Health Hazard Evaluation of Deepwater Horizon Response Workers

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The front cover shows a controlled oil burn (in-situ burn) on the Gulf of Mexico during the Deepwater Horizon Response: June 2010.

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Introduction

The April 20, 2010, explosion and collapse of the BP Deepwater Horizon oil platform in the Gulf of Mexico resulted in the release of millions of barrels of oil into Gulf waters. The response to this disaster involved the efforts of tens of thousands of workers in a variety of capacities across Louisiana, Mississippi, Alabama, Florida, Texas, and in the Gulf of Mexico itself. The diverse work included oil and tar ball removal from beaches, oil skimming and booming near shores, burning of surface oil near the source of the oil release, surface application of dispersant by vessels and aircraft, and containment and recovery work on vessels at the release site. The nature of these activities raised concerns about potential occupational exposures to chemical and physical hazards and mental stressors. The Deepwater Horizon oil release was an unprecedented event in the United States in many respects, requiring response work across a vast area of multiple jurisdictions. The type, location, and quantities of oil released; the types and quantities of dispersant used; and climatic and geographical conditions differentiate this release from past oil spills.

On May 28, 2010, the National Institute for Occupational Safety and Health (NIOSH) received a request for a health hazard evaluation (HHE) from BP management concerning health effects experienced by responders to the oil release. The request was prompted by the May 26, 2010, hospitalization of seven fishermen who were working in BP's Vessels of Opportunity (VoO) program in the Gulf of Mexico. The fishermen had been hospitalized for symptoms that were initially believed to be related to exposures experienced during their response activities, particularly booming and skimming oil.

In response to this request, we began an investigation on June 2, 2010, with an opening meeting held at the BP Operations Center in Houma, Louisiana. In attendance were representatives from NIOSH, BP, the Center for Toxicology and Environmental Health (CTEH), O'Brien's Response Management, the U.S. Coast Guard (USCG), and the Occupational Safety and Health Administration (OSHA). Objectives of this opening meeting were to discuss the initial investigations conducted by CTEH and OSHA into the events surrounding the hospitalization of the fishermen and to plan the NIOSH investigation. These plans included interviews, health symptom surveys, and on-site industrial hygiene assessments of response work activities similar to those performed by the fishermen.

As the plans were developing, BP requested that we expand the scope of the HHE to include all major offshore response activities. In addition to oil booming and skimming conducted by workers on VoO vessels, these activities included aerial and vessel-based dispersant releases, in-situ surface oil burning, containment and recovery work at the oil source, and other related offshore oil removal activities. In the weeks that followed, teams of NIOSH industrial hygienists, medical officers, and other occupational health specialists conducted on-site investigations at locations throughout the Gulf region to collect quantitative and qualitative data on potential worker exposures, health symptoms, work practices and procedures, and work organization.

On June 22, 2010, NIOSH received a request from BP for a second HHE to investigate potential hazards associated with onshore response work activities. In response to this request, teams of NIOSH personnel

evaluated practices and procedures including wildlife cleanup operations, beach cleanup operations, and decontamination and waste management activities throughout the states of Louisiana, Alabama, Mississippi, and Florida. In contrast to the offshore evaluations, which relied on traditional industrial hygiene exposure assessment methodologies and quantitative exposure monitoring to identify potential hazards, the onshore assessment relied on qualitative assessment techniques, including the use of professional judgment and expertise during observations of onshore work activities. Health symptom surveys, however, were similar to those used for the offshore evaluations.

The goals of the NIOSH HHE assessments were to describe acute health effects, evaluate occupational exposures in qualitative or quantitative assessments, and generate hypotheses regarding symptoms potentially related to work activities. These assessments were not intended to describe or investigate potential long-term or chronic health effects. The results of these investigations were reported in a series of nine interim reports and report summaries posted on the NIOSH website. The full reports were distributed electronically to key contacts for each work activity evaluated. Included in the reports were conclusions regarding the extent of hazards and exposures identified as well as recommendations for improving workplace conditions. Furthermore, all exposure and health symptom survey data were compiled in electronic spreadsheets and posted on the NIOSH website. This information can be accessed at http://www.cdc.gov/niosh/topics/oilspillresponse/gulfspillhhe.html. Additional information about other components of the NIOSH Deepwater Horizon response activities outside of the HHE investigation, including response worker rostering efforts, analyses of injury and illness data, and guidance and educational materials developed for the response can be found on the NIOSH website at http://www.cdc.gov/niosh/topics/oilspillresponse/.

This final report summarizes our evaluations made during the course of the offshore and onshore HHE investigations and describes the conditions and characteristics encountered during the event. Overarching conclusions and recommendations drawing from the entirety of the HHE investigations are also presented.

Overview and Results

Review and Evaluation of Hospitalizations

In response to the BP request to evaluate the May 26, 2010, hospitalizations of seven fishermen involved in VoO operations, we reviewed hospital records from West Jefferson Medical Center in Marrero, Louisiana, BP Healthcare Provider Reporting Forms completed by nurse case managers, and the OSHA preliminary Incident Report of Fishermen Evacuated near Grand Isle Shipyard. We also interviewed nurse case managers and CTEH and OSHA investigators. Although all seven fishermen were hospitalized on the same day, we found that their symptoms could not be linked to the chemical dispersant that some of the fishermen had originally suspected. The seven fishermen worked on five different vessels, none of which were operating in the area of dispersant use at the time. Most of the

seven fishermen reported headache, upper respiratory irritation or congestion, and nausea. Although these symptoms had disappeared or decreased in severity by the time the fishermen arrived at the hospital, they were admitted for observation as a precaution because they had reported chemical exposure. Two fishermen were hospitalized for potentially serious medical problems that were unrelated to oil or chemical exposure. All seven patients were discharged when their condition was determined to be stable or when test results were negative. Six were discharged within 1 day of admission, and the seventh was discharged after an additional day of testing. We concluded that the symptoms of headache, upper respiratory irritation or congestion, and nausea were unlikely to be related to dispersant exposure. Work-related factors (e.g., heat, fatigue, and unpleasant odors from undiluted terpene solutions used for cleaning boat decks and equipment) might have contributed to workers' symptoms.

