

# Mental health indicators associated with oil spill response and clean-up: cross-sectional analysis of the GULF STUDY cohort



Richard K Kwok, John A McGrath, Sarah R Lowe, Lawrence S Engel, W Braxton Jackson 2nd, Matthew D Curry, Julianne Payne, Sandro Galea, Dale P Sandler



## Summary

**Background** Adverse mental health effects have been reported following oil spills but few studies have identified specific responsible attributes of the clean-up experience. We aimed to analyse the effects of the 2010 Deepwater Horizon (Gulf of Mexico) disaster on the mental health of individuals involved in oil spill response and clean-up.

**Methods** We used data from the Gulf Long-term Follow-up Study, a cohort of workers and volunteers involved in oil spill clean-up after the Deepwater Horizon disaster. We included 8968 workers (hired after completing training for oil spill response and clean-up) and 2225 non-workers (completed training but were not hired) who completed a Patient Health Questionnaire-8 and four-item Primary Care PTSD Screen to assess for probable depression and post-traumatic stress disorder (PTSD) indicators. Participants were recruited between March 28, 2011, and March 29, 2013. The mental health indicators were assessed at home visits done between May 12, 2011, and May 15, 2013. We used regression models to analyse the effect of potentially stressful job experiences, job type, and total hydrocarbon exposure on mental health indicators.

**Findings** Oil spill response and clean-up work was associated with increased prevalence of depression (prevalence ratio [PR] 1.22, 95% CI 1.08–1.37) and PTSD (PR 1.35, 95% CI 1.07–1.71). Among workers, individuals who reported smelling oil, dispersants, or cleaning chemicals had an elevated prevalence of depression (1.56, 1.37–1.78) and PTSD (2.25, 1.71–2.96). Stopping work because of the heat was also associated with depression (1.37, 1.23–1.53) and PTSD (1.41, 1.15–1.74), as was working as a commercial fisherman before the spill (1.38, 1.21–1.57; and 2.01, 1.58–2.55, respectively). An increase in exposure to total hydrocarbons appeared to be associated with depression and PTSD, but after taking into account oil spill job experiences, only the association between the highest amount of total hydrocarbons and PTSD remained (1.75, 1.11–2.76).

**Interpretation** Oil spill clean-up workers with high amounts of total hydrocarbon exposure or potentially stressful job experiences had an increased prevalence of depression and PTSD. These findings provide evidence that response and clean-up work is associated with adverse psychological effects and suggest the need for mental health services both before and after the event.

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## Introduction

The 2010 Deepwater Horizon oil spill disaster was the largest marine oil spill in US history.<sup>1</sup> Previous studies<sup>2,3</sup> of communities affected by oil spills suggest several factors that might have increased the risk of psychological adversity after the disaster among Gulf Coast residents. These include negative media coverage, severe harm to ecosystems and wildlife, disruption to local industries (eg, fishing, oil and gas exploration, and tourism), uncertainty about the physical health effects of the oil and chemical dispersants, residential proximity to the oil spill, and previous experiences with disasters among those individuals affected, including Hurricanes Katrina and Rita in 2005, and Hurricane Isaac in 2008.<sup>4–13</sup>

Despite these risks, two studies<sup>14,15</sup> of Gulf Coast residents documented few prominent changes in mental health in the general population from before to after the spill. Several factors have been proposed that might have acted as potential buffers to a psychological effect of the event in the general population, particularly the small number of spill-related injuries and deaths, minimal disruptions to vital services, and few long-term economic effects of the disaster.<sup>16</sup> However, mental health after the oil spill varied substantially, with residents at greater risks of adverse outcomes if they had physical exposure to oil during the oil spill or were financially impacted by it.<sup>12</sup> Individuals who participated in oil spill response and clean-up activities are potentially a high-risk group.<sup>17</sup> These workers repeatedly witnessed the vast effects of

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Epidemiology Branch, National Institute of Environmental Health Sciences, National Institutes of Health, Department of Health and Human Services, Research Triangle Park, NC, USA (R K Kwok PhD, Prof D P Sandler PhD); Department of Psychology, Montclair State University, Montclair, NJ, USA (S R Lowe PhD); Department of Epidemiology, University of North Carolina at Chapel Hill, Chapel Hill, NC, USA (L S Engel PhD); Social & Scientific Systems Inc, Durham, NC, USA (J A McGrath MA, W B Jackson 2nd MPH, M D Curry MA); RTI International, Durham, NC, USA (J Payne PhD); and School of Public Health, Boston University, Boston, MA, USA (Prof S Galea MD)

