Dispersants improved air quality for responders at Deepwater Horizon

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A study published Aug. 28, 2017, in the *Proceedings of the National Academy of Sciences* adds a new dimension to the controversial decision to inject large amounts of chemical dispersants immediately above the crippled oil well at the seafloor during the Deepwater Horizon disaster in 2010. The dispersants may have significantly reduced the amount of harmful gases in the air at the sea surface—diminishing health risks for emergency responders and allowing them to keep working to stop the uncontrolled spill and clean up the spilled oil sooner.

In the midst of the Deepwater Horizon crisis, officials made the unprecedented and controversial decision to inject more than 700,000 gallons of chemical dispersant over 67 days immediately above the oil rig's severed wellhead at the bottom of the ocean. The goal was to break up petroleum that surged uncontrollably from the wellhead into smaller droplets in the deep sea, with the goals of diminishing oil slicks and reducing the amount of harmful gases arriving at the ocean surface.

Proponents claim the dispersants did help dissipate oil slicks on the sea surface, causing less oil to taint shoreline beaches and marshes. Opponents said the dispersants themselves were toxic, may have caused environmental damage, and were not effective at reducing the already small droplets forming at the wellhead.

To this debate, the new study demonstrates a beneficial effect of dispersants: The subsea dispersant injection may have allowed emergency responders literally to breathe easier. By breaking up petroleum into smaller droplets that dissolved faster in the deep ocean, the dispersants decreased the amounts of volatile toxic compounds that rose to the surface and outgassed into the air. That dramatically improved the air quality for responders and presumably reduced the number of days when the air quality was too poor and responders had to don respirators and/or had to suspend cleanup efforts.

The research team included: Jonas Gros, Scott Socolofsky, Anusha Dissanayake, and Inok Jun (Texas A&M University); Lin Zhao and Michel Boufadel (New Jersey Institute of Technology); Christopher

Reddy (Woods Hole Oceanographic Institution); and J. Samuel Arey (Swiss Federal Institute of Aquatic Science and Technology). The research was funded by the Gulf of Mexico Research Initiative and the National Science Foundation.

Dispersants have been applied to oil slicks on the ocean surface for half a century to break petroleum into smaller droplets that dissipate into waters of the open ocean so that less oil reaches ecologically sensitive coastlines. But, they had never been used at the unprecedented depth of 5,000 feet beneath the surface, where an estimated 7,500 tons per day of oil and 2,400 tons per day of natural gas were jetting from the ruptured wellhead near the seafloor. This flow rate is equivalent to 57,000 barrels per day of oil and 92 million cubic feet per day of gas being produced at standard conditions at the sea surface. During the period studied by the authors, 19,000 barrels per day of oil were also captured by an inverted funnel, or "top hat," that was placed directly above the wellhead, which decreased the amount of oil that escaped into the sea.

"Government and industry responders were faced with an oil spill of unprecedented size and sea depth, pitting them in a high-stakes battle against big unknowns," Reddy and Arey wrote in an article in Oceanus magazine. They made a crucial decision to proceed with the subsurface injection of Corexit EC9500A, a dispersant that roughly resembles a mix of food-grade mineral oil, windshield-wiper fluid, and household dish detergent.

Aerial photographs and anecdotal accounts suggested that the deep-sea dispersant injection may have helped dissipate the oil slicks at the surface and improve air quality around responder boats working near the disaster site. But in the heat of the crisis, officials did not take the time to design and implement robust experiments to measure the detailed effects of the injection.

In the new study, scientists built and tested a mathematical model that simulated the complex chemical and physical interactions among water, oil, gas, and dispersant that occurred during Deepwater Horizon. They focused on the period starting June 3, 2010, when the riser pipe was cut at the wellhead by engineers, until July 15, 2010—a timespan when a large number of scientific observations were collected nearby in the air and ocean. To test the model's ability to simulate the real-world disaster, they compared the model predictions to the observations. Nearly all those comparisons aligned with the model's output, indicating that the model replicated many aspects of what happened to oil and gas under the ocean surface.

The research team then used the model to conduct a key test that was never done in real life: They ran the model to see what likely would have happened if dispersants had not been injected immediately above the wellhead during the same time period.

The model results indicated that deep-sea dispersant injection had a profound effect on air quality at the ocean surface. The injection of the subsea dispersant caused the turbulent jet of petroleum fluids to form oil droplets that were about 30 times smaller (by volume) than they would have been without dispersants, according to the model results. This subtle change caused many volatile petroleum chemicals to dissolve more rapidly and become entrapped in the deep sea. According to the study, most of the highly toxic benzene and toluene in the oil were transported away in deep currents, along with other entrapped petroleum compounds that affected organisms on and near the sea floor. The benzene and toluene likely would have become biodegraded within weeks.

"In 2010 when NSF began rapid response funding for research on Deepwater Horizon, it was important to characterize the initial conditions of the spill, such as plume dynamics and ecological effects," said Don Rice, a program director in the NSF's Division of Ocean Sciences. "These scientists and others did just that. As the findings of this study clearly demonstrate, the discoveries of basic scientific research and the ensuing practical applications in their wake are often utterly unanticipated."

The model showed that the dispersant injection decreased the overall concentration of all volatile organic chemicals in the atmosphere by a modest amount (about 30 percent). But it also significantly reduced the amount of chemicals most harmful to humans, such as benzene and toluene. The atmospheric concentration of benzene, for example, decreased by about 6,000 times, dramatically improving air quality.

Without the dispersant injection, the model showed that benzene concentrations in the air 2 meters above the sea surface would have been 13 times higher than the levels considered acceptable to breathe during a 10-hour working day or a 40-hour work week, based on guidelines by the National Institute of Occupational Safety and Health (NIOSH). However, with dispersant injection, the model showed atmospheric benzene concentrations were 500 times lower than the levels considered acceptable to breathe by NIOSH.

"These predictions depend on local weather conditions that can vary from day to day. However, we predict that cleanup delays would have been much more frequent if subsurface dispersant injection had not been applied," Reddy and Arey say.

"But this one study is not the final say on the usage of dispersants," they added. "It is another row on a ledger sheet called the 'spill impact mitigation analysis,' " which assesses various strategies and tools to reduce environmental and economic damage caused by oil spills. "All potential positive and negative effects of dispersant injection need to be taken into account before final judgements on their future use can be robustly determined," they said.

The debate about using dispersants is becoming increasingly politicized and acrimonious, and the National Academy of Sciences has recently assembled a committee of scientists, government officials, and industry to evaluate the use of chemical dispersants in oil spill response.

More information: Jonas Gros el al., "Petroleum dynamics in the sea and influence of subsea dispersant injection during Deepwater Horizon," *PNAS* (2017). www.pnas.org/cgi/doi/10.1073/pnas.1612518114

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