In the period after these seven hospitalizations, the Louisiana Department of Health and Hospitals received reports of 10 additional hospitalized response workers. We reviewed these workers' hospital records. The conditions of these 10 hospitalized response workers were more severe than the conditions of the seven fishermen hospitalized on May 26, 2010, with hospitalization times ranging from 1 to 6 nights.

Five of the 10 workers, including onshore and offshore workers, identified heat as a major problem. The five workers who reported heat exposure also reported a variety of work-related and personal risk factors for heat illness; several reported multiple risk factors. All five of these workers had evidence of dehydration or a diagnosis of heat exhaustion or possible heat stroke. Five of the 10 workers (one of whom had also reported heat exposure) reported exposures to oil, hydrocarbons, or dispersant. The medical records of these five did not include information to identify specific chemicals, indicate how they came into contact with those chemicals, or describe how long they were exposed. It was reported that two of these workers were instructed to avoid exposures and, if exposed, to wear a respirator. However, the medical records of these two workers did not include sufficient detail about their oil and chemical exposures to determine whether their symptoms or diagnoses could have been related to chemical exposure and whether respiratory protection was necessary.

Exposure Evaluations of Offshore Work

Oil Dispersant Release Activities

We conducted two evaluations on board vessels releasing dispersant. These vessels were deployed to perform small-scale releases of dispersant in an area with surface oil contamination.

On June 4–5, 2010, we evaluated potential exposures experienced by workers on two vessels, the International Peace and the Warrior. During this evaluation, we conducted personal breathing zone (PBZ) and area air monitoring on both vessels (which maintained positions close to each other) during and after the application of 50 gallons of Corexit® EC9500A dispersant (Nalco, Naperville, Illinois) from the International Peace onto surface oil. An additional aerial release of 125 gallons of this dispersant onto the surface oil occurred from a support aircraft in the area. Sampling was conducted for volatile

organic compounds (VOCs), propylene glycol (a component of the dispersant), diesel exhaust, mercury (a possible component of crude oil), the benzene soluble fraction of total particulate matter, carbon monoxide (CO), and hydrogen sulfide (H_2S). The measured substances were either not detected or were present at low concentrations below individual occupational exposure limits (OELs).

On June 21–22, 2010, we conducted further exposure assessments on board the International Peace. During this evaluation, we conducted air monitoring for a number of the substances listed above during and after the application of 50 gallons of Corexit® EC9500A dispersant onto surface oil from the vessel. The substances measured were either not detected or were at concentrations well below OELs.

In-Situ Oil Burning

We assessed exposures during in-situ (i.e., on site) burns of surface oil on June 8–10, 2010. The in-situ burn team was composed of a fleet of vessels including two lead vessels (the Premier Explorer and the Sea Fox), support and safety vessels, shrimping trawlers, and rigid-hulled inflatable boats. Each shrimping trawler and a partner trawler towed one end of an approximately 300-foot long boom behind them, creating a U-shaped area to contain a quantity of surface oil suitable for burning. The duration of the burn depended on the quantity of oil enclosed by the boom and ranged from 45 minutes to 6½ hours. Typically, one to five burns could be conducted by each trawler pair per day. During a burn, the trawlers were located approximately 300 feet from the area within the boom where the burn was occurring.

During the evaluation, we conducted PBZ and area air sampling on shrimping trawlers towing booms during in-situ burns and on boats from which the burns were ignited. Sampling was conducted for VOCs, aldehydes, CO, H_2S, benzene soluble fraction of total particulate matter, diesel exhaust, and mercury. Exposures for all compounds sampled were either below detectable concentrations or well below applicable OELs, with one exception being a peak exposure of 220 parts per million (ppm) of CO recorded on the double-engine ignition boat. This peak was likely due to the build-up of exhaust from the gasoline powered engines when idling with no movement of the boat and little wind.

Oil Booming, Skimming, and Vacuuming

During June 10–20, 2010, we assessed exposures on six fishing and shrimping trawlers in the VoO program that were assigned to remove surface oil by booming and skimming. While coordinating and preparing for the evaluations on board the VoOs, we were informed that the presence of oil in any specific location was sporadic because the Gulf currents moved the oil patches frequently. On days when oil was not present on the water surface in the areas to which these vessels were assigned, the captains often directed their vessels through patches of foam (described by the crew as “dispersant foam”) on the sea surface to break up this foam.

We conducted PBZ and area air sampling for VOCs, propylene glycol, diesel exhaust, mercury, CO, H_2S, total particulate matter, and the benzene soluble fraction of total particulate matter during work

activities on the six vessels. During these evaluations, the VoOs on which we were present spent most of their time scouting for oil and breaking up foam patches. Because no oil was encountered by the VoOs on these days, we did not observe any oil cleanup work. The PBZ and area air concentrations of the measured compounds were below detectable levels or well below OELs.