Correspondence to:  
Dr Richard K Kwok, Epidemiology Branch, National Institute of Environmental Health Sciences, Research Triangle Park, NC 27709-2233, USA  
[richard.kwok@nih.gov](mailto:richard.kwok@nih.gov)

### Research in context

#### Evidence before this study

Little is known about the potential health effects of exposures from oil spills. A MEDLINE search of peer-reviewed publications from Jan 1, 1955, to March 1, 2017, under the search terms “oil spill”, “human health effects”, “mental health”, “depression”, “PTSD”, “disaster response”, and “petroleum” yielded only eight oil spills that were studied for health effects among affected community members or response workers, despite the fact that more than 38 major oil tanker spills have happened since 1970. Although we reviewed all published studies, we focused on prospective studies done around the oil spills of the Exxon Valdez (Prince William Sound, Gulf of Alaska), Hebei Spirit (South Korea), Prestige (Galicia, Spain), and Deepwater Horizon (Gulf of Mexico). Crude oil contains a number of components known to be toxic to human health. The Deepwater Horizon oil spill was unprecedented in size and duration, and response activities involved exposure to oil, combustion products, chemicals in dispersants and cleaning solutions, and a range of physical and psychological stressors that could affect health. Although previous studies following other oil spills, such as Exxon Valdez, indicated increased risk for psychological health effects, it is not clear whether this effect is from direct chemical exposure or from non-chemical oil spill experiences.

#### Added value of this study

To our knowledge, we have done the first study to document the psychological impact of oil spill response and clean-up

work from the Deepwater Horizon oil spill. We used data from more than 6200 individuals in the GuLF STUDY, which is considerably larger than previous studies, to investigate whether quantitative exposures and experiences during oil spill response and clean-up work were associated with increased prevalence of depression and post-traumatic stress disorder (PTSD). The inclusion of quantitative exposure measures at the individual level is also a considerable advance from previous studies.

#### Implications of all the available evidence

We found that participants who engaged in clean-up work had a significantly higher prevalence of both depression and PTSD, even when accounting for demographic characteristics and other predictors of post-disaster mental health, including pre-existing mental health conditions, residential proximity to the oil spill in the Gulf of Mexico, and previous disaster experience. Potentially stressful experiences, such as smelling oil, dispersants, or cleaning chemicals, having to stop working because of the heat, or having worked as a commercial fisherman before the spill (indicating the potential loss of livelihood because of the spill), were particularly crucial. These findings provide further evidence that clean-up work is associated with adverse psychological consequences and suggest the need for prescreening and postevent services to treat workers' mental health needs when the next disaster inevitably strikes.

the Deepwater Horizon oil spill on the environment and had direct contact with hazardous chemicals typically found in oil, chemical dispersants, and cleaning solutions, such as benzene, toluene, ethylbenzene, xylene, 2-butoxyethanol, and propylene glycol, which increase the risk for adverse health conditions (eg, respiratory conditions and headaches).<sup>6,7</sup> These exposures could be associated with poor mental health.<sup>7,18,19</sup> Additionally, it is possible that the chemical exposures encountered through oil spill response and clean-up might be neurotoxic, and physical contact with these chemicals could have the potential to directly induce adverse mental health effects.<sup>20</sup>

Results of two previous studies<sup>21,22</sup> suggest that oil spill response and clean-up increases the risk for adverse mental health indicators. The first, a study of the Exxon Valdez (Gulf of Alaska) oil spill, found an increased prevalence of post-traumatic stress disorder (PTSD) and depression among residents, including workers involved in oil spill response and clean-up, who were classified as highly exposed.<sup>21</sup> The second, a community survey after the Deepwater Horizon oil spill, found higher PTSD symptoms among respondents employed in any of five occupations classified as at-risk (including oil rig work) than among respondents not employed in at-risk occupations.<sup>22</sup> However, these studies were done

primarily among a small sample of community members who tended to have little or no direct physical contact with oil. Furthermore, to our knowledge, no study has evaluated the mental health risks of oil spill response and clean-up from the Deepwater Horizon oil spill. Disaster recovery work has been associated with elevated mental health risks in other contexts, including in the aftermath of the terrorist attacks on Sept 11, 2001.<sup>23</sup> However, whether these results apply to oil spills is not known.

