A Review of Literature Related to Human Health and Oil Spill Dispersants

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for

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by

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Glossary

This paper contains several technical terms. Some of the terms which can be defined easily are defined below. Caution is advised as some terms imply much more than a simple phrase can render and are the summation of many years of study by experts. These are best left as a technical term in the summaries.

Adipogenesis – A two-step developmental process in which undifferentiated tissues of the lymphatic and circulatory systems, as well as the musculoskeletal system, differentiate into a pre-adipose tissue, which then undergoes a secondary differentiation step to become a lipid-filled adipocyte. This is an important step in cell transformation which can be easily affected by toxic chemicals.

CEWAF - Chemically-Enhanced Water Accommodated Fraction - The sum total of oil in a water sample including chemically and physically dispersed and soluble oil

Corexit 9527 alternatively Corexit EC9527 - Brand name of a dispersant from Nalco

Corexit 9500 alternatively Corexit EC9500A- Brand name of a dispersant from Nalco

Cytotoxicity – Toxicity to cells

DOSS - Dioctyl Sulfosuccinate, one of the surfactants in Corexit dispersants

DWH - Deepwater Horizon (alternatively DeepWater Horizon), also known as the Macondo spill

Epidemiological – The scientific study of the causes, distribution, and control of disease or disorders in populations.

Epithelial – The thin tissue forming the outer layer of a body's surface and lining the alimentary canal and other hollow structures.

Genotoxicity - A property of chemical agents that damage the genetic information within a cell which causes mutations and which may lead to cancer

GuLF Study – Gulf Long-Term Follow-up Study – A NIOSH health study of individuals who helped with the oil spill response and clean-up, took training, signed up to work, or were sent to the Gulf to help in some way after the Deepwater Horizon spill

In-vivo – Testing the effects of a substance on whole, living organisms or cells

LOC – level of concerns – a health or safety level for exposure to a certain compound or substance

Mammalian – Typically a study relating to a mammal. Historically most chemical substances were tested on rats, and this became a typical mammalian study. Now, mammalian can mean any mammal.

Obesogen – Chemicals that alter lipid homeostasis and fat storage, change metabolic setpoints, disrupt energy balance or modify the regulation of appetite to promote fat accumulation and obesity.

Oncology – The study and treatment of tumors.

PAH – Polycyclic Aromatic Hydrocarbon(s)

Prevalence Ratio – **PR** – The ratio of the proportion of the persons with disease over the proportion with the exposure. An example is provided in the matrix below, see also (https://www.ctspedia.org/do/view/CTSpedia/PrevalenceRatio) and adjusted PR note below.

		Disease	
		Yes	No
Exposure	Yes	a	b
	No	c	d

$$PR = \frac{\frac{a}{a+b}}{\frac{c}{c+d}}$$

***Adjusted Prevalence Ratio** - Prevalence ratios that are adjusted to compensate for null or background that might be more than prevalence ratio - for this purpose they are similar and compensate for background levels. This background would be, for example, those that cough or have the measured symptoms without any exposure - typically about 1 to 5%.

Transcriptomic - Techniques used to study an organism's transcriptome, the sum of all of its RNA transcripts.

VOC - Volatile Organic Carbon - fraction of hydrocarbons which evaporate readily

WAF - Water-Accommodated Fraction - The sum total of oil in a water sample including physically dispersed and soluble oil.

Human Health Aspects of Dispersants

Introduction

The Deepwater Horizon spill marked the first time that the effects of dispersants on human health were studied extensively and directly. This was studied through a variety of methods including epidemiological studies. It is important to distinguish between the substances to which the subjects of the study are being exposed. There are three possible test substances considered for this study: oil only, dispersants only and dispersants and oil mixed. It is important that the study distinguishes between these and also that the study makes the comparison between all three, where applicable.

Abstract

Several human health studies relating to dispersants (typically Corexit 9500A) and dispersants with oil were carried out. An important series of studies was carried out by performing epidemiological studies on workers employed during the Deepwater Horizon spill. One set of studies was performed on US Coast Guard workers by comparing workers assigned to the Deepwater Horizon to those not working on the Deepwater Horizon spill. The symptoms included wheezing with an adjusted prevalence ratio (PR, the ratio of the proportion of the persons with disease over the proportion with the exposure) of 5.06. This is several times the PR of oil-only exposed workers and also above those workers not exposed to either oil or dispersants. The second symptom reported was that of shortness of breath with a PR of 4.65, and finally, coughing with a PR of 2.72. Another separate study was performed among a variety of spill workers. The findings showed that the PR of having a burning sensation in the nose and throat was 1.61. Tightness in the chest was reported as having a PR of 1.58 and burning in eyes, a PR of 1.48. Still another study showed dispersant-exposed workers were 61% more likely than unexposed workers to report burning in the nose, throat, or lungs, 58% more likely to report chest tightness, 49% more likely to report eye irritation, and about 40% more likely to report coughing or wheezing. These studies indicate that there is an issue with nose, throat and breathing problems for those exposed to dispersants or dispersant-treated oil. Separate studies show that dispersants promote the formation of nano-aerosols by as much as two orders-of-magnitude. These nano particles may be the source of the respiratory irritation noted in the several epidemiological studies of dispersant exposure.

