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Creating a Safer and Healthier World by Advancing the Science of Toxicology

The Deepwater Horizon Oil Spill

Introduction

The Deepwater Horizon (DWH) oil spill was the largest accidental release of crude oil in modern history. Even though the flow of oil and gas has stopped, many questions concerning the spill and its cleanup remain. Major areas in need of further research include, but are not limited to, determining what happened to the oil and chemicals used in the cleanup and assessing their long-term effects on the environment and human health. Members of the Society of Toxicology are specifically trained to study these important questions and interpret the findings. Their efforts will help ensure that policy decisions regarding the DWH spill and future oil spills are based on sound science.

The Chemistry and Toxicology of Oil and Dispersants

The first step in assessing the impact of any release of chemicals into the environment is to identify the chemicals involved, their environmental fate (what happens to them after release), and their potential impact on ecosystems and human health. In the case of the DWH incident, scientists are concerned with the crude oil and natural gas released from the well and dispersants applied to help mitigate the spill. An additional concern is exposure to chemicals formed when the oil burned. Crude oil and natural gas are complex, naturally occurring mixtures that together comprise thousands of different chemicals. Dispersants are also complex mixtures. Each component of these mixtures has its own physical, chemical, and toxicological properties, which can combine in unpredictable ways. The DWH incident not only released much more oil than previous spills such as the IxtocI blowout in the Gulf of Mexico (1979) and the Exxon Valdez tanker accident (1989), but the oil was released at a much greater depth (1,544 meters vs. 50 meters). The greater depth of the DWH spill means that additional factors such as temperature, pressure, and salinity may have affected the physical and chemical behavior and transport of the oil, complicating the assessment of dispersant effects.

The DWH release added a substantial new source of oil to the ongoing natural and human-induced releases that routinely occur in the Gulf of Mexico. By current estimates, the DWH spill released about 4.9 million barrels (795 million liters) of crude oil, accompanied by a similar volume of natural gas. Added to this was approximately 7 million liters of dispersants that were applied either at the surface (two-thirds) or at the wellhead (one-third). Crude oil contains hundreds of hydrocarbons of various types, as well as chemicals containing sulfur, nitrogen, or oxygen. The toxicity of oil has been studied extensively. Some of the most toxic components of oil include benzene, toluene, ethylbenzene, xylene, and polycyclic aromatic hydrocarbons.

Once released, the oil was subjected to a variety of physical, chemical, and biological processes including dissolution in seawater and evaporation (collectively called "weathering"), dispersion as small droplets into seawater (natural and facilitated by dispersants), sedimentation, transport, photodegradation, biodegradation, emulsification, and intentional combustion. Research by several groups and calculations made by federal agencies have provided a tentative approximation of the initial fate of the escaped oil. Although there is substantial uncertainty in some of the estimates, large fractions of the oil appear to have dispersed into small droplets, dissolved in seawater, or evaporated upon reaching the surface. In addition, some of the dispersed and dissolved oil remains as "plumes" at a depth of about 1,100 meters. Some of the oil that made it to the surface, which was not burned or evaporated, migrated to coastal habitats. The use of dispersants likely increased the bioavailability of the oil (its ability to be taken up or acted upon by organisms) and enhanced the opportunities for biodegradation. However, it also may have increased the potential exposure of sensitive organisms. The fate of the released oil and its many components remains poorly understood. This is an active area of research among oceanographers, engineers, and marine chemists.