We aimed to assess the psychological effect of oil spill response and clean-up from the Deepwater Horizon oil spill. We investigated both quantitative chemical exposures and qualitative experiences during this work to determine any potential association with increased prevalence of PTSD symptoms and depression. The types of jobs related to oil spill response and clean-up were also analysed as a proxy for all exposures encountered during the spill to determine specific responsible attributes from the various jobs that might lead to negative mental health effects.

## Methods

### Data collection and participants

We used data from the Gulf Long-term Follow-up (GuLF) STUDY, a prospective cohort study of individuals aged 21 years or older who completed oil spill clean-up safety

training and were either hired to do oil spill response and clean-up (workers) or were not hired (non-workers) in 2010.<sup>24</sup> A detailed description of the GuLF STUDY has been published previously.<sup>24</sup> Briefly, telephone interviews for enrolment were done between March 28, 2011, and March 29, 2013, and gathered information about spill-related activities, demographics, lifestyle, and health. Extensive efforts were taken to encourage participation and minimise non-response, including multiple contact attempts, on-the-ground locating, and mass media advertising campaigns. Within a few weeks after enrolment, participants from the five Gulf states (Alabama, Florida, Louisiana, Mississippi, and Texas, USA) were invited to participate in a home visit where additional questionnaires, biological and environmental samples, and anthropometric and physiological measurements were collected by trained staff who also obtained written informed consent during the home visits that occurred between May 12, 2011, and May 15, 2013. Participants received US\$50 for completing the home visit. Data on mental health indicators were collected during the home visit and were used in the analyses presented. The Institutional Review Board of the National Institute of Environmental Health Sciences approved the GuLF STUDY protocol.

### Outcomes

We used two standardised mental health inventories shown to have strong validity and reliability in previous work.<sup>25,26</sup> The Patient Health Questionnaire-8 (PHQ-8) contains eight questions asking participants how many days they have had symptoms of depression during the past 2 weeks. For each item, a value was assigned corresponding to the number of days participants reported symptoms: 0 was 0–1 days, 1 was 2–6 days, 2 was 7–11 days, and 3 was 12–14 days. The values for all items were summed to arrive at a total PHQ-8 score, with scores of ten or more suggesting a probable indication of moderate to severe depression, hereafter referred to as depression (Cronbach's  $\alpha=0.90$ ).<sup>27</sup>

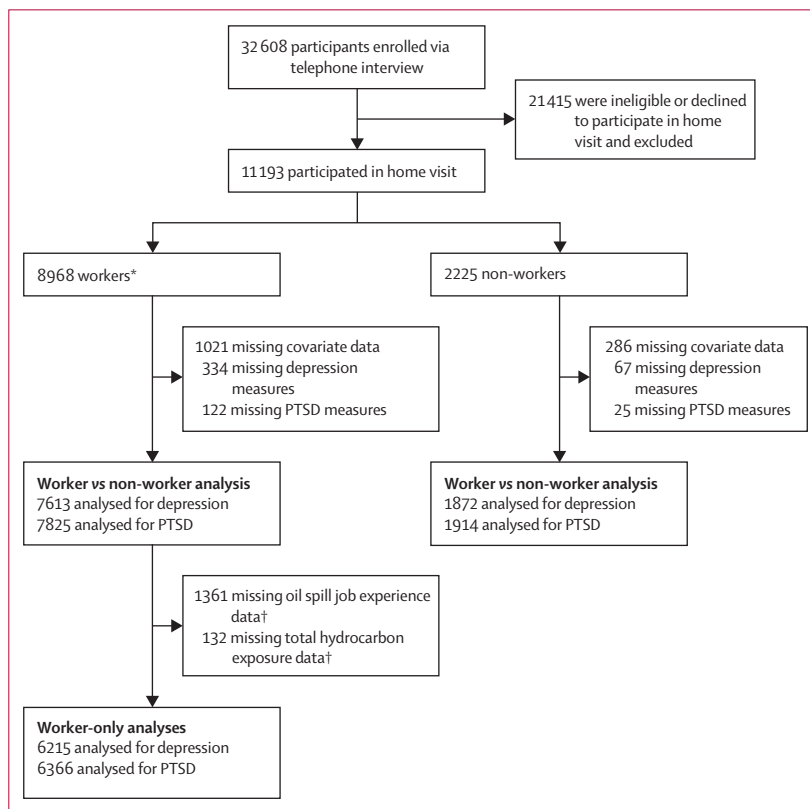
Participants also completed the four-item Primary Care PTSD Screen, which elicited symptoms indicative of PTSD in the past month. These items were linked to the oil spill and clean-up activities. Positive responses to three or more questions suggest a probable indication of moderate to severe PTSD (Cronbach's  $\alpha=0.76$ ).<sup>26</sup>