An exposure assessment of an offshore oil skimming and recovery mission involving a platform supply vessel, the Queen Bee, was conducted on June 14–16, 2010. The Queen Bee was retrofitted with a USCG-operated weir skimmer, skimming control stand, high volume pumping unit, boom system, three on-deck 500-barrel storage capacity tanks, and an industrial crane used to move booms and the skimmer. The vortex weir skimmer consisted of a heavy-duty frame holding a central collection bowl and three floats. The central bowl of the skimmer created a void in the water into which the oil/water mix poured. Under the bowl were the hydraulic lines and the hose for transporting the oil/water mix to the on-deck storage tanks.

We used PBZ and area air sampling to evaluate exposures to VOCs, propylene glycol, diesel exhaust, CO, H_2S, total particulate matter, and the benzene soluble fraction of total particulate matter. PBZ and area air concentrations of the contaminants measured were below applicable OELs. The potential existed for dermal contact with oil while placing and removing the skimmer and boom from the water and during cleaning activities on deck. However, workers wore the necessary protective equipment during tasks with increased potential for dermal contact.

On June 25, 2010, we visually inspected oil skimming operations on a set of barges located in Coup Abel Pass, offshore from Grand Isle, Louisiana. The 18 barges were divided into six sets of three barges each, with each set containing a semi-truck fitted with a vacuuming system. To vacuum oil and potentially oil-contaminated plant material from the water surface near the side of the barges, workers extended a 2-inch diameter rubber vacuum hose over the side of the barge deck and lowered it approximately 8 feet to the water surface. We noted a lack of fall protection for the workers, a lack of hearing protection during vacuuming and pile driving, and musculoskeletal risks from working in awkward postures with sustained or repeated back flexion and twisting.

Oil Source Activities

On June 21–23, 2010, we assessed exposures aboard the Development Driller II (DDII) and the Discoverer Enterprise, located at the site of the Deepwater Horizon Mississippi Canyon 252 Well Number 1. At the time of the NIOSH evaluation, DD II was drilling a relief well for the purpose of pumping mud and concrete into the blown well to suppress the release of crude oil. The Discoverer Enterprise, which was located directly above the blown well, captured oil and gas from the damaged well through a lower marine riser package cap, which was placed on top of the failed Deepwater Horizon blowout preventer.

We conducted PBZ and area air sampling aboard the DD II on June 21, 2010, and aboard the Discoverer Enterprise on June 23, 2010. Air sampling on these vessels was conducted to characterize exposures of workers who were closest to the point of release where the potential for exposure to VOCs from the oil

was expected to be greatest. Unlike crews and cleanup workers aboard VoOs and cleanup workers onshore, the crews of the DD II and Discoverer Enterprise were performing operations that utilized their usual and standard work skills, PPE, training, and experience (i.e., well drilling aboard the DD II and storage and processing of crude oil aboard the Discoverer Enterprise). We surmised that the only source of nonroutine occupational exposures aboard these vessels to which the crews might have been exposed was oil on the sea surface that had been released from the blown well. PBZ and area air sampling was conducted for VOCs, sulfur compounds, propylene glycol ethers, polycyclic aromatic hydrocarbons (PAHs), CO, and H_2S. Airborne concentrations for all contaminants evaluated on the DD II and the Discoverer Enterprise were well below applicable OELs.

Exposure Evaluations of Onshore Work

Wildlife Cleanup

In June and July 2010, we made multiple site visits to assess factors related to potential exposures and occupational hazards at onshore wildlife cleaning and rehabilitation centers. The wildlife cleaning centers visited included two in Louisiana (Fort Jackson and Grand Isle) and one each in Alabama (Theodore), Florida (Pensacola), and Mississippi (Gulfport).

Birds were the most common type of wildlife being cleaned and rehabilitated at the centers. Common activities involved in the cleaning and rehabilitation process for most birds included search and retrieval; baseline health assessment of the birds; stabilization, including rehydration and feeding if needed; a series of cleaning steps that usually included the use of compounds derived from vegetable oils as pretreatment, followed by cleaning with repeated detergent and water rinses; and post-cleaning placement in a drying area, followed by placement in holding pens for rehabilitation while awaiting transport.

The task of wildlife cleaning and rehabilitation presented the opportunity for repeated and prolonged skin contact with water used in washing and rinsing the animals. This water varied from “oily” to “clean” as the animals went through the cleaning process. Routine use of PPE included safety glasses, gloves, sleeve protectors, rubber boots, Tyvek® suits, other protective coveralls, and plastic aprons. Workers handling the wildlife prior to cleaning had some potential for direct skin exposure to the oil on the animals; with PPE use, this exposure was observed to be minimal in most cases.

We identified heat as a primary exposure of concern. All sites were aware of concerns about heat and were taking actions to prevent heat stress in workers. Sites established either a formal work-rest schedule or managed potential heat stress in workers by requiring frequent rest breaks, encouraging fluid replacement, and observing workers for signs of heat-related illness.

Beach Cleanup

In July 2010, we made multiple visits to onshore worksites where beach cleanup was occurring. Onshore worksites were chosen for evaluation based on input from the command centers. Among the factors

considered in selection of sites were estimates of the level of contamination likely to be encountered, type of work activity, and number of workers. Efforts were made to evaluate worksites in each of the four affected states of Louisiana, Mississippi, Alabama, and Florida.

