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Mathematical modelling of oil spill fate and transport in the marine environment incorporating biodegradation kinetics of oil droplets

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Oil biodegradation by native bacteria is one of the most important natural processes that can attenuate the environmental impacts of marine oil spills. However, very few numerical models of oil spill fate and transport include biodegradation kinetics of spilled oil. Furthermore, in models where biodegradation is included amongst the oil transformation processes simulated, it is mostly represented as a first order decay process neglecting the effect of several important parameters that can limit biodegradation rate, such as oil composition and oil droplets-water interface. To this end, the open source numerical model MEDSKIL-II, which simulates oil spill fate and transport in the marine environment, has been modified to include biodegradation kinetics of oil droplets dispersed in the water column.

MEDSLIK-II predicts the transport and weathering of oil spills following a Lagrangian approach for the solution of the advection-diffusion equation. Transport is governed by the 3D sea currents and wave field provided by ocean circulation models. In addition to advective and diffusive displacements, the model simulates several physical and chemical processes that transform the oil (evaporation, emulsification, dispersion in the water column, adhesion to coast). The fate algorithms employed in MEDSLIK-II consider the oil as a uniform substance whose properties change as the slick weathers, an approach that can lead to reduced accuracy, especially in the estimation of oil evaporation and biodegradation. Therefore MEDSLIK-II has been modified by adopting the "pseudo-component" approach for simulating weathering processes. Spilled oil is modelled as a relatively small number of discrete, non-interacting components (pseudo-components). Chemicals in the oil mixture are grouped by physical-chemical properties and the resulting pseudo-component behaves as if it were a single substance with characteristics typical of the chemical group. The fate (evaporation, dispersion, biodegradation) of each component is tracked separately. Biodegradation of oil droplets is modelled by Monod kinetics. 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. In order to test the performance of the modified MEDSLIK-II model, it has been applied to a test case built-in the original code. The total fate of the oil spill is simulated both without biodegradation kinetics and when biodegradation is taken into account, for reasons of comparison. Several parameters that control biodegradation rate, including initial oil concentration and composition, size distribution of oil droplets and initial microbial concentration have been investigated. This upgraded version of MEDSLIK-II can be useful not only for predicting the transport and fate of spilled oil in the short term but also for evaluating different bioremediation strategies and risk assessment for the mid- and long term.

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