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Urinary metabolites before and after cleanup and subjective symptoms in volunteer participants in cleanup of the Hebei Spirit oil spill

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ABSTRACT

Background: On December 7th, 2007, the Hong Kong tanker Hebei Spirit (HS) (146,848 tons) was crushed by a crane ship near the shore of Taean, Korea. More than 12,547 kl of crude oil spilled into the sea and contaminated the western coastline of the Korean peninsula. For a period of six months after the accident, approximately 1,000,000 volunteers participated in the cleanup. Our goal in this study was to examine the exposure status and acute health effects on volunteers that participated in the oil spill cleanup.
Methods: A survey questionnaire was filled out by 565 volunteers, requesting information regarding physical symptoms. Out of the total number of participants, urine samples from 105 university student volunteers were collected before and after the cleanup work, and metabolite levels of volatile organic compounds and polycyclic aromatic hydrocarbons were analyzed.
Results: Volunteers that participated for longer cleanup work reported an increase in physical symptoms including visual disturbance, nasal and bronchus irritation, headaches, heart palpitations, fatigue and fever, memory and cognitive disturbance, and abdominal pain. The levels of t,t-muconic acid, mandelic acid, and 1-hydroxypyrene were significantly higher in samples after cleanup than those measured before participation ($p<0.05$). Other than the associated risk of dermal irritation with the difference in the t,t-muconic acid level between the post- to pre-cleanup levels, no other physical symptoms demonstrated a significant association with changes observed in the levels of urinary metabolites.
Conclusions: Based on the significant increase of subjective symptoms in volunteers participating in the study, monitoring of the long term health effects, focusing on those with longer exposure, is warranted.

1. Introduction

The Hong Kong tanker, the Hebei Spirit (HS) collided with a crane ship five miles northwest of Taean's Manri-po Beach, Korea on Dec 7th, 2007. It was estimated that more than 12,547 kl of oil (about 78,962 bbl or 3,314,562 gal) spilled into the sea. The oil reached the western coastline of the Korean peninsula with a range in spread of 1052 km and was found in Chungnam, Jeonbuk, Jeonnam, and as far as Jeju island. The spill was confirmed as the largest oil spill contamination to occur in Korean history (Ha et al., 2008). The Taean-gun area, an agricultural and fishing region including 119 small islands, 530.8 km of coastline, and an area of 503 km^2 with a recorded population of 63,939 people as of 2006 (County chief of Taean, 2007), received the most severe damage.

Three types of crude oil were carried by the HS; UAE Upper Zakum, Kuwait Export Crude, and Iranian Heavy. The main chemical components were primarily composed of hydrocarbons, e.g., volatile organic compounds (VOCs) and polycyclic aromatic hydrocarbons (PAHs), including alkylated types, and minor heavy metals (Marine Environmental Information Service Center, 2009). Approximately 30–50% of VOCs in the crude oil were estimated to be volatized into the air during the first few days after the initial spill. The airborne

Abbreviations: HS, Hebei Spirit; VOCs, volatile organic compounds; PAHs, polycyclic aromatic hydrocarbons.

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concentrations of PAH (16 PAHs listed on the US EPA priority) were 130–277 ppm and those of alkylated PAHs were 4511–8259 ppm (Marine Environmental Information Service Center, 2009). The HS crude oil also contained traces of heavy metals and released hydrogen sulfide gas (Marine Environmental Information Service Center, 2009).

VOC exposure is associated with acute, reversible effects to the CNS (headache, nausea, sleepiness) and irritation of mucous membranes. Prolonged exposure to certain VOCs and PAHs can cause axonal neuropathy. Aromatic compounds, such as 1,2-diethylbenzene, are more potent axonal neurotoxins than aliphatic compounds such as n-hexane (Agency for Toxic Substances and Disease Registry, 1995). Among the crude oil VOCs, benzene is classified as a Group I agent, a proven human carcinogen. Other VOCs including toluene, ethylbenzene, and stylene, belong to Group 2B, which are considered as possible human carcinogens based on published animal studies (International Agency for Research on Cancer, 2006). PAHs such as benzo[a]anthracene, benzo[a]pyrene, and dibenzo[a,h]anthracene are classified into Group 2A, probable human carcinogens, while chrysene, naphthalene, benzo[b]fluoranthene, benzo[k]fluoranthene, and indeno[1,2,3-cd]pyrene are members of Group 2B (International Agency for Research on Cancer, 2006).

Following the accident, local residents, along with many other people from around Korea, worked to clean up the spilled oil. A total of 2,122,296 days were estimated as the total number of days dedicated by participants to the cleanup as of July 4th, 2008 (Lee et al., 2009). Most local residents participated in the cleanup for a period of days to several months and both military personnel and governmental employees (59,118 person-days) were also recommended by their organizations to voluntarily participate in the cleanup efforts for several days or months. Professional cleanup workers (about 200–300 persons) covered 48,809 person-days. Additionally, approximately 1,000,000 persons (contributing 1,161,086 person-days) voluntarily gathered at the spill sites to volunteer for a range of a few hours to days to clean up all around the country, i.e., members from civic groups, schools and universities, companies, communities, and families and individuals.