Sixty-seven onshore worksites were evaluated. At 59 of the 67 sites, a structured exposure assessment checklist was used. Of those 59 sites, 36 (61%) were beach cleaning sites, with six in Alabama, seven in Florida, five in Louisiana, and 18 in Mississippi. The exposure assessment checklist included a qualitative assessment by the NIOSH investigator about the level of oil residue at the site at the time of the survey. We judged 24 sites to have a level of light residue, six to have a level of moderate residue, and three to have a level of heavy residue. All sites with heavy residue and five of the six with moderate residue were in Mississippi. Even at worksites where oil residue was judged to be heavy, worker exposure to oil residue typically was judged to be limited because of the nature of the oil residue (oil-soaked sand or solid to semisolid tar balls) and the use of PPE. We saw no evidence of exposure to dispersant at the shore cleaning sites.

During the evaluations, we observed that beach cleaning tasks involved risk factors for musculoskeletal disorders, including repetitive awkward postures of the back and upper extremities while using moderate force. Workers at the beach cleaning sites used shovels, rakes, and improvised hand tools to manually remove tar balls from the sand. The most common operation observed involved workers walking the beach using tools to collect solid or semi-solid oil residue and placing the residue in large trash bags. Generally, the workers placed two or three shovels of material into a bag; filled bags weighed about 10 to 20 pounds. The main risk factors observed in the use of these tools included the following: repetitive and sustained back flexion/twisting, squatting, ground-sitting, or kneeling; repetitive upper extremity motions; awkward wrist/forearm twisting; moderate upper extremity forces to handle tools and mixtures of sand and tar balls; and moderate low back force to handle bags of sand and tar balls. We recommended further evaluation and testing of different types of manual tools to improve their design, manufacture, and selection for future onshore oil spill cleaning work.

We identified heat to be a primary exposure of concern. Site supervisory staff measured heat and humidity in a variety of ways at the work sites. Recommended work/rest regimens were based on the heat index. The guidelines called for work/rest regimens varying from “no limit” to the most limiting regimen of 10 minutes of work followed by 50 minutes of rest. We observed variability in application of the heat stress guidelines. Some contractors appeared to do the minimum to follow the guidelines, while others followed a work/rest regimen more conservative than called for by the guidelines.

Decontamination and Waste Management

During July and August, we conducted observational exposure assessments and site characterizations at 15 equipment and boat repair/decontamination or waste management sites throughout Florida, Mississippi, Alabama, and Louisiana. Decontamination activities provided potential for exposure to weathered oil and cleaning agents. The use of diesel- and gasoline-powered equipment also posed risks of potential exposures to diesel exhaust, CO, and noise. However, we deemed heat stress as the most

significant hazard at the visited sites; we noted that decontamination workers were at increased risk because of layering of PPE. We found that issues related to heat appeared well-managed and controlled by on-site safety contractors. For boom repair workers, skin exposures to solvent-based chemical adhesives were identified as a potential health hazard because workers had not been provided or were not wearing chemically-resistant gloves at the times of the assessments. The ergonomic hazards faced by repair/decontamination and waste management workers were unique among response workers. Work tasks such as handling and moving booms and other equipment to be cleaned and the actions associated with operating the pressure washers led to awkward and heavy lifting tasks, which could contribute to musculoskeletal symptoms.

In August, we conducted quantitative exposure assessments at two boom and vessel decontamination operations in Port Fourchon, Louisiana. Decontamination job tasks included spraying a chemical cleaner onto oil-contaminated equipment with a standard hand-held garden-type sprayer, scrubbing the equipment with brushes, and rinsing the oil-contaminated equipment with water supplied by diesel-operated pressure washers. PPE used by these workers included protective steel-toed boots, an inner nitrile glove under an outer chemical resistant glove, full-body coveralls, hard hat, safety glasses, and face shield. To minimize heat stress, work/rest regimens consisting of cycles of 20 minutes of work followed by 40 minutes of rest in a cooled or shaded environment were enforced during each work shift.

We collected PBZ and area air samples for VOCs, glycol ethers, total particulate matter, the benzene-soluble fraction of the total particulate matter, PAHs, CO, diesel exhaust, and noise during decontamination activities. Temperature and relative humidity measurements were also taken. Examples of VOCs found to be present included C_9-C_{16} aliphatic hydrocarbons, 2-butoxyethanol, propylene glycol t-butyl ether, and limonene. The air concentrations for these and other chemicals quantified were below applicable OELs. Noise exposure monitoring showed the potential for noise exposures above the NIOSH recommended exposure limit of 85 decibels A-weighted. Recommendations were made for employees to wear hearing protection during pressure washing, to use such hearing protection within the context of a hearing conservation program, and for site safety officers to monitor these and other work practices for potential noise exposure hazards. We observed heat stress as a significant issue for workers, particularly due to the PPE required for these activities. Recommendations were made for continued application of the enforced work/rest regimen and attention to worker training in the recognition of the heat stress hazard, potential symptoms associated with heat stress, and the importance of hydration.

Infirmary Log Reviews

We collected and reviewed daily infirmary logs from June 1–30, 2010, for response workers seen at the Deepwater Horizon Venice, Louisiana, Branch Infirmary. Among the 1004 reported visits, 363 (36%) were for ear, nose, and throat and respiratory complaints. Of the respiratory complaint visits, 230 (63%) were classified as sinus/congestion. Orthopedic/injury was the second most commonly reported complaint, accounting for 146 (15%) visits. Heat-related disorders were reported in 2% of visits; however, nonspecific signs (e.g., headache, dizziness, and cramps) recorded separately could have been early signs of heat-related disorders. Of these 1004 infirmary visits, 717 (71%) resulted in on-site

evaluation by emergency medical technicians and treatment with over-the-counter medications. Although this evaluation analyzed infirmary log data from only one location for 1 month of the response, we determined that these data do not reveal unrecognized or unreported occupational illness due to workplace exposures.