### Oil spill exposure

Participants who worked at least 1 day in support of the Deepwater Horizon oil spill response were categorised as workers, and detailed information about their jobs and tasks were obtained at enrolment. Workers encompassed a diverse group; some had direct contact with oil and related petrochemicals, whereas others worked in supportive roles such as information technology, transportation, and security. Non-workers trained to be part of the clean-up effort but were not hired.

Industrial hygienists created a job exposure matrix (JEM) on the basis of quantitative ambient and personal monitoring measurements of volatile organic compounds collected at the time of the Deepwater Horizon oil spill clean-up.<sup>28</sup> From this JEM, various jobs and tasks were assigned total hydrocarbon amounts that could vary by time and location. On the basis of their questionnaire responses, worker exposures to total hydrocarbon could then be determined as a proxy for all petroleum-based products encountered.<sup>28</sup> The present analysis used the maximum total hydrocarbon amount for each worker, across all tasks and time periods.<sup>28</sup> Additionally, industrial hygienists classified participants into six job groups and also by probable exposure to burning oil.<sup>28</sup>

The enrolment questionnaire asked workers about other experiences related to oil spill response and clean-up that were not necessarily highly correlated with total hydrocarbon exposure, but could have been stressful or related to other chemical and non-chemical exposures. These seven potentially stressful job experiences included whether they smelled oil, dispersants, or cleaning chemicals; their skin or clothing contacted oil, tar, or oily water; they ever stopped work because of the heat; their job involved handling oiled plants or wildlife; their body or clothing ever became wet with chemicals; their job involved handling dispersants; or they had



**Figure:** Trial profile

PTSD=post-traumatic stress disorder. \*Oil spill response and clean-up workers. †Numbers include 239 individuals missing depression data and 88 missing PTSD data.

	Workers (n=8968)	Non-workers (n=2225)
Age >60 years	948 (11%)	368 (17%)
Age at enrolment, years	43 (13)	47 (13)
Sex		
Female	1794 (20%)	647 (29%)
Male	7174 (80%)	1578 (71%)
Race		
White	4911 (55%)	1195 (54%)
Black	3125 (35%)	756 (34%)
Asian	47 (1%)	29 (1%)
Other	596 (7%)	154 (7%)
Other or multiracial	259 (3%)	74 (3%)
Income (US\$)		
≤20 000	3266/8355 (39%)	899/2042 (44%)
20 001–50 000	2829/8355 (34%)	632/2042 (31%)
>50 000	2260/8355 (27%)	511/2042 (25%)
Unemployed at time of home visit	3818/8767 (44%)	980/2189 (45%)
Separated, divorced, or widowed	2063 (23%)	547 (25%)
More worried about paying bills since spill	4837 (54%)	1165/2199 (53%)
Pre-existing mental health condition	1564/8856 (18%)	503 (23%)
Displaced by Hurricane Isaac or Hurricane Katrina	1978/8770 (23%)	493/2187 (23%)
Other oil industry experience	1507 (17%)	367/2206 (17%)
Duration of spill work (days)	145 (145)	0
Skin or clothing exposed to oil, tar, or oily water	5466/8641 (63%)	0
Smelled oil, dispersants, or cleaning chemicals	4722/8472 (56%)	0
Ever had to stop working because of heat	3632/8553 (42%)	0
Job involved oily wildlife, plants, or animals	3425/8826 (39%)	0
Body or clothing ever became wet with chemicals	2696/8583 (31%)	0
Any self-reported work with dispersants	1156/8573 (13%)	0
Worked as a commercial fisherman	1498 (17%)	0
Maximum overall total hydrocarbon exposure		
≤0.29 ppm	1320 (15%)	0
0.30–0.99 ppm	3284 (37%)	0
1.00–2.99 ppm	2994/8929 (34%)	0
≥3.00 ppm	1331 (15%)	0
Worker job type		
Response work	1680 (19%)	0
Operations work	1888 (21%)	0
Clean-up on water work	1319 (15%)	0
Decontamination work	1794 (20%)	0
Clean-up on land work	1462 (16%)	0
Support work	825 (9%)	0
Exposure to burning or flaring	823 (9%)	0

Data are n (%), mean (SD), or n/N (%). Workers were hired and non-workers were not hired after completing oil spill response and clean-up training. ppm=parts per million.

