Partial Photochemical Oxidation Was a Dominant Fate of Deepwater Horizon Surface Oil

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Results and Discussion

Following the Deepwater Horizon (DWH) blowout in 2010, oil floated on the Gulf of Mexico for over 100 days. In the aftermath of the blowout, substantial accumulation of partially oxidized surface oil was reported, but the pathways that formed these oxidized residues are poorly constrained. Here we provide five quantitative lines of evidence demonstrating that oxidation by sunlight largely accounts for the partially oxidized surface oil. First, residence time on the sunlit sea surface, where photochemical reactions occur, was the strongest predictor of partial oxidation. Second, two-thirds of the partial oxidation from 2010 to 2016 occurred in less than 10 days on the sunlit sea surface, prior to coastal deposition. Third, multiple diagnostic biodegradation indices, including octadecane to phytane, suggest that partial oxidation of oil on the sunlit sea surface was largely driven by an abiotic process. Fourth, in the laboratory, the dominant photochemical oxidation pathway of DWH oil was partial oxidation to oxygenated residues rather than complete oxidation to CO2. Fifth, estimates of partial photo-oxidation calculated with photochemical rate modeling overlap with observed oxidation. We suggest that photo-oxidation of surface oil has fundamental implications for the response approach, damage assessment, and ecosystem restoration in the aftermath of an oil spill, and that oil fate models for the DWH spill should be modified to accurately reflect the role of sunlight.

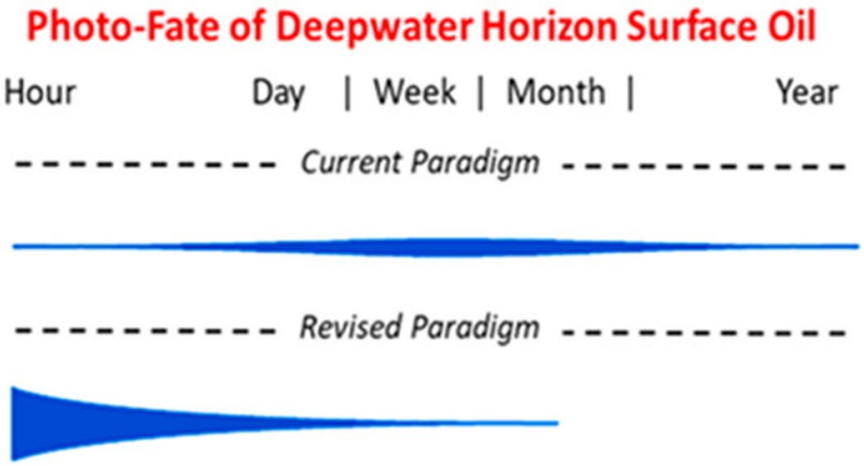

Figure 1: The oxygen content analysis of 340 field residues collected from 2010 to 2016, including ~80 collected within ~100 days from the start of the spill provided a comprehensive assessment of the magnitude of partial oxidation during transit on the sea surface versus oxidation following deposition in coastal ecosystems. The high resolution FT-ICR MS analysis confirmed the presence of oxygenated transformation products that were not present in the parent (unaltered) oil. In the laboratory, we measured apparent quantum yields for partial photo-oxidation, and incorporated these yields into a model to calculate daily rates of photo-oxidation throughout the 102-day period of surface oiling (24 April to 3 August 2010). To determine the contribution of photochemical processes to partial oxidation of the surface oil, we compared our modeled estimate for partial photo-oxidation of the surface oil to the observed oxidation in the field. Results provide multiple quantitative lines of evidence that demonstrate that partial photochemical oxidation was the primary driver for the observed oxidation of DWH surface oil. Thus, the current model for the importance and time scale for photo-oxidation in oil spills required revision.

Acknowledgments

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References (citation of the publication)

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