Health Symptom Surveys

Voluntary health symptom surveys were distributed to workers at offshore and onshore locations where we conducted evaluations. Given the magnitude of the response and large number of response workers employed in the cleanup, we administered the survey to convenience samples of workers performing a wide variety of job tasks. Throughout our health symptom survey analysis, we compared groups of workers self-reporting exposure(s) to 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. Although we believe our recommendations, which are based on the results of these surveys, are applicable for response workers performing similar tasks in other locations, we acknowledge that we surveyed a small subset of the entire response workforce.

From June 7–22, 2010, 826 surveys were completed by workers in the Plaquemines Branch Incident Command System, also known as the Venice, Louisiana, Field Operations Branch (FOB). Workers were asked to report symptoms they experienced while working during response activities. The most frequently reported symptoms were headache, upper respiratory symptoms, and symptoms consistent with heat stress. Workers who reported exposures to oil and dispersant reported higher prevalences of all types of symptoms compared to workers who reported no such exposures.

During the June 4–5, 2010, evaluation of dispersant release on board the International Peace and the Warrior, health symptom surveys were distributed to vessel workers immediately and 4 hours after release of the dispersant. Of the 17 respondents, very few on either vessel reported upper or lower respiratory, gastrointestinal, musculoskeletal, or psychological symptoms or injuries. Those on the International Peace reported very few symptoms, while some workers on the Warrior reported constitutional (i.e., headaches and fatigue) and skin symptoms, similar to a comparison group of workers recruited from the Venice, Louisiana FOB and the Commanders' Camp who reported that they had not worked on boats and had no exposures to oil, dispersant, cleaner, or other chemicals. Health symptom surveys were also distributed to five vessel workers on board the International Peace during the June 21–22, 2010 evaluation. Health symptoms reported by vessel workers surveyed during this evaluation included itching eyes, exhaustion, musculoskeletal pain, and feelings of "work pressure."

We distributed and collected health symptom survey forms on June 10, 2010, for workers on board the lead in-situ burn team vessels, the Sea Fox and the Premier Explorer. The types of symptoms reported by the 39 respondents were similar to those reported by response workers who were not performing in-situ burning. The most frequently reported symptoms on both vessels were similar: upper respiratory symptoms and constitutional symptoms. Workers on the Sea Fox also reported itchy eyes, coughing, musculoskeletal pain, and psychosocial symptoms (i.e., feeling worried, stressed, pressured, etc.).

Overall, workers involved in the in-situ burn did report a higher frequency of these symptoms than the comparison group.

Health symptom surveys were distributed at a USCG safety and administrative meeting on June 18, 2010, to workers who were either USCG personnel providing safety oversight to off-shore vessels or administrative/command services at the Venice, Louisiana FOB, or civilian contractors providing safety oversight for other responders working off-shore. A total of 74 attendees completed the survey. The types of symptoms reported among these USCG members and contractor safety personnel were similar to a comparison group of response workers who reported no exposures to oil, dispersant, cleaner, or other chemicals. Headaches, however, were reported more frequently in those surveyed at the USCG safety meeting. Those reporting exposure to oil and dispersants had significantly higher prevalences of upper respiratory symptoms and cough than those not exposed. Symptoms related to heat exposure were the most frequent in all groups.

We collected self-administered health symptom surveys from response workers on a floating barge hotel, Floating City #1 (located 10 miles northeast of Venice, Louisiana, at the mouth of the Baptiste Collette channel), on June 19–23, 2010. Of 500 eligible responders, captains, and deckhands, 189 completed the survey. The types of symptoms reported among respondents were similar to those reported by a comparison group of response workers who reported no exposures to oil, dispersant, cleaner, or other chemicals. Symptoms related to heat exposure and upper respiratory symptoms were the most frequently reported in both groups.

Health symptom surveys were distributed on June 21–23, 2010, to a convenience sample of workers onboard the DDII and Discoverer Enterprise at the site of the oil release. Overall, the 28 workers onboard the DDII who completed the survey reported a wider variety and a higher number of health symptoms than the 34 employees aboard the Discoverer Enterprise or the comparison group. Headache and symptoms consistent with heat stress were reported among survey respondents on both vessels, while symptoms of feeling worried or stressed, and feeling pressured were highest among respondents who worked aboard the DDII.

During June and July 2010, we asked workers at onshore wildlife cleanup sites to complete a health symptom survey. Most of the health outcomes and symptoms reported in these surveys were more prevalent in the wildlife cleaning workers than the comparison group of workers who had no reports of exposure to oil, dispersant, or other chemicals. Among the 54 wildlife cleaning workers who completed the survey, scrapes and cuts were reported by 67%, itchy or red skin or rash were reported by 46%, and symptoms of headache or feeling faint, dizzy, or fatigued were reported by 35%. Hand, shoulder, or back pain was reported by 39% of the wildlife cleaning workers. Twenty-four percent of participants reported one or more of five psychosocial symptoms (feeling worried or stressed; feeling pressured; feeling depressed or hopeless; feeling short-tempered; frequent changes in mood).

In July 2010, health symptom surveys were distributed to beach cleanup workers. More injuries and symptoms were reported among the 1,899 responding workers than among the comparison group. One or more of nine nonspecific symptoms that could be related to heat stress was reported by 37% of the

beach cleaning workers. Four or more of those symptoms, a constellation of symptoms considered in this evaluation as a more specific indicator of heat stress, were reported by 7%. Among the individual symptoms reported most frequently were headaches (28%); coughing (19%); and hand, shoulder, or back pain (17%). Eighteen percent of participants reported one or more of five psychosocial symptoms.