**Table 1: Characteristics of home-visit participants**

worked as a commercial fisherman in the past (and presumably suffered employment disruption).

### Covariates

We collected demographic and financial variables—age, sex, race, annual household income, marital status, employment status, and reported concern about paying

bills since the Deepwater Horizon oil spill—via questionnaire and included them in the analysis. To distinguish between the effects of clean-up work and proximity to the spill more generally, a dichotomous indicator for whether or not participants resided in a county directly on or adjacent to the Gulf Coast where oil appeared was included. Two other measures of potential susceptibility to spill-related adverse mental health outcomes—previous mental health diagnosis and previous residential displacement by Hurricanes Isaac or Katrina—were included in the analysis along with duration of time spent in oil spill response and clean-up and previous oil industry experience.

### Statistical analysis

We used log binomial regression to compare the prevalence of depression and PTSD between workers and non-workers (n=11 193) and among workers only (n=8968), comparing those individuals who differed in either potentially stressful experiences related to oil spill response and clean-up, or exposure to total hydrocarbons. We did separate analyses for depression versus PTSD. For the workers, we examined the seven potentially stressful job experiences as exposures. We also examined three types of job-related exposures (estimated maximum total hydrocarbon exposure, job type, and exposure to burning or flaring). Finally, we examined the seven job experiences as exposures while controlling for maximum total hydrocarbon exposure. We used log binomial regression to calculate prevalence ratios (PRs) to compare exposed and unexposed groups; PRs are less biased than odds ratios (produced by logistic regression) when predicting moderately prevalent health outcomes.<sup>29</sup> In preliminary models (not reported), we analysed the given exposures alone (eg, worker vs non-worker, or each of the seven job experiences individually), in relation to each outcome, and then introduced the covariates in steps to assess inter-relationships. For the final models, we entered all covariates along with the exposures to produce fully adjusted PRs. Thus, depression and PTSD were the two regressions for workers versus non-workers. Among workers only, there were two regressions (depression and PTSD) for the seven job experiences entered simultaneously, six regressions for the three types of job-related exposures and each of the two outcomes (depression and PTSD), and two regressions (depression and PTSD) for the seven job experiences (entered simultaneously) controlling for maximum total hydrocarbon exposure. Among workers, the sensitivity analyses included a series of regressions, which analysed each of the two outcomes for each of the seven job experiences individually (14 regressions) in the listwise-deleted data; these results were compared with identical regressions done in larger datasets (without listwise deletion when considering the seven job experiences individually rather than as a group).

Covariates were chosen to reflect basic demographic characteristics that could differ among comparison groups (sex, race, age, income, and proximity to Gulf or Deepwater Horizon oil spill), in addition to potentially stressful life circumstances (divorced, widowed, or separated; unemployment; worrying about paying bills; displacement by Hurricanes Katrina or Isaac; or pre-existing mental health condition) that could account for group differences in depression or PTSD. Duration of spill work was an additional covariate used in the worker-only analyses. We did all analyses with SAS version 9.4.

### Role of funding source

The funders did not have any role in study design, data collection, data analysis, data interpretation, or writing of the report. The corresponding author had full access to all the data in the study and had final responsibility for the decision to submit for publication.

### Results

In this analysis we included 8968 workers and 2225 non-workers who participated in home visits (figure). Participants missing any covariate (286 [13%] of 2225 non-workers and 1021 [11%] of 8968 workers) were excluded from the worker versus non-worker analyses, along with those participants missing either depression (67 non-workers [3%] and 334 workers [4%]) or PTSD measures (25 non-workers [1%] and 122 workers [1%]). For the worker-only analyses, after exclusion of those participants who were missing a covariate ( $n=1021$ ) or key exposure variable (experiences related to oil spill response and clean-up,  $n=1361$ ; total hydrocarbon exposure  $n=132$ ), 239 were missing depression data, leaving 6215 for depression analyses, and 88 were missing PTSD data, leaving 6366 for PTSD analyses.