Several other studies, typically mammalian exposures, showed that they may be a concern with dispersants or dispersant-treated oils; however, it is difficult to relate some of these studies to actual exposures or concentrations at spill sites.

Executive Summary

The most significant finding in the literature is that of association of workers with symptoms of respiratory difficulties such as breathing difficulties and coughing. A major study of US Coast Guard workers (both working and not working in the Gulf during and after the Deepwater Horizon spill) has concluded that there were definitive symptoms resulting from exposure to dispersants (Alexander et al., 2018). The symptoms included wheezing with an adjusted prevalence ratio of 5.06. This is several times the PR of oil-only exposed workers and also above those workers not exposed to either oil or dispersants. The second symptom reported was that of shortness of breath with a PR of 4.65 and finally, coughing with a PR of 2.72. This was complimented by a study of workers not exposed or exposed to oil only (Rusiecki et al., 2018). Two separate and independent studies used the results of the Gulf Long-term

Follow-up Study (GuLF STUDY) which surveyed all available workers working on the Deepwater Horizon spill. McGowan et al. (2018) studied between 27,659 and 29,468 participants who provided information on respiratory, dermal, and eye irritation health. The findings showed that the PR of having a burning sensation in the nose and throat was 1.61 for those reporting dispersant and oil exposure. Tightness in the chest was reported as having a PR of 1.58 and burning in eyes, a PR of 1.48. Konkel et al. (2018), in a separate study, found that dispersant-exposed workers were 61% more likely than unexposed workers to report burning in the nose, throat, or lungs, 58% more likely to report chest tightness, 49% more likely to report eye irritation, and about 40% more likely to report cough or wheeze.

The exposures described in the reviewed studies above may be due to the fact that the use of surfactants, i.e., dispersants, increase the emission of small nano particles by as much as one or two orders of magnitude (Afshar-Mohajer et al., 2017, 2018). Studies by this group showed that the release of nano particles by water, oil and surfactant systems were increased by as much as one to two orders of magnitude (10 to 100 times) by the presence of the dispersant. Afshar-Mohajer et al. note that "Once in the air they [the nano particles] don't come down easily, and they can travel quite far, depending on wind directions, they can easily travel 50 miles away." This study employed a test tank and wind and wave values were related to the emission of particulate matter. Another study by Zhang et al. (2016) also showed similar results.

An epidemiological study by Green et al. (2014) compared workers and some chemical exposures between the Prestige spill and the Deepwater Horizon spill. This study found that the exposure in the Deepwater Horizon was less than that of the Prestige spill; however, only a few chemicals were selected and included little correlation to Corexit 9500A used in the Deepwater Horizon spill.

There were several other studies that appeared in recent literature. These are summarized in point form:

- Black et al. (2016) studied the effect of contact with possibly contaminated beach sand near the Deepwater Horizon spill, on children. It was concluded that this would not be a significant exposure pathway.
- Chen and Reese (2016) studied the cytotoxicity of oil and dispersants as did Bowers et al. (2016). Both studies showed that there was measurable cytotoxicity of oil and dispersant mixtures in direct contact with tissue.
- Konkel (2017) did a theoretical study of aerial dispersant application, concluding that the droplets would not spread further than 0.5 nautical miles.
- Liu et al. (2016, 2017) studied the effect of oil and dispersants on human airway epithelial cells and found that oil/dispersant combinations produced detrimental effects and possible carcinogenic effects.
- Ramesh et al. (2018) studied the effects of oil/dispersant contact with mice and found contact altered the white blood cells and platelet counts.
- Rung et al. (2015) and Samarco (2016) found that the spill and the use of dispersants caused mental anxiety among workers and their families.
- Sathiakumar et al. (2017) studied the effects of seafood consumption by children from the Deepwater Horizon spill. The study indicated no increase in the risk of exposure despite higher seafood consumption by locals closer to the sea shore.
- Singleton et al. (2016) deployed particulate samplers near contaminated and uncontaminated areas on shore of the Deepwater Horizon spill and found that contaminated areas produced many more aerosols even up to three years after the spill.

Detailed Study Summaries

Afshar-Mohajer et al. (2017, 2018) studied aerosol size distribution from 10 nm to 20 µm, total particle-bound aromatic hydrocarbons (pPAH) and volatile organic compounds (VOCs) in a 6 x 0.3 x 0.6 m tank as plunging and breaking waves entrained oil slicks. The experiments were performed for seawater with slicks of crude oil, crude oil-dispersant mixture and dispersant only. The measurements investigated the effects of wave energy and slick properties on the temporal evolution of the emissions. The total concentrations of particles originating from the oil-dispersant mixture are 1–2 orders of magnitude higher than those of crude oil across the entire nano-scale range, reaching 100x for 20 nm particles. Conversely, the differences in concentrations are small in the micrometer (µm) range. The average concentrations of pPAH are variable but similar (150–270 ng/m^3). The VOC concentrations for crude oil-dispersant mixtures are 2–3 times lower than those of crude oil, presumably due to the surfactant effect on mass diffusion. The drastic increase in ultrafine particle concentrations may raise concerns about effects of inhalation by cleanup workers and downstream communities though VOC emissions. The findings of this study provide insight into how dispersant spray may change the ratio of airborne particulate matter and VOC emissions from seawater due to natural processes.

