Optimization of response strategies in the emergency response planning process for crude oil spills: compilation of lab data, pilot scale experiments, drift modelling and sensitivity mapping

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Introduction

The weathering of crude oils spilled at sea is complex as different processes (evaporation, dispersion, emulsification, photo-oxidation…) take place simultaneously, mainly governed by environmental conditions. In addition, each oil has its own chemical composition, and the extent of the various weathering processes depends on its initial physical-chemical characteristics.

In order to assess the fate and behaviour of a crude oil for a particular site at risk, modelling software can be used, but these generally do not consider the specific physical-chemical properties of the product. To provide responders with more reliable data, Cedre has developed several pilot scale devices which, in combination with laboratory tests, fully document the crude oil potential behaviour. Understanding these transformations is a key element in evaluating the potential impacts of oil and assessing the efficiency and time windows of response strategies: mechanical recovery, chemical dispersion, in situ burning.

Such results can be integrated as inputs of stochastic models in order to characterize the drift and to transpose potential impacts on threatened area as well as time windows into operational ranges. Compared with mobilisation time of the required equipment, such analyses are the only way to ensure that available resources are in adequacy with the required ones and, if needed, to identify gaps in response and preparedness. The maps produced, when combined with sensitivity atlases will allow planners to draw strategical and tactical ones and to get reliable decision making tools.

Main Results

Over the last few years, Cedre has developed many original pilot scale device designed to answer the various questions related to oil spill response. These tools cover a wide range of issues: oil weathering and dispersibility, *in situ* burning, behaviour in the water column and on the shoreline, oil adhesion and cleaning... and are often used to anticipate the fate and behaviour of crude oils which characteristics have the most significant impacts on response options. In parallel, many modelling tools were used and adapted to integrate the results of such analyses and get strategical and tactical maps as outputs.

<u>Lab data to characterize the oil and anticipate its behaviour</u>

To simulate the main weathering processes, crude oils are exposed to a systematic, stepped procedure including distillation and emulsification processes, thus leading to different samples (which can also be photo-oxidized), representative of the potential evolutions at sea. This “bench-scale experiment” is performed at the reference temperature of the oilfield or area liable to be impacted, and can be extrapolated to various temperatures and wind speeds by using modelling software. This test matrix is in agreement with the set of data required by the Oil Weathering Model (OWM) developed by SINTEF (Daling and Strøm, 1999). On a larger scale, tests can also be performed in the flume at different temperatures, assuming a moderate surface energy [waves, wind and current about sea state 3]. The tests last 7 days in Cedre’s hydraulic canal, which is used with the water being continuously circulated to simulate open sea conditions. During the tests, approximately 15 surface oil samples are taken periodically to assess the oil characteristics: density, viscosity, water content, evaporation rate … as previously described (Guyomarch et al., 2012, update of Guyomarch et al., 2000). In addition or directly in the flume, the weathered crude oils are subjected to dispersibility tests using the IFP laboratory protocol and/or the MNS method.

In order to better understand the oil behaviour, a detailed chemical characterization can be conducted. Oil samples are characterized through different chemical analyses, either focused on individual compounds or on families or compounds such as asphaltenes and waxes. In particular, the analysis of Volatile Organic Compounds (31 molecules), PAHs (43 molecules or groups of molecules), combined with a global characterization of saturates and aromatics, leads to a set of data in agreement with the requirements of the OSCAR model.

Pilot scale experiments to define strategies and techniques

Dispersion

In order to assess the time-window of opportunity for dispersant use, the emulsions prepared at the laboratory scale are systematically tested according to the IFP and MNS protocols, at the test temperatures and considering a reference dispersant. From these results, it is possible to specify the chemical dispersibility of the tested oil according to its viscosity, then classified as fully dispersible, potentially dispersible, or non-dispersible as well as to assess the time-window of opportunity for dispersant use.

One “laboratory” sample characterized by a reduced dispersibility can be selected for comparative test aiming at selecting the most efficient dispersant amongst those which are available in local stockpiles. All the tests are carried out according to the IFP protocol as this low-energy protocol is more adapted to reveal differences between various commercial dispersants products.

In situ burning

Regarding ISB, the efficiency of the technique is related to the oil nature, slick thickness, weathering degree, water content… In order to assess the influence of these parameters on the ignitability and burning efficiency, an experimental device was developed at Cedre: the Burning Bench. At the end of a burning test, residues are collected and quantified after solvent extraction in order to determine the degradation rate. Different analyses are then performed on the residues: density, viscosity, simulated distillation, PAH and alkanes distribution and content …

Combined with weathering experiments, this enables the definition of a time-window of opportunity for in situ burning.

Containment and recovery

Thanks to bench-scale experiment and/or flume tests, the viscosity of the product can also be assessed to define the time-window conceivable for different types of recovery systems: mechanical or oleophilic skimmers, sorbents.

To go further, tests can be run, with a specific crude oil and specific skimmers available locally using a trial method applied at Cedre in agreement with the French AFNOR or ASTM standards. Such performances assessment is focused on recovery rates, selectivity and efficiency, the notion of selectivity referring to the percentage of oil in the mixture recovered.

