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Research Article

A Study of Ship Discharge State Analysis in the Narrow Water Way: The Contribution of Mathematical Modeling

Zuhal Er[1*], Beril Tuğrul[2]

[1] ITU Faculty of Arts and Sciences, Physics Engineering Department (13b), 34469 Maslak, Istanbul
[2] Istanbul Technical University, Nuclear Researches Division, Istanbul-Turkey

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Abstract

Discharging of diesel oil pollution incident in the narrow water ways were analyzed firstly experimental and evaluated by mathematically, in this study. It was performed by utilizing the radiation tracing technique which comprises the real life application of a ship's oil pollution for various scenarios. The modeling phenomena developed by using Fick's 2nd law can provide the opportunity to propose expected solutions including the finite systems and half finite systems. The experimental research was designed based on the determination of various discharge quantities of diesel oil for narrow water ways. This study aims beyond the scope of marine accident scenarios since it takes into account various discharges from shore-based facilities as well. Then experiments were held for ten various discharge quantities in this study where the alternative dilution levels of the effluents have been estimated in advanced with graphical assessments. Consequently this study provides a proposed mathematical model for the determination of spillage by the aid of radiation tracing technique while taking into account different incident types.

Keywords: Infrared measurement, Narrow water ways, Marine casualty, petroleum discharge, Ship sourced pollution.

1. Introduction

Oil-spill happens when liquid petroleum is released into the environment by vehicle, vessel or pipeline. It can cause on a large scale problem and is mostly seen in water bodies. It happens due to human negligence and spilling can be occur by many ways e.g. drilling rigs, offshore oil platforms and from the sea tankers. An oil spills and their effects can also be experienced with refined or raw petroleum or waste oil from large scale industries. All of them is important for the environmental pollution and generally damage on the environment drastically. They caused permanent effects and takes a long time to clean up. Therefore, oil spilling is a serious subject in the maritime transportation and also environmental pollution.

This study indicates a mathematical model multi-physics condition capability applied to oil-spill problem, which is a serious subject in the maritime transportation environmental pollution prevention taking into account oil spill modeling [1-4]. Therefore purpose of this study is to investigate the physics of the oil spill into the sea water in case of an incident when a ship goes through a narrow channel (e.g. Strait of Istanbul).

2. Experimental Procedure

To protect the environment and health of organisms there are water quality standards which are determined by international and/or national laws [12]. These standards are continuously improved via the theoretical and experimental studies for real life applications. Experimental technique can be modeled using "Volume Warmed Oil Flow" approach to understand the basic transport event using via the Infrared Measurement Technique, which is originally proposed in this study. On the other hand, discharged oil waste that owned momentum by the difference in density between the waste and seawater begins to transport into seawater where from a defined point to low level potential points.

It is aimed that o demonstrate the experimental study capability of free surface flows and oil transport into no stream reservoir. The problem is mainly steady in nature; both streams are moving with respect to each other via ground force. "Volume Warmed Oil Flow" approach is taken account for the oil spillage is modeled as from the perspective of the physics modeling of the process, the flow was assumed to be incompressible and laminar. Due to the steady nature of the processing, the analyses were performed in laboratory.

For the study some assumptions were considered as; a single ship, far from coastal state assumption enables to ignore the boundary effect of shore side, there were no special swell effects taken into account in this study, large variety of spectrum

Discharge quantities of oil spill on various experiments illustrated in Table 1 as relative unit and according to their analogy or similarity in real life applications that condition of experiment in the laboratory scale conditions. The system is assumed to include three regions; namely seawater, oil and the air.

[1] Corresponding Author: ITU Faculty of Arts and Sciences, Physics Engineering Department (13b), 34469 Maslak, Istanbul, erzuh@itu.edu.tr

Furthermore, it is modeled as free surface flow in this sense. Inlet region considered small and it does the spillage of the oil into the seawater. The outlet region is also the default outlet. The symmetry condition was used for the all other surfaces of the model. The fluids used for the modeling were seawater, air and oil with constant properties.

Spilling of petroleum from the ships are generally caused by the holes occurred due to torn sheet irons [5,6]. As all as leakage is dependent on system pressure. When a hole occurred on the wall or bottom of the ship, the pressure difference where is between the sea medium and petroleum container produce an natural flow of the petroleum into the water way. Basically, the higher the pressure, the larger the leak flow and vice versa [13]. In this respect, the common discharge effect of spill cases that are caused by holes are taken into account during marine accident simulation. The type of discharged quantity has also significant effect on environment and for this reason it is preferred to carry out experiments with diesel oil which has the significant impact on sea surface pollution and causes serious environmental problems in the long-run. Table 1 illustrates the relative discharge quantity of oil spill that is the ratio between the spilling amount and perimeter area depending on the various experiments with their analogy or similarity in real life applications in the condition of experiment under the laboratory scale conditions.

Table 1 *Discharge quantities of oil spill on various experiments*

Experiment No	Type of Accident		Relative Discharge Amount
A1	Discharge (Leakage or Spill or Flow out) Accidents	Leakage	3
A2			7
A3		Spill	10
A4			20
A5			50
A6			100
A7			200
A8			300
A9			

As the radiation can travel large distances between the interactions in the detector material before detection is possible, the detectors do not have 100% efficiency. In the radiation measurement, one of the most important characteristics of a detector is the efficiency of the detector that the efficiency of the detector depends not only on detector properties but also on the details of the counting geometry [11].