Alexander et al. (2018) conducted a study of United States Coast Guard (USCG) personnel who were deployed in response to the Deepwater Horizon (DWH) oil spill. The human respiratory effects as a result of spill-related exposures were studied as an exposure example. USCG personnel who responded to the DWH oil spill were queried using a survey on exposures to crude oil and oil dispersant and acute respiratory symptoms experienced during deployment at the DWH. The prevalence ratios (PRs) and 95% confidence intervals (CI) were reported on the associations between oil spill exposures and respiratory symptoms. 4,855 USCG personnel completed the survey. More than half (54.6%) and almost one-fourth (22.0%) of responders were exposed to crude oil and oil dispersants, respectively. Coughing was the most prevalent symptom (19.4%), followed by shortness of breath (5.5%), and wheezing (3.6%). Adjusted analyses showed an exposure-response relationship between increasing deployment duration and likelihood of coughing, shortness of breath, and wheezing in the pre-capping period. A similar pattern was observed in the post-capping period for coughing and wheezing. Adjusted analyses revealed increased PRs for coughing (PR=1.92), shortness of breath (PR=2.60), and wheezing (PR=2.68) for any oil exposure. Increasing frequency of inhalation of oil was associated with increased likelihood of all three respiratory symptoms. A similar pattern was observed for contact with oil dispersants for coughing and shortness of breath. The combination of both oil and oil dispersants presented associations that were much greater in magnitude than oil alone for coughing (PR=2.72), shortness of breath (PR=4.65), and wheezing (PR=5.06). Results from the study suggested strong relationships between oil and oil dispersant exposures and acute respiratory symptoms among spill responders.