From modelling results to decision making tools

The results of oil characterization can be integrated as inputs of stochastic models which provide an overview of the most likely drift in the area concerned according to variations in meteo-oceanic statistical data and the parameters of the scenario considered. It analyses trajectories of hundreds of individual cases for each spill scenario, providing several types of results: the probability of the oil slick drift at sea, the probability of deposits ashore as well as the shortest time needed to reach the impacted coastline.

Knowing the potential impacts of the oil, these maps will help to determine the threatened area. Having defined the dispersion, ISB and/or recovery time windows, these maps will help decision makers to define their operational ranges.

The objective of these maps will be to present, in a simple and practical format, clear, operational information that can be used directly by the decision-maker(s) in terms of strategic and tactical choices in line with the main strategies validated by the affiliate on the basis of NEBA (Net Environmental Benefit Analysis) / SIMA (Spill Impact Mitigation Analysis).

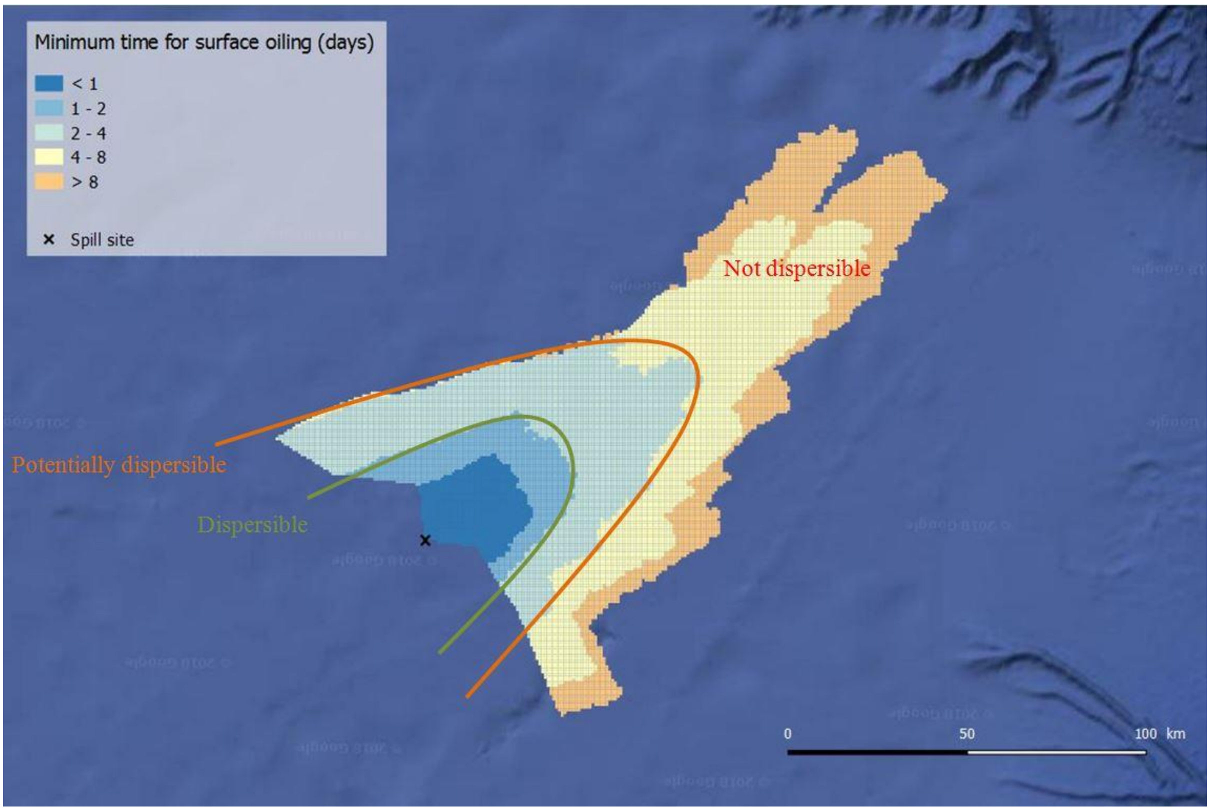
Compared with mobilisation time of the equipment required, these analyses will represent an essential tool to ensure that available resources will be mobilised within the time allotted. If it not the case, the strategical and tactical maps will help the decision makers adapting their response options, to acquire additional equipment and/or to relocate their stockpiles.

Conclusion

To better assess the risks of pollution, and consequently the most appropriate response option and means, the stochastic drift is particularly useful. Combined with the time-window of opportunity for dispersant use, for example, it leads to distances from the source of pollution characterized by various levels of dispersibility. The logistics can then be reliably sized in terms of distance range and capacity of treatment.

The various characterizations, experiments, modelling and mapping can be achieved in the framework of the preparedness of an Oil Spill Contingency Plan, for instance or during a crisis. The final objective of combining these decision-making tools is to reduce uncertainties thanks to reliable inputs, the behaviour of the oil remaining closely related to its drift in the marine environment, and the efficiency of response conditioned by the pollutant fate, meteorological conditions as well as efficient resources available.

Supporting Images or Graphs



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