The mean age was 43 years (SD 13) for workers and 47 years (13) for non-workers, and most participants were men (table 1). Over half of the participants in each group were white and roughly two-fifths reported annual incomes less than \$20 000 (table 1).

After we controlled for residential proximity to the Gulf of Mexico, age, sex, race, income, marital status, employment status, financial strain, displacement because of Hurricanes Katrina or Isaac, and pre-existing mental health conditions, the prevalence of depression was increased among those participants who did work involving oil spill response and clean-up compared with non-workers (PR 1.22, 95% CI 1.08–1.37). The association was unchanged after we controlled for other oil industry experience (table 2). In an adjusted model, PTSD was also associated with work involving oil spill response and clean-up (1.34, 1.06–1.69) and the association remained after we controlled for other oil industry experience (table 2).

Among workers, the median days of work involving oil spill response and clean-up was 93 (range 1–1044; IQR 60–181). After we adjusted for both total hydrocarbon

and stressful oil spill exposures, the prevalence of depression did not increase with increasing days worked (PR 0.99, 95% CI 0.98–1.01). However, PTSD increased with a PR of 1.02 (1.01–1.04) for each 30-day increment.

Workers who reported smelling oil, dispersants, or cleaning chemicals had increased adjusted prevalence of depression (table 2). Other experiences associated with depression and PTSD were having to stop work because of the heat and being a commercial fisherman (table 2). Those workers who reported that their body or clothing ever became wet with chemicals had increased PTSD, but not depression (table 2).

Increasing total hydrocarbon exposure was associated with increasing prevalence of depression (table 3). When total hydrocarbon exposure and stressful work experiences were considered together, the association between the highest total hydrocarbon exposure ( $\geq 3$  ppm) and PTSD was reduced but still significantly elevated, although the association with depression was no longer apparent (table 3).

Workers were classified hierarchically (from lowest probable total hydrocarbon exposure to highest) according to the types of jobs or tasks done.<sup>28</sup> Elevated prevalence of depression was found for response work, operations work, and decontamination tasks (table 3). Job types were not significantly associated with PTSD (table 3). However, exposure to burning or flaring of the oil was associated with PTSD, but not depression (table 3). After we added potential stressors related to oil spill response and clean-up into the models, these associations were not significant.

Potentially stressful experiences, such as smelling oil, dispersants, or cleaning chemicals, having to stop working because of the heat, or having worked as a commercial fisherman before the spill (which indicates the potential loss of livelihood because of the spill), were not highly correlated with exposure to total hydrocarbon

	Depression	PTSD
<b>Workers and non-workers*</b>		
Worked on the oil spill response and clean-up	1.22 (1.08–1.37)	1.35 (1.07–1.71)
<b>Workers only†</b>		
Smelled oil, dispersants, or cleaning chemicals	1.56 (1.37–1.78)	2.25 (1.71–2.96)
Skin or clothing in contact with oil, tar, or oily water	1.04 (0.91–1.20)	1.17 (0.88–1.55)
Had to stop working because of heat	1.37 (1.23–1.53)	1.41 (1.15–1.74)
Job involved oily wildlife, plants, or animals	0.96 (0.87–1.07)	1.17 (0.95–1.44)
Body or clothing ever became wet with chemicals	1.06 (0.95–1.18)	1.23 (1.00–1.51)
Any self-reported work with dispersants	1.04 (0.92–1.19)	1.15 (0.91–1.45)
Worked as a commercial fisherman	1.38 (1.21–1.57)	2.01 (1.58–2.55)

Data are prevalence ratios (95% CI). Ratios are adjusted for age, sex, race, annual household income, marital status, employment status, financial worries, displaced by Hurricanes Isaac or Katrina, mental health diagnosis before the spill, other oil industry experience, duration of clean-up work, and residential proximity to the Gulf of Mexico. Workers were hired and non-workers were not hired after completing oil spill response and clean-up training. PTSD=post-traumatic stress disorder. \*9485 participants for depression analysis and 9739 participants for PTSD analysis. †6215 participants for depression analysis and 6366 participants for PTSD analysis.