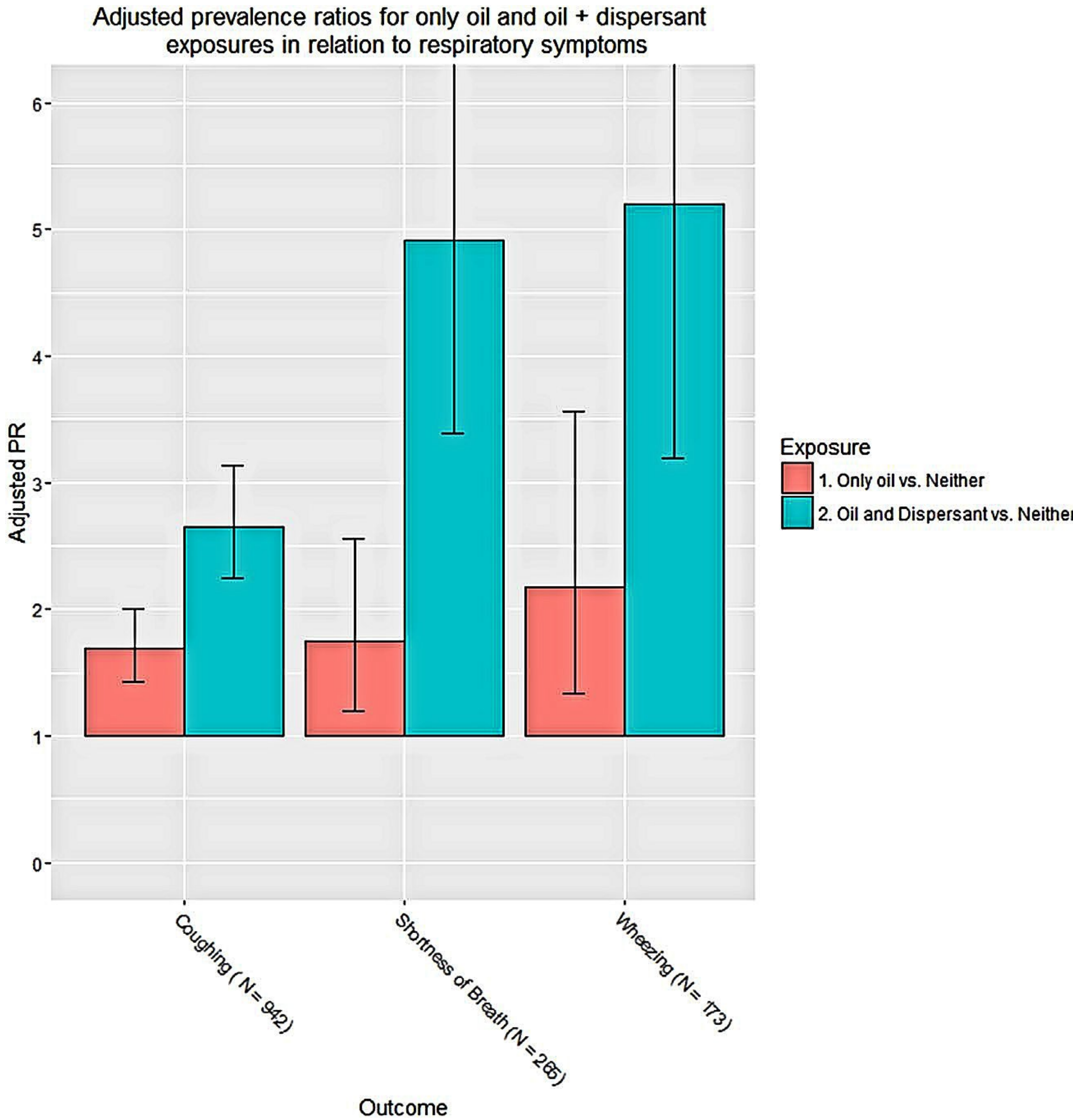

Figure 1 Summary Diagram of Alexander et al. Findings. (From Alexander et al., 2018)

Black et al. (2016) evaluated the health risk to children who potentially contacted beach sands impacted by oil spill dispersants and substances in the oil from the Deepwater Horizon disaster. To identify chemicals of concern, the U.S. Environmental Protection Agency's (EPA's) monitoring data collected during and immediately after the spill were evaluated. This dataset was supplemented with measurements from beach sands and tar balls collected five years after the spill. Of interest is that metals in the sediments were observed at similar levels between the two sampling periods; some differences were observed for metals levels in tar balls. Although PAHs were not observed five years later, there is evidence of weathered-oil oxidative by-products. Comparing chemical concentration data to baseline soil risk levels, three metals (As, Ba, and V) and four PAHs (benzo a pyrene, benz a anthracene, benzo b fluoranthene, and dibenz a,h anthracene) were found to exceed guideline levels, prompting a risk assessment. For acute or sub-chronic exposures, hazard quotients, computed by estimating average expected contact behavior, showed no adverse potential health effects. For cancer, computations using 95% upper confidence limits for contaminant concentrations showed extremely low increased risk in the 10^{-6} range for oral and dermal exposure from arsenic in sediments and from dermal exposure from benzo a pyrene and benz a anthracene in weathered oil. Overall, results suggest that health risks are extremely low, given the limitations of available data. Limitations of this study are associated with the lack of toxicological data for dispersants and oil-spill degradation products. They also recommend studies to collect quantitative information about children's beach play habits, which are necessary to more accurately assess exposure scenarios and health risks.

Bowers et al. (2016) studied the Corexit-enhanced Water Accommodated Fraction (CWAF) of DWH crude oil which contains PPARγ transactivation activity, which is attributed to dioctyl sodium sulfosuccinate (DOSS), a probable obesogen. In addition to its use in oil dispersants, DOSS is commonly used as a stool softener and food additive. Because PPARγ functions as a heterodimer with RXRα to transcriptionally regulate adipogenesis, they investigated the potential of CWAF to transactivate RXRα and herein demonstrated that the Corexit component Span 80 has RXRα transactivation activity. Span 80 bound to RXRα in the low micromolar range and promoted adipocyte differentiation of 3T3-L1 preadipocytes. Further, the combination of DOSS and Span 80 increased 3T3-L1 adipocyte differentiation substantially more than treatment with either chemical individually, likely increasing the obesogenic potential of Corexit dispersants. From a public health standpoint, the use of DOSS and Span 80 as food additives heightens concerns regarding their use and suggests further study.

Chen and Reese (2016) studied Retinol (vitamin A) signaling, mediated by all-trans retinoic acid (RA), which is essential for neural tube formation and the development of many organs in the embryo. The physiological levels of RA in cells and tissues are maintained by the retinol signaling pathway (RSP), which controls the biosynthesis of RA from dietary retinol and the catabolism of RA to polar metabolites for removal. RA is a potent activating ligand for the RAR/RXR nuclear receptors. Through RA and the receptors, the RSP modulates the expression of many developmental genes; interference with the RSP is potentially teratogenic. In this study, the mouse P19 embryonal cell, which contains a functional RSP, was used to evaluate the effects of the Corexit dispersants on retinol signaling and associated neuronal differentiation. The results showed that Corexit-EC9500A was more cytotoxic than Corexit-EC9527A to P19 cells. At non-cytotoxic doses, Corexit-EC9527A inhibited retinol-induced expression of the Hoxa1 gene, which encodes a transcription factor for the regulation of body patterning in the embryo. Such inhibition was seen in the retinol- and retinal-induced, but not RA-induced, Hoxa1 up-regulation, indicating that the Corexit chemicals primarily inhibit RA biosynthesis from retinal. In addition, Corexit-EC9527A suppressed retinol-induced P19 cell differentiation into neuronal cells, indicating potential neurotoxic effect of the chemicals under the tested conditions. The surfactant ingredient, dioctyl sodium sulfosuccinate (DOSS), may be a major contributor to the observed effect of Corexit-EC9527A in the cell.