Although some studies investigated the health effects of cleanup workers from exposure to an oil spill (Palinkas et al., 1992; Suarez et al., 2005; Carrasco et al., 2006; Zock et al., 2007; Perez-Cadahia et al., 2007, 2008; Rodríguez-Trigo et al., 2010; Goldstein et al., 2011) or local residents living in the polluted sites (Palinkas et al., 1993; Campbell et al., 1993; Crum, 1993; Campbell et al., 1994; Lyons et al., 1999; Morita et al., 1999; Janjua et al., 2006; Carrasco et al., 2007; Sim et al., 2010; Cheong et al., 2011), no study has been reported regarding the exposure of volunteers for a short range of time, including a few hours to several days. Since a huge number of volunteers participated in the cleanup work for the HS oil spill accident, even a small health risk, possibly due to exposure to crude oil during cleanup, may have an important impact on public health.

This particular study examined the exposure of volunteers to crude oil by analyzing changes in urinary metabolites of VOCs and PAHs before and after cleanup as well as the incidence of subjective physical symptoms using a survey questionnaire.

2. Materials and methods

2.1. Study subjects

The questionnaire survey for volunteers was conducted between the second and third week after the accident (Dec 14, 2007 to Dec 24, 2007). Questionnaires were administered to people working for the cleanup in three contaminated areas at the end of the work day. A total of 724 subjects (out of 1000 questionnaires distributed) responded to the questionnaire, which included questions about the cleanup work conducted, physical symptoms, and other socio-demographic factors. After excluding incomplete questionnaires, 565 questionnaires were analyzed and included in our study.

A subgroup of the total number of participants, included a group of university students (n = 312), who were organized by a university, were also asked to provide their urine before and after the cleanup work participation. A total of 121 out of 272 students responded to the questionnaire and provided urine samples, and a total of 105 urine pairs were analyzed after excluding unpaired urine.

The study protocol was approved by the Institutional Review Board of Dankook University Hospital, and informed consent was obtained from all subjects.

2.2. Survey questionnaire on the cleanup work and subjective symptoms

The authors developed a symptom questionnaire based on the possible effects of the crude oil composition (Agency for Toxic Substances and Disease Registry, 1995) following the format of previously published questionnaires and reported symptoms for oil spill accidents in other countries (Janjua et al., 2006; Rodriguez-Trigo et al., 2007). A total of 41 physical symptoms were grouped into 14 categories classified with regard to organ systems, which were described in previous reports (Lee et al., 2009; Cheong et al., 2011): eye irritation, visual disturbance, nasal irritation, sore throat, bronchial irritation, dermal irritation, headache, palpitations (fast heartbeat), nausea or vomiting, abdominal pain, fatigue and fever sensation (heat-stress related), memory or cognitive function disturbances, musculoskeletal symptoms, and back pain.

Information on the duration of cleanup work was obtained ("How many days did you participate in the cleanup efforts?"(one day or more than one day) and "If the response is more than one day, write in the total number of days"). The type of job responsibility could be chosen among three possibilities: participating in direct cleanup work (i.e., oil skimming, cleaning of rocks, sands, and wildlife), a logistics-related job (i.e., pouring, moving or transporting oil trash), and others. The degree of skin contamination to oil could be reported as "not at all," "a bit," "much," or "profound".

We also obtained and identified demographic information as confounders or covariates: age (open question, which was categorized: ≤29, 30–<39, 40–<49, or 50 or more), gender, occupation (students, office workers, manufacturing workers, agriculture, fishery, others), educational level (<12, 12, 13 or more years), current smoker (no, yes), health concerns about the oil spill (no, yes), past history of asthma diagnosis (no, yes), and wearing protective items, such as work clothes, gloves, boots, and mask (no or yes for each).

2.3. VOCs and PAHs metabolite analysis in urine sample pairs

Urine collection was performed prior to the work day between 6 and 7 a.m. and at the end of the work day between 7 and 8 p.m. Collected urine samples were immediately stored in a portable refrigerator and transported to −20 °C freezers within 4 h of collection. One month later, the urine samples were packed on dry ice and transferred to the laboratory for analysis.

Among the aromatic hydrocarbons, which composed approximately 30% of all chemicals in the HS crude oil, the VOCs, including benzene, toluene, ethylbenzene, and xylene (BTEX) composed 53–65%, followed by 33–45% of alkylated PAHs and 1% of 16 PAHs listed on the US EPA priority list (Marine Environmental Information Service Center, 2009). Based on the information on the chemical compositions of the oil spill and their known health effects, five metabolite compounds, t,t-muconic acid, mandelic acid, 2-methyl hippuric acid, 3-methyl hippuric acid, 4-methyl hippuric acid, and hippuric acid, were analyzed using gas chromatography–mass spectrometry (GC–MS, Agilent Technologies, Santa Clara, CA, USA). The analysis methods for metabolites of VOCs have previously been described in detail (Lee et al., 2010).