We distributed health symptom surveys to workers at repair/decontamination and waste management sites during July and August 2010. One or more of nine nonspecific symptoms that could be related to heat stress were reported by 38% of the 499 responding repair/decontamination and waste management workers. Four or more of the symptoms which were more specific indicators of heat stress were reported by 6%. Other individual symptoms reported most frequently were headaches, coughing, and hand, shoulder, or back pain, as well as one or more of five psychosocial symptoms.

Psychosocial and Work Organization Issues

In August 2010, we conducted focus groups to assess work organization processes and practices as well as job stress among safety professionals involved in the response. Work organization refers to the work processes (the way jobs are designed and performed) and to the organizational practices (management and work methods and accompanying workforce policies) that influence how jobs are designed. The purpose of these focus groups was to gain a more in-depth understanding of the way the work was designed and performed, the policies that were in place, and job stress and protective (e.g., coping) factors among emergency response workers during response operations. Safety professionals operating out of Venice, Louisiana, were chosen as the target population because of their knowledge of the organization of work, policies, and procedures for response workers on the water. While not necessarily representative of the general population of response workers, this target group of safety professionals was familiar with the day-to-day operations of the Deepwater Horizon responders, and worked closely with them on health and safety-related issues.

The following themes, listed in order of most frequently reported, emerged from the discussions as work organization factors and job stressors for the safety professionals and individuals they supervise or oversee: (1) heat and environmental conditions, intensified by the use of PPE; (2) basic living issues (including physical and mental fatigue) and food arrangements; (3) job insecurity; (4) management and communication issues including a lack of clarity about the chain of command for decision-making and who had tasking authority and priority; (5) frequent changes in rules, procedures, and protocol; and (6) varying levels of safety knowledge, experience, and training. Indicators of job stress included loss of temper, acting out in frustration or anger, loss of enthusiasm, and low morale.

Discussion and Conclusions

These evaluations revealed the potential for numerous occupational hazards. PBZ and area air sampling at specific sites and during specific activities consistently revealed nondetectable to low levels of

individual chemicals. Nonetheless, mixed low-level exposures to crude oil, dispersant, and other chemicals; heat stress, psychosocial strains, ergonomic and other injury hazards; and pre-existing personal health risk factors all may have contributed to health symptoms reported by response workers. An additional potential contributing factor for the acute respiratory symptoms reported by some response workers is the formation of reactive aldehydes and ozone from the environmental photochemical activity on volatile hydrocarbons [Goldstein et al. 2011]. Nonspecific symptoms such as headache, eye and respiratory irritation, and fatigue were more commonly reported by responders who self-reported exposures to oil, dispersants, or other chemicals compared to workers who self-reported no such exposures. While no one hazard or exposure can explain the increased reporting of such symptoms among this group of workers, eliminating or reducing all such hazards in as comprehensive a manner as possible will decrease the likelihood of health effects during future responses such as this.

Heat Stress

In most work sites evaluated, the conditions for heat stress were present, significant, and often the most pressing concern for the health and safety of response workers. Where we measured environmental conditions, temperatures often exceeded 90°F–100°F, with high relative humidity, creating conditions for severe heat strain. With the addition of required PPE such as full body coveralls and protective gloves and boots, the possibility of health effects related to heat was intensified. In response to these conditions, heat stress management plans were developed by BP and observed in use at the sites evaluated. These protocols often centered on a work/rest regimen that provided a sufficient rest period for the worker to cool and rehydrate after a work period. A common cycle was a 20-minute work period followed by a 40-minute rest and rehydration period, but this varied by site and conditions. At many locations, these cycles were strictly enforced, as was mandatory rehydration with water or electrolyte-providing beverages, which were uniformly observed to be plentiful and readily available. However, surveillance conducted by the Louisiana Department of Health and Hospitals revealed 10 workers hospitalized between May 28, 2010, and June 22, 2010. Of these 10 workers, five identified heat as a major problem and reported a variety of work-related and personal risk factors for heat illness. These five had evidence of dehydration or a diagnosis of heat exhaustion or possible heat stroke. To prevent such health effects, it is imperative to strictly adhere to heat stress management protocols at all locations. These protocols should include the provision of shaded or cooled rest areas and the improvement of worker training regarding the hazards of heat stress and the identification of early signs and symptoms of heat strain.

The role of PPE worn by workers is intended to be a protective one to prevent harmful exposures. It is imperative to conduct continual evaluations of the need for specific PPE such as full-body coveralls throughout emergency responses such as this to determine their necessity. When exposures have been evaluated and determined to be minimal or insignificant, overuse of PPE can have an unintended effect of burdening the worker with unnecessary gear that can exacerbate heat stress, limit visibility, and increase the possibility of slips and trips. It is important that trained occupational safety and health professionals develop and implement guidelines for determining when PPE use is truly necessary. Balancing the need to protect workers from potential exposures without creating unnecessary hazards

for workers from too high a level of PPE is critical. Medical support staff was available at many sites where workers were required to wear PPE. This staff played an important role in monitoring possible health effects and providing on-site medical assessments with referral for higher levels of care as needed.