Green et al. (2014) carried out a 5-yr study to identify potential long-term health effects to workers involved in the response to the Deepwater Horizon Oil spill. The levels of contaminant exposure received by Deepwater Horizon response workers were evaluated and the aspects of exposure were compared to the limited amount of information available for the Prestige oil spill response for which researchers have reported evidence of long-term health effects. Monitored chemicals included: various measures of oil and its constituents (e.g., petroleum distillates, BTEX compounds, and H_2S), the dispersants employed (e.g., 2-butoxyethanol), and combustion by-products (e.g., PAH). The frequencies and concentrations of chemicals detected in air were reviewed and, using benzene as an example, evaluated to determine whether exposures led to adverse acute and chronic effects on human health. Approximately 89% of the measurements for Deepwater Horizon cleanup workers were less than measurements reported for paid cleanup workers during the Prestige spill, largely the result of the differing nature of the two releases.

Konkel et al. (2018) studied between 27,659 and 29,468 oil spill cleanup workers who provided responses via a telephone survey about respiratory, skin, and eye irritation symptoms during and after the Deepwater Horizon response. The survey was conducted between 2011 and 2013, one to three years after the spill. All respondents were part of the Gulf Long-term Follow-up Study (GuLF STUDY), an ongoing investigation of potential long-term health outcomes among workers involved in the Deepwater Horizon oil spill cleanup. After adjusting for estimated co-exposures, including crude oil and other chemical decontaminants, the researchers found that workers with potential exposures to either EC9527A or EC9500A were more likely to report that they experienced certain systems during the cleanup. Dispersant-exposed workers were 61% more likely than unexposed workers to report burning in the nose, throat, or lungs, 58% more likely to report chest tightness, 49% more likely to report eye irritation, and about 40% more likely to report cough or wheeze.

Konkel (2017) examined aerial application of oil dispersant use during the Deepwater Horizon oil spill response in the Gulf of Mexico in 2010. This theoretical analysis examined aerial dispersant application with a Lockheed C-130, the platform for the largest volume of dispersant applied at the water surface, under the extremes of the range of wind conditions in which dispersant application was expected. The results determined that in the unlikely event that dispersant application was undertaken with the aircraft experiencing a cross-wind ranging up to 35 knots, dispersant spray would not exceed a drift distance beyond 0.5 nautical miles.

Liu et al. (2016) evaluated the transcriptomic profile of human airway epithelial cells grown under treatment of crude oil, the dispersants Corexit 9500 and Corexit 9527, and oil-dispersant mixtures. They identified a very strong effect of Corexit 9500 treatment, with 84 genes (response genes) differentially expressed in treatment vs. control samples. They found an interactive effect of oil-dispersant mixtures; while no response gene was found for Corexit 9527 treatment alone, cells treated with Corexit 9527 + oil mixture showed an increased number of response genes (46 response genes), suggesting a synergic effect of 9527 with oil on airway epithelial cells. Through GO (gene oncology) functional term and pathway-based analysis, they identified upregulation of gene sets involved in angiogenesis and immune responses and downregulation of gene sets involved in cell junctions and steroid synthesis as the prevailing transcriptomic signatures in the cells treated with Corexit 9500, oil, or Corexit 9500 + oil mixture. Interestingly, these key molecular signatures coincide with important pathological features observed in common lung diseases, such as asthma, cystic fibrosis and chronic obstructive pulmonary disease. The study provides mechanistic insights into the detrimental effects of oil and oil dispersants to the respiratory system and suggests significant health impacts of the recent BP oil spill to those involved in the cleanup.

Liu et al. (2017) performed RNA-seq analyses of a system of human airway epithelial cells treated with the BP crude oil and/or dispersants Corexit 9500 and Corexit 9527. Based on the RNA-seq data, they systemically analyzed the transcriptomic perturbations of the cells at the KEGG pathway level using two pathway-based analysis tools, GAGE (generally applicable gene set enrichment) and GSNCA (Gene Sets Net Correlations Analysis). The results suggested a pattern of change towards carcinogenesis for the treated cells marked by upregulation of ribosomal biosynthesis, protein processing, Wnt signaling, neurotrophin signaling and insulin signaling pathways under dispersant Corexit 9527 treatment, as identified by GAGE analysis. Furthermore, through GSNCA analysis, they identified gene co-expression changes for several KEGG cancer pathways, including small cell lung cancer pathway, under various treatments of oil/dispersant, especially the mixture of oil and Corexit 9527. Overall, the results suggested carcinogenic effects of dispersants (in particular Corexit 9527) and their mixtures with the BP crude oil and provided further support for more stringent safety precautions and regulations for operations involving long-term respiratory exposure to oil and dispersants.

