Chemical exposure from the Hebei spirit oil spill accident and its long-term effects on mental health

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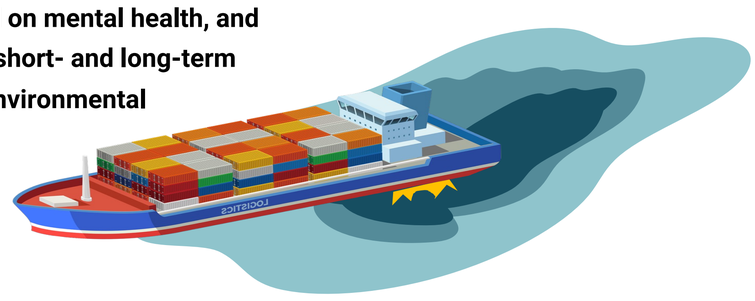
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INTRODUCTION

- Oil spill accidents are environmental disasters that not only result in economic losses from damage to fishing and tourism industries but also impact the ecosystem and human health. On December 7, 2007, the Hebei Spirit Oil Spill, a large-scale oil spill, occurred near a residential area in Korea, causing extensive damage to residents. During emergency cleanup efforts, 85% of Taean residents were directly exposed to oil without protective equipment.
- Exposure to oil spill chemicals has been linked to various health issues, including respiratory, cardiovascular, nervous system, and cancer-related problems. Moreover, experiences related to environmental disasters can exacerbate stressors and increase the risk of psychiatric symptoms over time. However, it remains unclear whether these mental health impacts arise primarily from disaster-related stress or from chemical exposure.
- This study aims to evaluate the cross-sectional and longitudinal effects of indirect and direct exposure to the Taean oil spill on mental health, and to clarify the implications for short- and long-term mental-health support after environmental disasters.



METHODS

STUDY PARTICIPANTS

- This study used data from the Health Effects Research on Hebei Spirit Oil Spill (HEROS) cohort from 2009 to 2016. To observe the association between oil spill exposure and mental health, both cross-sectional and longitudinal analyses were employed (FIGURE 1).

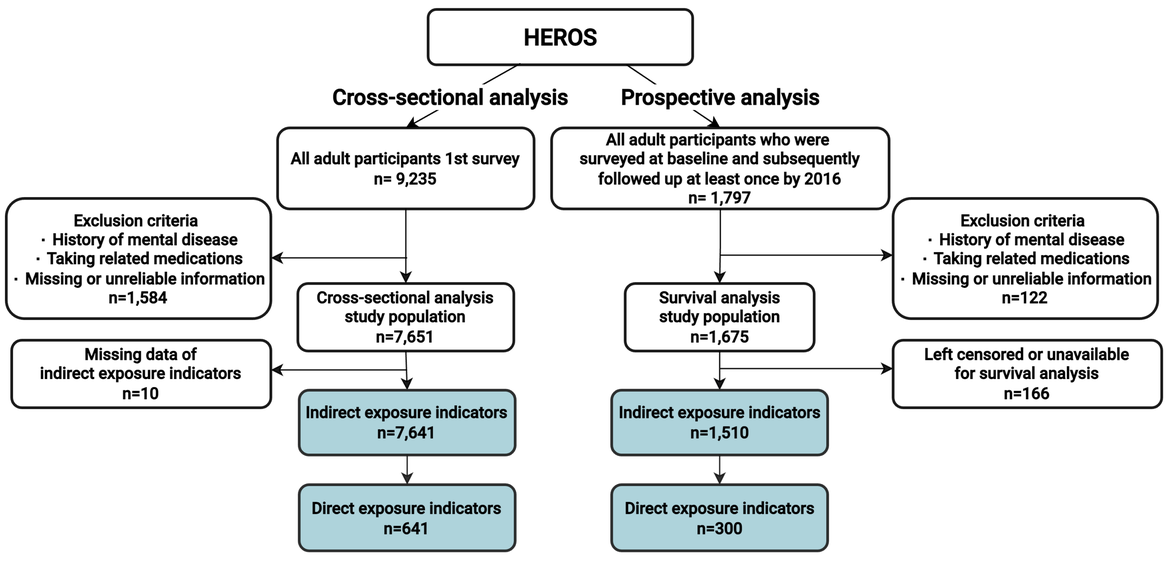


FIGURE 1 Study population in the Hebei Spirit oil spill survey (2009–2016)

VARIABLES

- To evaluate chemical exposure from the oil spill, we used both indirect and direct indicators. Indirect indicators were the residential distance (km) from the contaminated shoreline and the cumulative duration (days) of cleanup participation. Direct indicators were urinary metabolite concentrations (μg/g crea) of volatile organic compounds (VOCs) and polycyclic aromatic hydrocarbons (PAHs).
- To assess the mental health status of residents in the oil spill area, we included measures of posttraumatic stress disorder (PTSD), depression, state anxiety, and trait anxiety.

