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Modelling of deep-sea oil spill releases incorporating hydrocarbon biodegradation kinetic rates of the Eastern Mediterranean deep-sea consortia

Katerina Spanoudaki[1], Eleftheria Antoniou[2,3], Efsevia Fragkou[2], Georgia Charalambous[2], Evina Gontikaki[2,4], and Nicolas Kalogerakis[2,4]
[1]Foundation for Research and Technology-Hellas, Institute of Applied and Computational Mathematics, Heraklion, Crete, Greece (kspanoudaki@gmail.com)
[2]School of Chemical and Environmental Engineering, Technical University of Crete, 73100 Chania, Crete, Greece
[3]School of Mineral Resources Engineering, Technical University of Crete, 73100 Chania, Crete, Greece
[4]Foundation for Research and Technology-Hellas, Institute of GeoEnergy, 73100 Chania, Crete, Greece

Deep-sea oil releases from accidents during offshore exploratory drilling or production are of particular concern, as the potential for such accidents increases with the expansion of the offshore industry to more extreme environments. During the 2010 Deepwater Horizon, huge amounts of oil were released into the Gulf of Mexico, adversely affecting marine wildlife. What prevented a worse outcome was the ability of nature to biodegrade oil.

To this end, the community oi spill model MEDSKIL-II has been modified to incorporate biodegradation kinetics of dissolved oil and oil droplets dispersed in the water column. Biodegradation of oil can be modelled by Monod kinetics or as a first order decay process. The kinetics of oil particles size reduction due to the microbe-mediated degradation at water-oil particle interface is represented by the shrinking core model. Furthermore, a Lagrangian plume module has been developed and coupled to MEDSLIK-II, for predicting the fate of the spill until reaching the sea surface. The Lagrangian plume model is represented by elements that trace the plume's trajectory. Each Lagrangian element represents a mixture of water, oil and gas. Changes in the mass and composition of the element are accounted for by the turbulent entrainment of ambient water, leakage of gas bubbles and oil droplets from the plume, dissolution of gas in seawater, and formation or disintegration of gas hydrates. The motion of the element is computed from the conservation equations for mass, momentum, and buoyancy. Biodegradation kinetics are also represented in the model, to enhance prediction of fate and transport of deep-sea spills.

A novel sampling apparatus was designed for the collection of indigenous microbial populations from the deep Eastern Mediterranean Sea, maintaining *in situ* pressure throughout the entire process of retrieval and experimentation to determine microbial oil degradation. Seawater samples were collected on board the R/V Aegaeo (Hellenic Centre for Marine Research) on 2-29-2020, off Southeast Crete, Greece. The High Pressure (HP) Sampler collected seawater between 600 to 1000 m depth. A known volume of the collected sample was transferred via a

piston pump, without pressure disruption, into a HP-Reactor, at 10 MPa pressure and was incubated with crude oil at plume concentration for 77 days at *in situ* temperature (14^{o}C). Iranian light crude oil bioremediation was monitored for 35 days, and then the effect of dispersant addition (1:25 v/v COREXIT 9500) was observed until day 77. Kinetic analysis was used to estimate the degradation rates of hydrocarbon compounds, which were incorporated into the integrated modified MEDLSLIK-II model to simulate the effect of biodegradation on the fate and transport of subsurface spills for the Sea of Crete. Several scenarios have been considered to include the different laboratory data and oceanographic fields (water density, currents) for the area. To our knowledge, this is the first modelling effort incorporating area-specific data for biodegradation capacity of hydrocarbon degrading consortia to predict the fate of deep-water oil releases in the Eastern Mediterranean Sea.

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