McGowan et al. (2018) used the Deepwater Horizon opportunity to study associations between dispersant exposure (Corexit EC9500A or EC9527A) and human health. The objectives were to examine associations between potential exposure to the dispersants and adverse respiratory, dermal, and eye irritation symptoms. Using data from the detailed Gulf Long-term Follow-up (GuLF) Study enrollment interviews, they determined potential exposure to either dispersant from participant-reported tasks during the spill response work. Between 27,659 and 29,468 participants provided information on respiratory, dermal, and eye irritation health. They estimated prevalence ratios (PRs) to measure associations with symptoms reported during the response work and at study enrollment, adjusting for potential confounders including airborne total hydrocarbons exposure, use of cleaning chemicals, and participant demographics. The results show that exposure to either of the dispersants was significantly associated with all health outcomes at the time of the response, with the strongest association for burning in the nose, throat, or lungs [adjusted PR (aPR) =1.61], tightness in chest [aPR = 1.58], and burning eyes [aPR = 1.48]. Weaker, but still significant, associations were found between dispersant exposure and symptoms present at enrollment. It was concluded that exposure to Corexit EC9527A or EC9500A was associated with a range of health symptoms at the time of the response, as well as at the time of study enrollment, 1–3 years after the spill.

Murphy et al. (2016) examined approximately 10% of oil spill literature (1255 of over 11,000 publications) published from 1968 to 2015. They find that, despite its episodic nature, oil spill research is a rapidly expanding field with a growth rate faster than that of science as a whole. There is a massive post-Deepwater Horizon shift of research attention to the Gulf of Mexico, from 2% of studies in 2004–2008 to 61% in 2014–2015, thus ranking Deepwater Horizon as the most studied oil spill. There is, however, a longstanding gap in research in that only 1% of studies deal with the effects of oil spills on human health.

Popovech (2017) carried out a literature review on the health concerns of the ingredients of the constituents of Corexit 9527 and 9500. The review concluded the ingredients are similar to many household cleaners and thus do not constitute a concern.

Ramesh et al. (2018) investigated the in-vivo effects of DWH oil, Corexit, and oil-Corexit mixture on the general behavior, hematological markers, and liver and kidney functions of rodents. C57 Bl6 mice were treated with DWH oil (80 mg/kg) and/or Corexit (95 mg/kg), and several hematological markers, lipid profile, liver and kidney functions were monitored. The results show that both DWH oil and Corexit altered the white blood cells and platelet counts. Moreover, they also impacted the lipid profile and induced toxic effects on the liver and kidney functions. The impacts were more pronounced when the mice were treated with a mixture of both DWH-oil and Corexit. This study provides preliminary data to examine the potential toxicological effects of DWH oil, Corexit, and their mixtures on mammalian health.

Resnik et al. (2015) explore ethical issues that arose in the Gulf Long-term Follow-up Study (GuLF STUDY) and cleanup workers. Ethical issues encountered by GuLF STUDY investigators included a) minimizing risks and promoting benefits to participants, b) obtaining valid informed consent, c) providing financial compensation to participants, d) working with vulnerable participants, e) protecting participant confidentiality, f) addressing conflicts of interest, g) dealing with legal implications of research, and h) obtaining expeditious review from the institutional review board (IRB), community groups, and other committees. To ensure that ethical issues are handled properly, it is important for investigators to work closely with all agencies during the development and implementation of research and to consult with groups representing the community. Researchers should consider developing protocols, consent forms, survey instruments, and other documents prior to the advent of a public health emergency to allow for adequate and timely review by constituents. When an emergency arises, these materials can be quickly modified to take into account unique circumstances and implementation details.

Rung et al. (2015) conducted a survey of wives of cleanup workers of the Deepwater Horizon. The prevalence of depression in the sample was 31%, 33% reported increases in domestic fights, 31%–32% reported memory loss post-spill, and 39%–43% reported an inability to concentrate post-spill. An index representing total exposure to the spill, including both direct physical exposure to the oil/dispersants as well as indirect economic impact from the consequences of the oil spill, was constructed from 12 questionnaire items (mean 4.2, out of a possible range of 0–12) and further subdivided into physical exposure (mean score 1.6, out of a possible range of 0–6) and economic exposure indices (mean score 2.4, out of a possible range of 0–6). These results suggest that exposure to the Deepwater Horizon Oil Spill was associated with depression, increase in domestic partner fights, memory loss, and an inability to concentrate among female partners of oil spill clean-up workers.

Rusiecki et al. (2018) carried out a cohort study among Coast Guard personnel involved in the Deepwater Horizon (DWH) oil spill response and non-responders to investigate potential acute and long-term health effects from oil spill response work exposures. Results showed positive associations between crude oil exposure and various acute physical symptoms among responders, as well as longer-term health effects.

