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Oil product spreading on the water surface limitation using air stream

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Abstract

The oil spill in the marine environment is becoming a serious problem in the recent years. After it enters the water remediation techniques should be applied as soon as possible, because right after oil enters the water a number of weathering and transportation processes start changing its physical and chemical properties. Before deploying oil remediation techniques the direction and velocity of wind and water currents must be observed. Since wind is one of the parameters making oil to spread, it is believed that artificially caused air stream can help to control its spreading. During experiment was established that between 2.5–3.5 m/s air flow velocities diesel, as an used oil product, spreading at certain thicknesses can be limited.

Keywords: oil spreading; water surface; artificial air flow; limitation; movement

1. Introduction

Pollution of marine environment occurring after spills of the oil products is becoming a serious problem in the recent years. After oil spill fast and successful response is necessary and contingency plan the goal of which is to obtain information about oil spill clean-up and containment processes is required [1]. A good tool in these cases is oil spill modelling technique the aim of which is to predict the oil spill moving trajectory on the water surface as well as water column [2]. However, data about the spill, which includes the location and lost volume of the spill also the type

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of oil product, are often uncertain as well as environmental data about currents and wind forecasts and observations are sometimes not available or sparse [3].

Oil after the spill starts to disperse, spread and fragment because of the currents, gravity, and wind [4]. The primary actions after the oil spill are to control it moving, to reduce the negative impact on the marine environment and to speed up the degradation process of the unrecovered oil [5]. However, because of the lack of information about different physical processes the accurate predictions of the oil behavior and movement requires a lot of effort [3]. The most debated issue is oil spill clean-up and control, because there is no possibility to remove all of it from marine water [6], because it starts to spread immediately after spill. This oil spreading could be limited before other techniques will be applied.

1.1. Oil weathering and transport processes

A series of natural physical and chemical changes that oil undergoes following its release into the environment are called weathering processes. Weathering of oil depends on the type of oil (physical and chemical properties), environmental conditions (wind, waves, temperature and sunlight), the properties of seawater (salinity, temperature) and the presence of biodegrading microbes such as bacteria [7]. Weathering processes consist of evaporation, emulsification, dissolution, photo-oxidation and biodegradation. Also, oil products after spill are transported. Transport processes consist of dispersion, advection, encapsulation, sedimentation and spreading. Weathering and transport processes interact with each other and in this way they change oil properties. These processes start and end at different times. Some processes start immediately after the spill, such as evaporation, dissolution, spreading, natural dispersion and so on, and others occur after some time, like biodegradation, photo-oxidation or sedimentation [2].

One of the main oil transportation processes is spreading. For small oil spills, a complete spreading process occurs during the first hour after the spill [3]. It occurs due to viscosity, gravity, buoyancy and surface tension forces. As a result, a thin layer of oil covers large water surface area [8]. Much faster spreads lighter and less viscous oil products in warm water. The spreading process also depends on wind drift, surface current and other mixing processes like diffusion. These mechanisms can transport oil long distances [3].

1.2. Key parameters for surface oil spreading

As was mentioned earlier, oil begins to spread right after it enters the water [9]. After oil spills on the water surface, it begins to spread, disperse and fragment because of the currents, wind and gravity forces [4].

Fay was one of the first scientists who developed the most known oil spreading model. This model is dividing oil spreading process, based on braking and driving oil spreading forces, into three independent phases. The first driving force which causes relatively thick oil slick to spread laterally is gravity. After that, the dominant spreading force at the periphery becomes interfacial tension. There are also two breaking forces, the main of which is initially inertia, and another viscous drag of the water. Thus, before mentioned three independent phases are gravity-viscous, surface viscous and surface-viscous [9, 10].

However, in Fay's formula wind is not considered as a factor that has an influence on the slick of spilled oil or that wind can cause turbulence. This is why in the Fay formulation horizontal oil spreading diameter in comparison with observed measurements is not taken into account. Therefore, Fay formula was modified by involving the wind as an important factor in oil spreading equation (Eq. (1)):

$$A = 2270\left(\frac{\Delta\rho}{\rho_0}\right)^{2/3} V^{2/3} + 40\left(\frac{\Delta\rho}{\rho_0} V U_w\right)^{1/3} t \tag{1}$$

where A represents oil slick area (m^2); $\Delta\rho=\rho_w-\rho_o$, V is total spilled oil in volume (barrels), U_w is wind speed (knots), t is the time (minutes) [11].

Additionally, based on the description it can be concluded that the oil spreading is influenced not only by gravity, interfacial tension and viscosity, but also on turbulence force caused by the wind.