**Table 2: Associations of oil spill response and clean-up experiences with depression and PTSD**

	Depression (n=6134)		PTSD (n=6284)	
	Adjusted for covariates	Adjusted for covariates and OSRC experiences	Adjusted for covariates	Adjusted for covariates and OSRC experiences
Total hydrocarbon exposure effect estimate				
<0.30 ppm (ref)	..	..	..	..
0.30–0.99 ppm	1.31 (1.06–1.60)	1.18 (0.96–1.45)	1.29 (0.84–1.98)	1.10 (0.72–1.68)
1.00–2.99 ppm	1.32 (1.06–1.63)	1.06 (0.85–1.32)	1.63 (1.05–2.51)	1.16 (0.75–1.81)
≥3.00 ppm	1.44 (1.15–1.81)	1.07 (0.84–1.36)	2.61 (1.68–4.05)	1.75 (1.11–2.76)
Job type				
Support work (ref)	..	..	..	..
Response	1.44 (1.03–2.00)	0.94 (0.67–1.33)	1.70 (0.94–3.06)	0.71 (0.37–1.33)
Operations	1.71 (1.23–2.36)	1.19 (0.85–1.65)	1.69 (0.94–3.03)	0.69 (0.37–1.30)
Clean-up on water	1.36 (0.96–1.91)	1.00 (0.70–1.42)	0.91 (0.48–1.75)	0.44 (0.23–0.87)
Decontamination	1.45 (1.05–2.01)	1.13 (0.80–1.58)	1.23 (0.68–2.21)	0.58 (0.31–1.10)
Clean-up on land	1.32 (0.95–1.85)	1.18 (0.84–1.65)	0.92 (0.50–1.72)	0.57 (0.29–1.09)
No exposure to burning or flaring oil (ref)	..	..	..	..
Exposure to burning or flaring oil	1.07 (0.91–1.26)	0.97 (0.82–1.15)	1.37 (1.05–1.80)	1.21 (0.92–1.59)

Data are prevalence ratios (95% CI). Ratios are adjusted for age, sex, race, annual household income, marital status, employment status, financial worries, displaced by Hurricanes Isaac or Katrina, mental health diagnosis before the spill, other oil industry experience, duration of clean-up work, and residential proximity to the Gulf of Mexico. PTSD=post-traumatic stress disorder. OSRC=oil spill response and clean-up. ppm=parts per million.

**Table 3: Associations of oil spill exposures with depression and PTSD in workers**

See Online for appendix

(appendix p 1). Furthermore, the associations between potentially stressful work experiences and mental health effects remained after we adjusted for total hydrocarbon exposure (appendix p 2).

Comparison of those participants who were included and excluded from the analysis revealed no meaningful differences (appendix p 3). As expected, for the demographic and stress characteristics between those participants with and without depression or PTSD symptoms, participants with stressors such as unemployment, financial worries, and being displaced by Hurricane Isaac or Katrina scored positively for depression and PTSD (appendix p 4).

Sensitivity analyses, which compared results for single exposure models, produced nearly identical results to the reduced analysis sample and the larger sample obtained when not restricted to participants with data for all stressors and exposures (appendix p 5). For depression, this increased the sample size from 7282 to 7628 depending in the exposure of interest (appendix p 5). For PTSD, the sample size ranged from 7491 to 7840 (appendix p 5). This increase in sample size increased statistical power slightly, tightening confidence intervals, but point estimates were largely unchanged (appendix pp 5–6). To determine whether there might be differential associations for the seven job experiences, we isolated workers with only depression, only PTSD, and those workers with both, which yielded largely similar results presented in the main analysis (appendix p 7).

### Discussion

To our knowledge, this is the first study to document the impact of the Deepwater Horizon oil spill on the mental

health of workers involved in response and clean-up. We found that participants who engaged in clean-up work had a significantly higher prevalence of both depression and PTSD, even when we accounted for demographic characteristics and other predictors of post-disaster mental health, including pre-existing mental health conditions, residential proximity to the oil spill in the Gulf of Mexico, and previous experience of a disaster.

Overall, the results provide evidence that the Deepwater Horizon oil spill had substantial mental health consequences for workers involved in the response and clean-up, mainly attributed to their work experiences. These findings are consistent with those of previous studies,<sup>21,22</sup> which suggested (but did not explicitly show) mental health consequences associated with oil spill clean-up work. By contrast with these studies, which either used participation in clean-up work as the only indicator of spill exposure,<sup>21</sup> or studied community members whose occupations were likely to have been affected by the spill,<sup>22</sup> we examined the independent effects of various aspects of clean-up work on key mental health indicators, providing evidence that different activities confer unique mental health risks. These findings also contribute to the broader published work on disaster response by showing that the response-associated risks observed in other contexts (eg, in the aftermath of the Sept 11, 2001, terrorist attacks)<sup>23</sup> extend to oil spill disasters.