Sammarco et al. (2016) reviewed hydrocarbons in humans as a result of the DWH spill. During/after the BP/Deepwater Horizon oil spill, cleanup workers, fisherpersons, SCUBA divers, and coastal residents were exposed to crude oil and dispersants. These people experienced acute physiological and behavioral symptoms and consulted a physician. They were diagnosed with petroleum hydrocarbon poisoning and had blood analyses analyzed for volatile organic compounds; samples were drawn 5–19 months after the spill had been capped. The researchers examined the petroleum hydrocarbon concentrations in the blood. The aromatic compounds m,p-xylene, toluene, ethylbenzene, benzene, o-xylene, and styrene, and the alkanes hexane, 3-methylpentane, 2-methylpentane, and iso-octane were detected. Concentrations of the first four aromatics were not significantly different from US National Health and Nutritional Examination Survey/US National Institute of Standards and Technology 95th percentiles, indicating high concentrations of contaminants. The other two aromatics and the alkanes yielded equivocal results or significantly low concentrations. The data suggest that single-ring aromatic compounds are more persistent in the blood than alkanes and may be responsible for the observed symptoms. It was suggested that people should avoid exposure to crude oil through avoidance of the affected region, or utilizing hazardous materials suits if involved in cleanup, or wearing hazardous waste operations and emergency response suits if SCUBA diving. Concentrations of alkanes and PAHs in the blood of coastal residents and workers should be monitored well after the spill has been controlled.

Sathiakumar et al. (2017) characterized risk pertaining to seafood consumption patterns following the Deepwater Horizon oil spill, among school children (K to 4th grade) residing in close proximity to the Gulf of Mexico in Mobile County, Alabama. Responses on seafood consumption pattern including the type of seafood and intake rate during the pre- and post-oil spill periods, from parents of 55 school children from three schools located less than a 20-mile radius from the Gulf of Mexico shoreline (coastal group) were compared with those from parents of 55 children from three schools located more than 20 miles away from the shoreline (inland group). They also estimated levels of concern (LOCs) in seafood for selected chemicals found in crude oil including heavy metals, and polycyclic aromatic hydrocarbons (PAH), and dioctyl sodium sulfosuccinate (DOSS), the primary compound in dispersants. The coastal group ate more seafood consisting primarily of crustaceans (62% vs. 42%) and fin fish (78% vs. 58%) from the Gulf of Mexico compared to the inland group, while the inland group ate more fin fish not found in the Gulf of Mexico (62% vs. 33%). In the post-oil spill time period, both groups substantially reduced their consumption of sea food. On average, the coastal group ate more than 2 seafood meals per week, while the inland group ate less than 1 meal per week; these frequency patterns persisted in the post oil-spill period. Comparison of the estimated LOCs with contaminant levels detected in the seafood tested by the Food and Drug Administration and National Oceanic and Atmospheric Administration, post-oil spill, found that the levels of PAHs, arsenic, and DOSS in seafood were 1–2 orders of magnitude below the LOCs calculated in their study. Levels of methyl mercury (MeHg) in the seafood tested pre- and post- oil spill were higher than the estimated LOCs suggesting presence of higher levels of MeHg in seafood independent of the oil spill. In sum, the study found higher than average seafood consumption among children along the Mobile coastal area when compared to the inland children and the National Health and Nutrition Examination Survey (NHANES) estimates. Risk characterization based on the LOCs indicated no increase in risk of exposure despite higher seafood consumption rates among the study population compared to the general population.

Singleton et al. (2016) employed portable airborne particulate matter samplers and a genetically engineered bacterial reporter system (umu-ChromoTest from EBPI) to determine levels of genotoxicity of air samples collected from highly contaminated areas of coastal Louisiana including Grand Isle, Port Fourchon, and Elmer's Island in the spring, summer and fall of 2011, 2012, 2013 and 2014. Air samples collected from a non-contaminated area, Sea Rim State Park, Texas, served as a control for background airborne genotoxic particles. In comparison to controls, air samples from the contaminated areas demonstrated highly significant increases in genotoxicity with the highest values registered during the month of July in 2011, 2013, and 2014, in all three locations. This seasonal trend was disrupted in 2012, when the highest genotoxicity values were detected in October, which correlated with Hurricane Isaac landfall in late August of 2012, about five weeks before a routine collection of fall air samples. The data demonstrate: (i) high levels of air genotoxicity in the monitored areas over last four years post DWH oil spill; (ii) airborne particulate genotoxicity peaks in summers and correlates with high temperatures and high humidity; and (iii) this seasonal trend was disrupted by the hurricane Isaac landfall, which further supports the concept of a continuous negative impact of the oil spill in this region.

Starbird et al. (2015) examine how information about an oil spill, its impacts, and the use of dispersants to treat the oil, moved through social media and the surrounding Internet during the 2010 BP Deepwater Horizon oil spill. Using a collection of tweets captured during the spill, they employ a mixed-method approach including an in-depth qualitative analysis to examine the content of Twitter posts, the connections that Twitter users made with each other, and the links between Twitter content and the surrounding Internet. This article offers a range of findings to help practitioners and others understand how social media is used by a variety of different actors during a slow-moving, long-term, environmental disaster. They enumerate some of the most salient themes in the Twitter data, noting that concerns about health impacts were more likely to be communicated in tweets about dispersant use, than in the larger conversation. They describe the accounts and behaviors of highly retweeted Twitter users, noting how locals helped to shape the network and the conversation. Importantly, their results show the online crowd wanting to participate in and contribute to response efforts, a finding with implications for future oil spill response.