Chemical Exposures

A large number of chemicals was sampled for over the course of the HHE. These included VOCs, PAHs, and H_2S from the oil itself or cleaning chemicals used; VOCs, PAHs, aldehydes, CO, and particulates from combustion sources, including burning oil and natural gas or the use of gasoline-powered engines; VOCs, glycol ethers, and propylene glycol from dispersants; and diesel exhaust from the use of diesel engines. Sampling was conducted at offshore and onshore worksites during activities of concern. Our sampling strategies included full-shift air sampling using validated NIOSH sampling and analytical methods. Throughout the evaluation, results for all airborne chemicals sampled were uniformly nondetectable or at levels well below applicable OELs. The exception to this was peak CO levels likely due to the build-up of gasoline exhaust from idling outboard motors involved in in-situ burns. The results for all compounds measured at levels below detectable concentrations or at concentrations below OELs may reflect several important considerations. For example, the lack of significant exposures to VOCs may reflect the lack of high volatility compounds from the oil at those worksites. Higher volatility compounds initially present in the oil may have dissipated shortly after release and during the weathering process so that concentrations on vessels and onshore were minimal. Combustion byproducts produced at the in-situ burns did not appear to exist in high concentrations at the distance the boats maintained from the smoke plume, reflecting the upward migration of such compounds in the ascending column of smoke plume extending above the workers' location. Open air and wind action helped dilute airborne concentrations during the aerial and vessel-based dispersant releases evaluated so that concentrations at the vessel level were low.

We attempted to evaluate activities and job duties that were representative of the work responders conducted daily. The intent of the air sampling was to provide an accurate assessment of the types and levels of exposures to airborne chemicals to which the workers were exposed. On the basis of sampling results, recommendations for additional respiratory protection were not deemed necessary. However, it is recognized that changing conditions at worksites may present opportunities for exposures at levels differing from results obtained on the days NIOSH teams were present. Therefore, it is imperative that company and contractor health and safety representatives conduct thorough, full-shift and short-term exposure sampling throughout responses such as this to ensure that changing conditions can be immediately responded to and protections implemented, as warranted.

In addition to quantitative exposure sampling, we assessed work practices in a qualitative manner to identify potential hazardous exposures. In particular, we sought to identify potential dermal exposures to oil, dispersant, or other chemicals. Observational exposure characterization was performed at numerous beaches in Louisiana, Mississippi, Alabama, and Florida where cleanup was occurring. Even at beach cleaning worksites where oil residue was judged by our teams to be heavy, worker exposure to oil residue was typically observed to be limited, with no evidence of exposure to dispersant. While the use

of PPE (gloves, coveralls, face shields, goggles, etc.) was typically found to be matched to the level of expected or potential dermal exposure at many sites, PPE was not always used as directed. For example, safety protocol during in-situ burns dictated the use of flame-resistant coveralls and leather gloves by the individual placing the ignition package. On several occasions, we observed that only the top half of the coveralls was donned (i.e., the worker did not step into legs of the coveralls) and no gloves were worn. Proper training and consistent PPE use is an important component in preventing dermal exposures and injuries.

Work Organization Factors and Psychosocial Stress

In addition to physical and chemical stressors, the mental and psychosocial stressors of performing response work for this type of event are an important aspect of worker safety and health. Our health symptom surveys asked about the extent of stress-related and mental health symptoms experienced during response work. Among those surveyed, the percentage of response workers who reported one or more symptoms related to psychosocial stress (feelings of "work pressure," being worried or stressed, depressed or hopeless, short-tempered, or experiencing frequent changes in mood) ranged from 1% to 24% of those surveyed across groups. Although it is difficult from this type of survey to assess the extent to which reported symptoms were specifically related to work, the information provided by the focus groups, discussed below, was helpful in identifying work-related factors that should be addressed.

Focus group discussions on psychosocial issues revealed several themes that increased the chances of developing symptoms of stress, including heat and environmental conditions, basic living conditions, job insecurity, and management and communications issues. For example, workers in the focus groups reported being subjected to crowded and sometimes unsanitary living quarters with limited personal space or privacy. This resulted in some reports of tension and confrontations among workers. Focus group participants also reported that the long work days (generally more than 12 hours) resulted in considerable mental and physical fatigue, with little opportunity to recuperate after working many consecutive days. Uncertainty over how long the workers could expect to be employed resulted in many of the response workers feeling on edge. Confusion and frustration due to multiple, conflicting directives from various areas of the chain of command and issues related to poor communication concerning decision-making resulted in increased stress. The difficulty of being away from home and family also was regularly reported as a source of psychosocial stress.

Work organization, basic living conditions, job insecurity, and communication should be addressed in a comprehensive occupational safety and health prevention program. Development, implementation, and enforcement of clear policies and guidelines throughout a response can minimize psychosocial impacts for workers.

Ergonomics

Ergonomic issues were identified at several locations, and musculoskeletal symptoms were reported by workers in our health symptom surveys. We observed repetitive forceful movements and awkward postures of the back and upper extremities when performing lifting, pushing, and pulling activities at

decontamination and waste management sites, beach cleaning, wildlife cleaning, and oil skimming and vacuuming operations. Awkward and repetitive tasks can lead to increased risk of musculoskeletal disorders, particularly in the hand, shoulder, and back. In fact, musculoskeletal injuries were the second largest category of complaints found in infirmary logs we reviewed. Health and safety professionals should evaluate tasks and work practices for ergonomic hazards and devise preventive solutions to reduce the risk of musculoskeletal injury. Qualified ergonomists may contribute to the redesign of work processes and practices as well as the development of more ergonomically efficient tools appropriate for specific tasks (e.g., for beach cleaning activities).

