	Xylenes	43	8.69	<0.01 ppm
Deck	Xylenes	498	100	(0.0022 ppm)
Cabin	Xylenes	533	107	0.021 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)
‡N/A = not applicable
§Sample had breakthrough (>10% of the mass was on the back section of the sorbent tube; concentrations may be underestimated)
¶Short term area sample collected on deck during boat dispersal
**Short term area sample collected on deck during aerial dispersal

Analytical methods:

Acetone, Benzene, Ethanol, Ethylbenzene, Isopropyl alcohol, Limonene, Naphthalene, Toluene, Xylene: NMAM 1501 with modifications
Benzene soluble fraction: NMAM 5042
2-Butoxyethanol: NMAM 1403 with modifications
Carbon monoxide and hydrogen sulfide: Direct reading, BW Technologies Ltd., Calgary, Canada
Diesel exhaust: NMAM 5040
Dipropylene glycol butyl ether: NMAM 1403 with modifications
Dipropylene glycol methyl ether: NMAM 1403 with modifications
Mercury: NMAM 6009
Propylene glycol: NMAM 5523
Total hydrocarbons (as n-hexane): NMAM 1501 with modifications

Table 5. Personal breathing zone and area air concentrations for substances measured on June 5, 2010 on The Warrior

Activity/Location	Substance	Sampling Information		Sample Concentration*†
		Time (min)	Volume (Liters)	
Dispersant Applied by IP and Aircraft—Personal Breathing Zone Air Samples				
Fluorometry and Water Sampling	Acetone	219	43.8	(0.029 ppm)
Fluorometry and Water Sampling	Benzene	219	43.8	<0.001 ppm
Fluorometry and Water Sampling	Benzene soluble fraction	215	430	<0.1 mg/m^3
Fluorometry and Water Sampling	Ethanol	219	43.8	(0.98 ppm)
Fluorometry and Water Sampling	Ethylbenzene	219	43.8	<0.001 ppm
Fluorometry and Water Sampling	Isopropyl alcohol	219	43.8	<0.002 ppm
Fluorometry and Water Sampling	Limonene	219	43.8	0.0074 ppm
Fluorometry and Water Sampling	Naphthalene	219	43.8	<0.0009 ppm
Fluorometry and Water Sampling	Propylene glycol	218	436	<0.002 mg/m^3
Fluorometry and Water Sampling	Propylene glycol	216	432	<0.002 mg/m^3
Fluorometry and Water Sampling	Total Hydrocarbons	219	43.8	1.3 mg/m^3
Fluorometry and Water Sampling	Toluene	219	43.8	(0.0018 ppm)
Fluorometry and Water Sampling	Xylenes	219	43.8	<0.002 ppm
Dispersant Applied by IP and Aircraft—Area Air Samples				
Deck	2-Butoxyethanol	256	51.3	0.0040 ppm
Deck	Carbon monoxide	343	N/A‡	Range: 0–4 ppm; Avg: 0.24 ppm

Table 5. Personal breathing zone and area air concentrations for substances measured on June 5, 2010 on The Warrior (continued)

Activity/Location	Substance	Sampling Information		Sample Concentration*†
		Time (min)	Volume (Liters)	
Dispersant Applied by IP and Aircraft—Area Air Samples (continued)				
Deck	Diesel exhaust	185	370	EC: 6.2 µg/m^3; OC: (27 µg/m^3)
Deck	Dipropylene glycol butyl ether	256	51.3	<0.01 mg/m^3
Deck	Dipropylene glycol methyl ether	256	51.3	<0.006 mg/m^3
Deck	Mercury	255	50.3	<0.00002 mg/m^3

*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)

‡N/A = not applicable

Analytical methods:

Acetone, Benzene, Ethanol, Ethylbenzene, Isopropyl alcohol, Limonene, Naphthalene, Toluene, Xylene: NMAM 1501 with modifications

Benzene soluble fraction: NMAM 5042

2-Butoxyethanol: NMAM 1403 with modifications

Carbon monoxide: Direct reading, BW Technologies Ltd., Calgary, Canada

Diesel exhaust: NMAM 5040

Dipropylene glycol butyl ether: NMAM 1403 with modifications

Dipropylene glycol methyl ether: NMAM 1403 with modifications

Mercury: NMAM 6009

Propylene glycol: NMAM 5523

Total hydrocarbons (as n-hexane): NMAM 1501 with modifications

Table 6. Health symptom survey—demographics by vessel			
	International Peace	**Warrior**	**Unexposed***
Number of participants	10	7	103
Age range	22–56	27–54	18–70
Race†			
White	60%	71%	40%
Hispanic	10%	14%	29%
Asian	10%	0%	9%
Black	30%	14%	19%
Other	0%	0%	3%
Male	90%	86%	96%
Days worked oil spill	2–27	7–24	0–45
Days worked boat	2–27	2–15	0

*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.

†The total percentage is greater than 100% because some participants reported more than one race.

Table 7. Health symptom survey—reported injuries and symptoms by vessel			
	International Peace	**Warrior**	**Unexposed***
Number of participants	10†	7‡	103
Injuries			
Scrapes or cuts	0	1	11 (11%)
Burns by fire	0	0	1 (1%)
Chemical burns	0	0	0
Bad Sunburn	0	0	8 (8%)
Constitutional symptoms			
Headaches	0	4	5 (14%)
Feeling faint, dizziness, fatigue or exhaustion, or weakness	0	3	13 (13%)
Eye and upper respiratory symptoms			
Itchy eyes	0	2	5 (5%)
Nose irritation, sinus problems, or sore throat	0	1	16 (16%)
Metallic taste	0	0	0
Lower respiratory symptoms			
Coughing	0	1	8 (8%)
Trouble breathing, short of breath, chest tightness, wheezing	0	0	4 (4%)
Cardiovascular symptoms			
Fast heart beat	0	0	1 (1%)
Chest pressure	0	1	0
Gastrointestinal symptoms			
Nausea or vomiting	1	0	3 (3%)
Stomach cramps or diarrhea	0	0	7 (7%)
Skin symptoms			
Itchy skin, red skin, or rash	0	3	8 (8%)
Musculoskeletal symptoms			
Hand, shoulder, or back pain	0	0	6 (6%)
Psychosocial symptoms			
Feeling worried or stressed, pressured, depressed or hopeless, short tempered, or frequent changes in mood	1	2	7 (7%)
Heat stress symptoms §			
Any	1	4	21 (20%)
4 or more symptoms	0	1	3 (3%)

*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.

†The mission of the vessel International Peace was the application of dispersant to surface water. All 10 individuals on board completed the survey forms before the application. Interviews after application confirmed that there were no changes in survey responses. Only one person, who used personal protective equipment, was on deck during dispersant activities. All others were in the cabin.

‡The mission of the vessel Warrior was to collect water samples for measuring dispersant after aerial application. Only those on deck during the mission were asked to participate. Crew members of the vessel remained in the cabin during the mission and did not have potential for exposure. Participants completed the survey forms after their sampling activities.

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

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