Temkin et al. (2016) investigated the environmental contamination resulting from the Deepwater Horizon (DWH) oil spill, including the use of the oil dispersant Corexit in remediation efforts, to determine whether obesogens were released into the environment during this incident. They also sought to improve the sensitivity of obesogen detection methods in order to guide post-toxicological chemical assessments. Peroxisome proliferator-activated receptor gamma (PPARγ) transactivation assays were used to identify possible obesogens. Solid-phase extraction (SPE) was used to sub-fractionate the water-accommodated fraction generated by mixing Corexit, cell culture media, and DWH oil (CWAF). Liquid chromatography-mass spectrometry (LC-MS) was used to identify components of fractionated CWAF. PPAR response element (PPRE) activity was measured in PPRE-luciferase transgenic mice. Ligand-binding assays were used to quantitate ligand affinity. Murine 3T3-L1 preadipocytes were used to assess adipogenic induction. It was found that serum-free conditions greatly enhanced the sensitivity of PPARγ transactivation assays. CWAF and COREXIT had significant dose-dependent PPARγ transactivation activities. From SPE, the 50:50 water:ethanol volume fraction of CWAF contained this activity, and LC-MS indicated that major components of Corexit contribute to PPARγ transactivation in the CWAF. Molecular modeling predicted several components of Corexit might be PPARγ ligands. They classified dioctyl sodium sulfosuccinate (DOSS), a major component of Corexit, as a probable obesogen by PPARγ transactivation assays, PPAR-driven luciferase induction in vivo, PPARγ binding assays (affinity comparable to pioglitazone and arachidonic acid), and in vitro murine adipocyte differentiation. They concluded that DOSS is a possible obesogen worthy of further study, including epidemiological and clinical investigations into laxative prescriptions consisting of DOSS.

Zhang et al. (2016) carried out laboratory aerosolization experiments and classical molecular dynamics simulations, with the objective of investigating the individual effects of the two Corexit surfactants Span 80 (non-ionic) and dioctyl sodium sulfosuccinate (DOSS-ionic), on the aerosolization of oil spill material to the atmosphere. Their simulation results show that Span 80, DOSS, and the oil alkanes n-pentadecane (C15) and n-triacontane (C30) exhibit deep free energy minima at the air/seawater interface. C15 and C30 exhibit deeper free energy minima at the interface when Span 80 is present, as compared to the situation when DOSS or no surfactants are at the interface. These results suggest that Span 80 makes these oil hydrocarbons more likely to be adsorbed at the surface of seawater droplets and carried out to the atmosphere, relative to DOSS or to the situation where no surfactants are present. These simulation trends are in qualitative agreement with their experimental observations in a bubble-column setup, where larger amounts of oil hydrocarbons are ejected when Span 80 is mixed with oil and injected into the column, as compared to when DOSS is used. Their simulations also indicate that Span 80 has a larger thermodynamic gradient than DOSS to move from the seawater phase and into the air/seawater interface. This observation is also in agreement with their experimental measurements, which indicate that Span 80 is ejected in larger quantities than DOSS. The simulations also suggest that DOSS predominantly adopts a perpendicular orientation with respect to the air/seawater interface at a dispersant-to-oil ratio (DOR) of 1:20 but has a slight preference to lie parallel to the interfaces at a DOR = 1:5; in both cases, DOSS molecules have their tails wide open and stretched. In contrast, Span 80 has a slight preference to align parallel to the interfaces with a coiled conformation at both DOR values. The study suggests that the presence of dispersants increases the likelihood of aerosolization of oil-water-surfactant droplets.

Results from Previous Literature Reviews 2014 and Before

For the first time, there were studies on the effects of dispersant application inferred from models. Tests of inhalation models showed that there might be a concern over human inhalation of dispersant vapors. However, the exposures and the levels of exposures may not be pertinent to at sea applications. Some of the mammalian studies showed concern, however dosage may not be relevant to actual situations.

Conclusions

This review marks the first such review of literature dedicated to the human health issues associated with oil spill dispersants. The major finding is that studies show that workers during the Deepwater Horizon spill showed respiratory symptoms from specific exposure to oil and dispersants. The effects were elevated from those effects noted for exposure to oil alone. Studies also show that oil and dispersants together in waves generate nano-particles which can travel long distances and may cause some of the symptoms noted in the Deepwater Horizon epidemiological studies. Several other studies were conducted, mostly mammalian, and these showed detrimental effects of oil mixed with dispersant or dispersant only; however, the exposures in these studies are difficult to relate to specific real-world exposures. The findings certainly indicate that further studies are needed.

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Notes on Table A1

Table A1, below, is a bibliography on all literature found on this topic of dispersants and human health. Older literature is summarized in the brief paragraph above.

Table A1 - List of References for Health Studies on Dispersants Since 2001

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