STATISTICAL ANALYSIS

- To examine the cross-sectional association between oil spill exposure and mental health, we conducted adjusted multiple logistic regression analyses for all covariates (sex, age, marital status, monthly household income, education level, smoking status, alcohol consumption, physical activity, body mass index, sleep problems, and comorbidities).
- We performed Cox regression analysis to estimate the hazard ratio (HR) and 95 % CIs for assessing the long-term effects on mental health symptoms due to indirect and direct exposure indicators. We also evaluated the proportional hazards assumption by examining the correlation between Schoenfeld residuals and follow-up time.
- If the proportional hazards assumption was violated (*p*-value<0.05), we calculated the weighted hazard ratios (HRw) to obtain unbiased average HR estimates regardless of hazard proportionality.
- All processes of analyses were performed using R version 4.3.1 software, and the level of statistical significance was set to 0.05.

RESULTS

- During the baseline survey year, regions closer to the accident site had relatively higher proportions of mental health issues.
- Indirect exposure indicators showed significant associations with mental health. For direct exposure indicators, PAH metabolites exhibited a significant positive association only with PTSD.
- Some significant associations between indirect exposure indicator and mental health disappeared. Additionally, we observed a prospective association between urinary VOC and PAH metabolite levels and mental health, which was not evident in cross-sectional analyses.

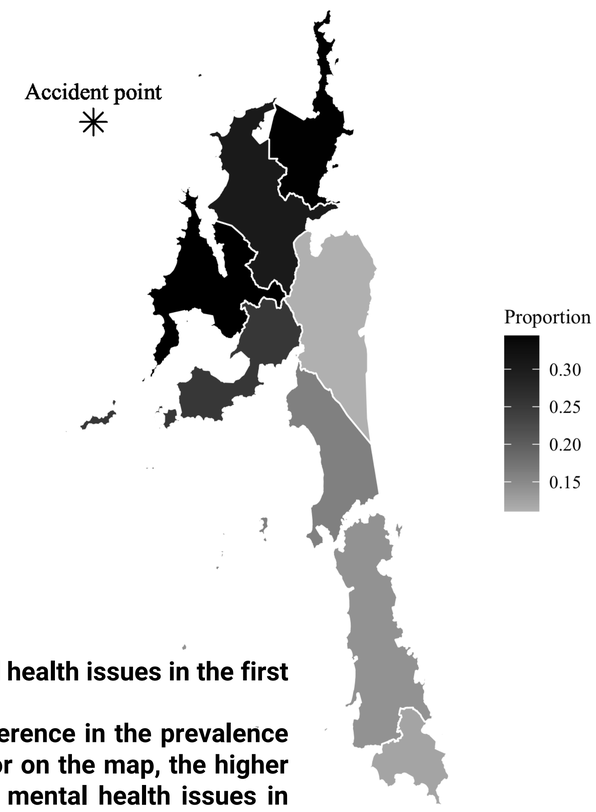


FIGURE 2 Proportion of individuals with mental health issues in the first survey of the study area (Taean, South Korea).
The chi-square test revealed a significant difference in the prevalence by region (*p*-value<0.001). The darker the color on the map, the higher the proportion of study population at risk for mental health issues in each region.

TABLE 1 The odds ratios and 95% CIs for the association of oil spill exposure on mental health.

