Numerical Prediction of the Dispersion in Fluvial Environment of Oil Mineral Aggregates Using Impeller Ship

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Abstract

The possibility of accidental oil spills in the St. Lawrence River during winter remains a significant concern for the Canadian Coast Guard (CCG), a branch of the Canadian Department of Fisheries and Oceans. Spill sources come from stevedoring in oil terminals, grounding on sand banks, collisions between ships or with obstacles to name a few. Although their frequency decreased, there are more or less 35 fluvial oil spills per year. The decontamination budget follows at a rate of several thousand dollars per ton. In winter conditions, the impact of an oil spill is all the more important that there exist no effective method of recovering spilled oil when water is encumbered with ice. The traditional mechanical oil recovery methods, deployed because there are no other alternatives, offer a poor performance in ice. As a result, at-sea recovery is very expensive and ineffective under these conditions.

Part of a venture in scientific co-operation that aims at assessing the effectiveness of using fine clay minerals as natural dispersant of oil in ice, the results of this study will allow the CCG to develop guidelines for an oil spill response procedure in ice-encumbered waters. The response procedure aims at neutralizing oil products by adding fine sediments and to disperse them in the form of oil-mineral aggregates (OMA) which have the property of being easily metabolizable by micro-organisms.

This promising alternative spill countermeasure takes advantage of the natural phenomenon of aggregation of oil droplets to mineral fines, which has proven to play a significant role in the “self-cleaning” of soiled low hydrodynamics energy environment. Also, given the hydrodynamic conditions and chemical characteristics of the water in the St. Lawrence Estuary, researchers came to the conclusion that a response method based on the formation of OMA could prove to be effective when sediments are artificially introduced along with some mixing energy, even when ice is present. That energy will have to be introduced artificially. It was then considered to use the turbulence produced

by an ice-breaker's impellers to generate sufficient mixing to initiate the formation of OMA. However, its dispersion potential is not well understood.
Hence, this study aims at assessing the effectiveness of using fine clay minerals as natural dispersant of oil in ice. The interest is to investigate the influence of an ice cover on the dispersion potential in winter conditions. The OMA drift and fate model is based on a one-way coupling solid-liquid model. A RANS model is used to obtain the turbulent velocity field that was combined to the sedimentation velocity field to build up the hydrodynamic database employed for OMA tracking. To evidence the potential dispersion, two hydrodynamic scenarios are retained, with and without an ice cover on the free surface. For each scenario, the computational results are presented for a selection of particle densities in order to appraise the model through comparison of the statistics of OMA distribution in the water column.
In the light of the results obtained, the following conclusions can be drawn:

- the ice cover influences the OMA distribution pattern;
- the proportion of OMA in the bulk of the water column is larger in winter condition versus ice-free conditions;
- impeller ship rotational speed influences the OMA potential dispersion.

keywords: dispersion, ice cover, impeller ship, modeling, oil-mineral aggregates, turbulent flow

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