Dispersants are used to enhance the mixing of oil with water, reducing exposure of organisms on the ocean surface and coastline. The trade-off with their use is that chemical dispersion of oil can increase the exposure of organisms below the surface in the water column and at the seafloor to oil, dispersants, and oil-dispersant mixtures. The dispersants used in the DWH incident (Corexit 9527 and Corexit 9500A) contain several surfactants (surface-active agents), solvents, and other chemicals. In short-term (2- to 4-day) laboratory tests using lethality as an endpoint, these dispersants tend to have relatively low acute toxicity to aquatic animals, although questions remain about potential sublethal or delayed effects: especially in sensitive species or life stages. The application of Corexit 9527 and Corexit 9500A in the deep ocean (1,500 meters) is unprecedented. Thus, there are no data on the fate and effects of dispersants applied in the deep ocean and how they may differ from what is known from surface application and from short-term (2- to 4-day) toxicity tests in the laboratory. An important question is how the impact of the dispersed oil differs from that of undispersed oil, and for the DWH spill this is not yet fully known. Certainly, the use of dispersants on the surface reduced the exposure of the coastline to oil and application of dispersants at the wellhead reduced the amount of oil reaching the surface. However, dispersant use in the deep ocean most likely increased the exposure of organisms in the water column and on the seafloor to dispersant and dispersed oil, and the potential effects of these chemicals in deepwater organisms are not well understood. Although most dispersants are thought to degrade rapidly in the environment, they have not been used previously in the deep ocean (1,500 meters) and persistence under these conditions is not known. Recent published research on the DWH incident suggests that at least some components of the dispersants applied at the well in deepwater were more resistant to biodegradation than expected, persisting up to 64 days after application was stopped. Dispersants are generally acknowledged to be less acutely toxic than the oil to which they are applied. However, application of dispersants increases the aqueous concentrations of petroleum hydrocarbons and distributes the oil over a larger volume, potentially increasing the exposure of benthic and mid-water organisms to oil. Understanding the fate and effects of dispersants applied in the deep ocean during the DWH incident continues to be an important need.

Environmental Effects

Toxicologists are involved in laboratory and field studies to measure the immediate impacts of the spill and to assess the potential for long-term effects. Understanding these impacts is complicated by the occurrence of a diverse array of ecosystems within the Gulf where the oil and dispersants migrated: includes deepwater bottom sediments and reefs, bays, estuaries, coastlands, bayous, and open water (surface and mid-water). It has been difficult to track the extent of contamination and persistence of the contaminants in each of these areas and, in turn, potential exposures to organisms. These environmental concerns are compounded by the fact that the Gulf also is home to both protected and commercially valuable species. When evaluating different ecosystems, the ranges, and life stages of species that passed through the affected areas immediately following the DWH incident must be considered. The species that are most sensitive to oil-related compounds, dispersants, or the complex mixture of the two are unknown, but are likely to include immature organisms, sessile organisms, and/or top predators. In addition to differences in species susceptibility, the potential for delayed or multigenerational impacts also must be considered. Distinguishing among the effects of this massive spill, the cleanup efforts, and the effects of natural releases of oil in the Gulf creates an additional complication.

Human Exposure and Health Effects

People can be exposed to chemicals in crude oil or dispersants through air, skin contact, or eating contaminated seafood from fisheries in the Gulf of Mexico. Because each source of crude oil has unique characteristics based on location, to understand the potential for short- and long-term health effects the specific toxicity of the source must be identified. Once we understand the toxicity related to human health effects, scientists will need to document the levels of exposure from combinations of breathing contaminated air, skin contact, and consumption of contaminated seafood. Fortunately, testing by state departments of health, the Food and Drug Administration (FDA) and National Oceanic and Atmospheric Administration (NOAA) has found primarily non-detectable or background concentrations of dispersants and Polycyclic aromatic hydrocarbons (PAH) in seafood and no increased health risks to humans consuming Gulf seafood (see Resources). Together the characterization of the component materials, research on their toxicity and measures of the amount of exposure will allow for the assessment of potential toxic effects resulting from the DWH incident. Scientists and policy makers can use the data collected on human exposure and toxicity information to describe potential short- and long-term health effects. This analysis should cover all potentially affected people, including those who have worked on the cleanup of the DWH spill and members of the communities impacted along the shoreline.

Summary & Future Directions

Current toxicological research has provided and will continue to provide important information about the human and environmental health consequences of the DWH incident. However, many areas of uncertainty and gaps in our knowledge remain. Although previous oil spills were studied extensively, each spill has unique characteristics. Therefore, one must be careful not to assume that all information from one incident will be fully transferable to other spills. Ongoing research will build on the results from current studies and define more completely the toxicity of the crude oil and dispersants released during the DWH incident and cleanup. Toxicologists are trained to investigate the human health, environmental and ecological effects of the DWH incident. The research conducted by toxicologists and their objective assessments of the data are critically important to the development of sound, science-based public policy regarding the DWH incident.