Tracing technique was applied by using infrared probe and detected the diesel oil temperature that has hotter than the seawater. Probe held without contacting the polluted seawater but put the probe nearly closed of it during the applications of radiation tracing technique. In order to complying the predefined requirement and boundary conditions, experimental facility is established similar to an open channel model using with the sea water.

3. Mathematical Model

In addition of experimental studies, analytical investigation is carried out for oil spill arrival distance. Fick's II Law is utilized to model the above phenomena especially for finite and semi finite systems [7-10]. The molecular diffusion can be expressed as in the following equation by Fick's law:

$$J_I = - D\nabla Q_i \qquad (1)$$

where; Ji is diffusion Flux (m3/s), D is separation coefficient of the dispersion of ith pollution and Qi represents ith Polluted concentration.

$$\nabla Q_i = \mathbf{i}\frac{\partial Q_i}{\partial x} + \mathbf{k}\frac{\partial Q_i}{\partial y} + \mathbf{k}\frac{\partial Q_i}{\partial z} \qquad (2)$$

The basic flow equation used is the continuity equation and concentration for single phase dispersion can be expressed as;

$$-\frac{\partial J_i}{\partial x} = D\frac{\partial^2 Q_i}{\partial x^2} = \frac{\partial Q_i}{\partial t} \qquad (3)$$

where; x is distance (m) and t represents the time (s). On the other hand the semi-analytical solutions are a mix of analytical methods considered the results of numerical calculations and experiments [14]. Using by the solution of above Equation 3 can be supported to calculate the reaching distance as;

$$x = \left[-4D_t \ln\frac{Q}{Q_0}\right] \qquad (4)$$

where Qo represents total polluted concentration and Dt is separation coefficient of the dispersion of ith pollution at time of t. Therefore, the problem in a simple approach while evaluating the experimental results with the semi finite solution equality can be illustrated in the Equation 4.

3. Results and Discussion

The results of arrival distance arranged by the rate of discharge hole are illustrated in the Figure 1. Therefore the results of the analytical analysis and experimental data show consistency to each other with the error rate below of 10 %. Furthermore the mean absolute error is below 5 % and the approximate error is nearly 1 %.

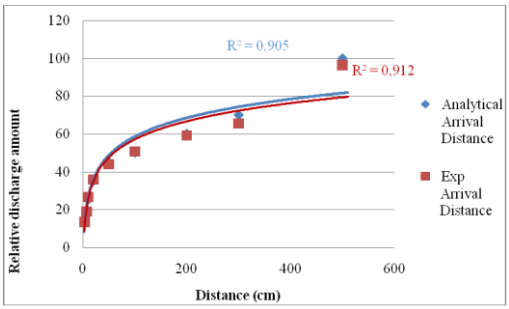

Fig. 1. *Reaching Discharge Rate versus Distance*

Petroleum spilled from the ships are generally caused by the holes occurred due to torn sheet irons. In this respect, the common discharge effect of spill cases that are caused by holes are taken into account during marine accident simulation. Figure 2 shows that Oil leave in sea water / beginning discharge points (TF5),

where are at the all of experiments, dealing with comparative graphs.

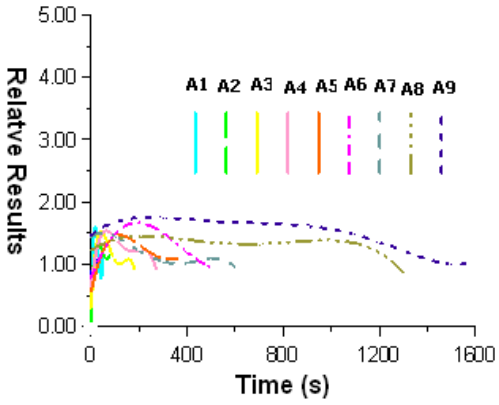

Fig. 2. *The beginning discharge points comparison graphic*

4. Conclusions and recommendations

This study is accomplished for obtaining a simulation on oil spillage into seawater where it is important as an ecological matter as well. The results show that Infrared Measurement Technique has this multi-physics capability for modeling such incidental spillage problems. The spillage and the transport of the oil were treated here as a "Volume Warmed Oil Flow" approach, the problem can also be named as free surface flow. In fact the problem demonstrated here is very complicated in physical terms and needs some simplifications and assumptions. The results showed that the multi-physics play an important role in the complicated environmental studies modeling.

Experiments were held for ten various discharge quantities of the diesel oil for narrow channels and narrow water ways utilizing radiation tracing technique and compatible results were obtained for the arrival distance determination, after the mathematical application were done and the results are compared respectively. This study constitutes the original applications of experimental and mathematical approach for the determination of spilled quantity caused by ships during the narrow channel navigation.

The agreement between the analytical and the experimental values is remarkable and it is recommended for use to possible estimate the quantity of oil spilled area. If the amount of the spillage is also known, the total area of the polluted surface can be calculated.

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