This study is the result of extensive efforts to identify and recruit a large sample of clean-up workers after the Deepwater Horizon oil spill—much larger than in previous studies. These efforts provide greater confidence that the results reflect the effect of clean-up work on

mental health in a larger population than if we had explored this event through other methods (eg, convenience or community-based sampling). Our use of a comparison group of residents who had completed clean-up safety training, but who did not go on to participate in the clean-up, suggests that the significant associations observed here were not due to pre-existing differences that might make residents more or less likely to seek out clean-up work opportunities.

In light of these strengths, the results of this study have potentially important clinical and research implications. They suggest the importance of screening clean-up workers for mental health symptoms and connecting them with services, as well as the need for empirically supported interventions to reduce depression and PTSD symptoms among this group. Primary care and other medical providers who are treating clean-up workers should be aware of the potential mental health consequences of clean-up activities, evaluate such consequences, and provide appropriate referrals as needed. The results also provide a rationale for future studies that explore the particular aspects of clean-up work that confer mental health risks, factors that could mitigate or exacerbate the effects of clean-up work, and processes through which clean-up activities could lead to adverse outcomes.

The findings should also be interpreted in view of limitations of this study. First, despite the substantial efforts to recruit all potential workers, only 44% of those eligible completed a home visit and thus the mental health assessments. However, differences in demographics and health were small between eligible Gulf state residents who completed the telephone enrolment interview only and those individuals who completed the home visit.<sup>24</sup> Similarly, meaningful differences between those participants included and excluded in this analysis were small, and sensitivity analyses using a less restrictive sample produced nearly identical results for single exposure models. Second, it is possible that differences were systematic between the residents who completed safety training and were paid to participate in clean-up work and those participants who did not. For example, there could have been a healthy worker effect whereby workers were in better physical and mental health than non-workers at baseline. We could not evaluate all such potential differences with the data collected. However, because the analyses focused on exposures and experiences among workers only, the results are internally consistent. Furthermore, a healthy worker effect would have biased the results toward finding no effect of clean-up work on mental health and therefore does not directly challenge our results.

Third, mental health status was based on interviewer-administered screening instruments and not a clinical assessment. The American Psychiatric Association revised the PTSD diagnostic criteria in the fifth edition of

its Diagnostic and Statistical Manual of Mental Disorders.<sup>30</sup> Criterion A requires either “directly experiencing the traumatic event(s),...or experiencing repeated or extreme exposure to aversive details of the traumatic event(s)... [which] include, but are not limited to,...natural or human-made disasters” for which workers in the GuLF STUDY would qualify as part of their professional duties.<sup>30</sup> Although these scales are intended to screen and are no substitute for clinical assessments, their use is normative and validated in large epidemiological studies.<sup>26,27</sup> Finally, retrospective reports of mental health before the oil spill and previous disaster experience could have been affected by mental health after the spill, inflating associations between them. However, these potentially inflated associations would have biased the analyses towards the null, making them less of a concern.

Despite these limitations, to our knowledge, this is the first study to investigate the effects of clean-up work in the aftermath of the Deepwater Horizon oil spill on mental health. We documented that clean-up work was significantly associated with increased prevalence of moderate-to-severe depression and PTSD, and that these findings held when we controlled for other known risk factors, such as pre-existing mental health conditions and previous disaster exposure. Furthermore, among Deepwater Horizon oil spill clean-up workers, the experience of the oil spill response and clean-up proved to be more traumatic than exposure to the oil, dispersants, and cleaning chemicals itself (as measured by total hydrocarbon exposure). These findings provide further evidence that clean-up work is associated with adverse psychological consequences and prescreening and postevent services might be needed to address workers' mental health needs when the next disaster inevitably strikes.

#### Contributors

RKK, LSE, and DPS designed the study and directed its implementation, including quality assurance and control. RKK, JAM, WBJ 2nd, and JP did the data analysis. RKK, JAM, SRL, LSE, SG, and DPS interpreted the results and suggested additional analyses as appropriate. RKK and SRL wrote the manuscript draft and all authors contributed revisions. MDC oversaw the data collection including quality assurance and control. All authors reviewed the manuscript and approved of the version to be published.

#### Declaration of interests

We declare no competing interests.

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