Suggested Resources

www.epa.gov/risk/

www.gulfspillrestoration.noaa.gov/

www.eoearth.org/oceanoil

www.restorethegulf.gov/

www.epa.gov/bpspill/dispersants.html

www.fda.gov/food/ucm210970.htm

www.noaa.gov/deepwaterhorizon/data/seafood_safety.html

www.dmr.ms.gov/Phttp://www.dmr.ms.gov/Publications/ms-seafood-safety-newsletter.pdf

www.dhh.state.la.us/reports.asp?Detail=802

"Oil in the Sea III: Inputs, Fates, and Effects. Committee on Oil in the Sea: Inputs, Fates, and Effects," National Research Council. 2003. ISBN: 0-309-50551-8.

"Understanding Oil Spill Dispersants: Efficacy and Effects." 2005. Committee on Understanding Oil Spill Dispersants: Efficacy and Effects, National Research Council. ISBN: 0-309-54793-8.

"Oil Budget Calculator: Deepwater Horizon." November 2010. The Federal Interagency Solutions Group, Oil Budget Calculator Science and Engineering Team. (**www.restorethegulf.gov/sites/default/files/documents/pdf/OilBudgetCalc_Full_HQ-Print_111110.pdf**)

Goldstein BD, Osofsky HJ, and Lichtveld MY. 2011. "The Gulf Oil Spill." *New England Journal of Medicine* 364:1334-1348.

Kessler JD, Valentine DL, Redmond MC, Du M, Chan EW, Mendes SD, Quiroz EW, Villanueva CJ, Shusta SS, Werra LM, Yvon-Lewis SA, and Weber TC. 2011."A Persistent Oxygen Anomaly Reveals the Fate of Spilled Methane in the Deep Gulf of Mexico." *Science* 331: 312-315.

Camilli R, Reddy CM, Yoerger DR, Van Mooy BA, Jakuba MV, Kinsey JC, McIntyre CP, Sylva S P, and Maloney JV. "Tracking Hydrocarbon Plume Transport and Biodegradation at Deepwater Horizon." 2010. *Science* 330: 201-204.

Kujawinski EB, Kido Soule MC, Valentine DL, Boysen AK, Longnecker K, and Redmond MC. "Fate of Dispersants Associated with the Deepwater Horizon Oil Spill." 2011. *Environ Sci Technol* 45: 1298–1306, (dx.doi.org/10.1021/es103838p).

Crone TJ, and Tolstoy M. 2010. "Magnitude of the 2010 Gulf of Mexico Oil Leak." *Science* 330: 634.

Schmidt CW. 2010. "Between the Devil and Deep Blue Sea: Dispersants in the Gulf of Mexico." *Environ. Health Persp* 118: A338-A344.

Hemmer MJ, Barron MG, and Greene RM. June 30, 2010. "Comparative Toxicity of Eight Oil Dispersant Products on Two Gulf of Mexico Aquatic Test Species." U.S. Environmental Protection Agency Office of Research and Development U.S.EPA/ ORD Contributors National Health and Environmental Effects Research Laboratory. (**www.epa.gov/bpspill/reports/ComparativeToxTest.Final.6.30.10.pdf**).

Valentine DL, Kessler JD, Redmond MC, Mendes SD, Heintz MB, Farwell C, Hu L, Kinnaman FS, Yvon-Lewis S, Du M, Chan EW, Garcia Tigreros F, and Villanueva CJ. 2010. "Propane Respiration Jump-starts Microbial Response to a Deep Oil Spill." *Science* 330: 208-211.

Reddy CM, Arey JS, Seewald JS, Sylva SP, Lemkau KL, Nelson RK, Carmichael CA, McIntyre, CP. Fenwick J, Ventura GT, Van Mooy BA, and Camilli R. July 18, 2011. "Science applications in the Deepwater Horizon Oil Spill special feature: Composition and Fate of Gas and Oil Released to the Water Column During the Deepwater Horizon Oil Spill." *Proc. Nat. Acad. Sci.* USA. (Published online before print July 18, 2011, doi: 10.1073/pnas.1101242108.)