Tobacco Use

We observed the extensive use of tobacco, especially cigarettes and smokeless tobacco products such as chew, dip, or snuff, by response workers at the sites. The health hazards associated with the use of tobacco products are well documented; effects include cardiovascular and coronary heart disease and a wide variety of cancers, including oral cavity, laryngeal, pharyngeal, esophageal, lung, and stomach cancers. While these health effects are widely acknowledged, less is known about the role exposure to tobacco products and cigarette smoke may play in an additive or synergistic manner with exposure to other chemical or physical hazards that may be present in emergency responses. Workers should pursue strategies to quit the use of tobacco products to prevent exposures to themselves and work colleagues. Smoking should be discouraged at all worksites, including contracted vessels. Employers are encouraged to provide smoking cessation programs for employees, ideally with the goal of attaining a smoke-free workplace.

Limitations of the Evaluations

We used a combination of quantitative and qualitative exposure methods during our evaluations. The quantitative evaluations focused on air sampling for a variety of chemicals to determine levels of exposure. Observational assessments provided a qualitative measure of potential exposures to complement sampling. The combination of these approaches provided valuable information on the types and extent of worker exposures. Despite attempts to identify potential hazards and issues of importance using these two approaches, several limitations were inherent in the investigations. These limitations include the fact that Deepwater Horizon response work was stretched over an extremely large geographical area, making the evaluation of all worksites infeasible. Response work activities and exposures were quite dynamic throughout the response, so conditions at one point in time may not fully represent all conditions encountered by workers. Despite these limitations, we believe the issues we identified are applicable to the overall response. The consistency of NIOSH results and conclusions across the sites and activities we evaluated, along with consistency of our results with the quantitative measurements reported by other investigating organizations such as OSHA, USCG, and BP and its contractors, support the idea that our results have accurately characterized occupational exposures for the types of work included in our evaluations.

Occupational Health Considerations for Future Large-Scale Response Events

Our evaluations identified hazards and occupational health considerations for future large-scale emergency response events. The development and effective implementation of comprehensive occupational safety and health programs are essential to preventing adverse health effects during emergency responses. Although each event presents unique issues, our experiences reveal needs and suggest strategies that would apply to most situations.

Illness/Injury Surveillance

Because of the large scale increase in the number of workers responding to the oil release, the necessity of rapidly establishing a widespread system of surveillance for illnesses and injuries was a high priority. The Louisiana Department of Health and Hospitals established a sentinel surveillance system to track and evaluate acute health effects reported through hospital emergency departments, clinics, physicians' offices, and the Louisiana Poison Control Center. The system captured reports of workers' symptoms and hospitalizations thought to be related to Deepwater Horizon response work.

For a surveillance system to capture the needed information, we recommend making occupational exposure history a component of a complete history and physical examination administered by the examining physician or healthcare professional. This occupational history would gather important information regarding the patient's exposures to chemicals or other potentially hazardous agents, including relationship of those exposures to the onset of symptoms, and any use of PPE or other protective measures. Additionally, we recommend collecting this information on incident reporting forms collected by on-site health and safety professionals so it can be relayed to physicians or other healthcare professionals should the worker require further medical attention.

Medical Clearance and Preplacement Evaluations

Preplacement evaluations are an important component in protecting workers with job duties that pose physical, mental, and chemical hazards, especially in large-scale emergency responses where workers may be performing unfamiliar tasks in unfamiliar environments. These evaluations are not meant to be a formal fitness for duty examination, but present a unique opportunity in several respects. They help health professionals identify individuals with health concerns that need to be addressed and those with specific susceptibilities whose activities may need to be restricted or modified. They also allow health professionals to identify medication, immunization, or training needs for workers and provide valuable information to the workers themselves on their health status and potential demands of the work they will encounter. These evaluations help document the worker's health status and may provide an opportunity for the worker to be directed to further medical evaluation as necessary. Finally, these evaluations can provide baseline information on health status that may be useful for future evaluations

or comparisons. Recommendations on when and what types of medical evaluations should be done and the minimum information to gather during such an evaluation can be found on the NIOSH website at http://www.cdc.gov/niosh/topics/oilspillresponse/preplacement.html.

Risk Communication

The clear and consistent use of effective risk communication strategies is critically important in emergency response events. Our experience in the Deepwater Horizon response shows that these strategies can be improved upon by all involved parties. Many groups such as response workers; the general public; the scientific and medical community; advocacy organizations; local, state, and federal government agencies; and the media sought timely and accurate information about the event. Meeting the needs of these diverse groups is challenging. We received reports that messages and information were at times insufficient for their intended audience. For example, the need for detailed, timely, and specific information on all aspects of the occupational exposure evaluations was important to the scientific community and advocacy organizations. Members of these groups described a lack of details in official reports and communications from BP. Missing details included circumstances, conditions, and specific locations during which exposure measurements were collected; specific sampling methodology used; activities the workers were performing at the time of data collection; whether the samples were general area air samples or PBZ samples; and descriptions of the quantities or presence of oil, dispersants, or other chemicals to which the workers may have been exposed. We also received reports of the necessity for improved and more widely disseminated risk messages. These messages should be conveyed in simple and easy-to-understand terms for workers and the general public. Likewise, they should be tailored to available forms of communication and use the primary language of the intended audience.

The importance of good risk communication cannot be understated. Understanding and implementing improved risk communication strategies and messages learned from the Deepwater Horizon oil release will allow for a clearer understanding of the occupational hazards faced by response workers. Such knowledge will improve our ability to respond to those hazards, and to protect workers from safety and health hazards.

Reference

Goldstein B, Osofsky H, Lichtveld M [2011]. The gulf oil spill. N Engl J Med *364*(14): 1334–1348.

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Availability of Report

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