Variables	PTSD OR (95% CI)	Depression OR (95% CI)	State anxiety OR (95% CI)	Trait anxiety OR (95% CI)
Indirect exposure indicators				
Distance (km)	0.97 (0.96, 0.97)	0.99 (0.99, 0.99)	0.99 (0.98, 0.99)	0.99 (0.99, 1.00)
Duration (30 days)	1.31 (1.27, 1.34)	1.17 (1.14, 1.20)	1.18 (1.15, 1.22)	1.13 (1.09, 1.17)
Direct exposure indicators				
VOCs (μg/g crea)				
Muconic acid	0.75 (0.58, 0.97)	0.98 (0.75, 1.28)	0.99 (0.73, 1.33)	1.21(0.84, 1.74)
PAHs (μg/g crea)				
1-Hydroxypyrene	1.20 (1.01, 1.43)	1.15 (0.97, 1.38)	1.11 (0.91, 1.35)	1.22 (0.95, 1.58)
2-Naphthol	1.25 (1.07, 1.46)	1.14 (0.98, 1.33)	1.10 (0.93, 1.31)	1.09 (0.88, 1.36)

Significant *p*-values (<0.05) are shown in orange.
Exposure to VOCs and PAHs was estimated using creatinine-adjusted urinary levels (μg/g crea) and natural log-transformed.
Multiple logistic regression was used to estimate ORs and 95% CIs after adjusting for sex, age, marital status, monthly household income, education level, smoking status, drinking status, physical activity, BMI, sleep problems, and comorbidities.

TABLE 2 The hazard ratios and 95% CIs for mental health by exposure to the oil spill using Cox regression models.

Variables	PTSD HR (95% CI)	PTSD HR_w (95% CI)[a]	Depression HR (95% CI)	Depression HR_w (95% CI)[a]	State anxiety HR (95% CI)	State anxiety HR_w (95% CI)[a]	Trait anxiety HR (95% CI)	Trait anxiety HR_w (95% CI)[a]
Indirect exposure indicators								
Distance (km)	1.00 (0.98, 1.02)	0.99 (0.97, 1.01)	1.01 (1.00, 1.02)[b]	1.01 (1.00, 1.02)	1.01 (1.00, 1.03)[b]	1.01 (1.00, 1.03)	1.02 (1.01, 1.04)[b]	1.03 (1.01, 1.04)
Duration (30 days)	1.13 (1.05, 1.21)	1.14 (1.05, 1.24)	1.06 (1.01, 1.11)	1.07 (1.00, 1.15)	1.06 (1.00, 1.13)[b]	1.18 (1.08, 1.29)	0.99 (0.93, 1.05)	0.98 (0.92, 1.06)
Direct exposure indicators								
VOCs (μg/g crea)								
Muconic acid	1.41 (0.82, 2.43)	1.66 (0.94, 2.93)	1.55 (1.05, 2.28)	1.54 (1.07, 2.22)	1.32 (0.84, 2.06)[b]	1.25 (0.80, 1.94)	1.02 (0.65, 1.62)	0.89 (0.55, 1.46)
PAHs (μg/g crea)								
1-hydroxypyrene	1.60 (1.03, 2.48)	1.84 (1.10, 3.06)	1.29 (0.99, 1.69)	1.22 (0.92, 1.62)	1.21 (0.91, 1.63)[b]	1.18 (0.89, 1.57)	1.03 (0.74, 1.42)	1.09 (0.78, 1.52)
2-naphthol	1.15 (0.81, 1.62)	1.30 (0.83, 2.04)	1.06 (0.85, 1.33)	1.08 (0.82, 1.43)	1.31 (0.99, 1.73)[b]	1.39 (1.00, 1.93)	1.27 (0.95, 1.71)	1.64 (1.15, 2.32)

Significant *p*-values (<0.05) are shown in orange.
Exposure to VOCs and PAHs was estimated using creatinine-adjusted urinary levels (μg/g crea) and natural log-transformed.
Cox regression analysis was used to estimate HRs and 95% CIs after adjusting for sex, age, marital status, monthly household income, education level, smoking status, drinking status, physical activity, BMI, sleep problems, and comorbidities.
[a] The weighted average hazard ratio (HR_w) was estimated by weighted Cox regression.
[b] The proportional hazards assumption was violated (Schoenfeld *p*-value <0.05).

CONCLUSION

Exposure to oil spill incidents have been associated with increased mental health risks, which appear to persist over the long term. Specifically, these long-term effects suggest the need to consider not only the psychosocial aspects of the accident itself but also the impact of direct chemical exposure. In this regard, it is suggested that environmental disaster mitigation and response plans should consider minimizing chemical exposures while also considering the duration and nature of mental health effects.

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