

## ORIGINAL ARTICLE

# Numerical Simulation of How to Absorb Industrial Oil Spill in an Absorbent Matrix Spherical Perlite

Iman Keshavarz<sup>1\*</sup>, Afshar Alihosseini<sup>2</sup>

<sup>1</sup>Department of Chemical Engineer, Tehran North Branch, Islamic University, Tehran, Iran

<sup>2</sup>Department of Chemical Engineer, Tehran Center Branch, Islamic University, Tehran, Iran

\*Corresponding author's E-mail: Imankeshavarz@outlook.com

### ABSTRACT

*With the growing use and exploitation of oil resources, its adverse effects are growing day by day. These adverse effects include rapid development of the coastal refineries, industrial and municipal discharges, as well as sediment transport of hydrocarbons through the air and a wide range of social and environmental impacts is very important to be included. In this paper, in addition to the hydrodynamic behavior of the oil patch in the marine environment and factors affecting it, how to absorb the stain was modeled by absorbing industrial perlite. For modeling, the momentum and mass transfer phenomena and laws in  $k-\epsilon$  model was used to investigate the disturbance. It was assumed that examined absorbent structure is spherical and absorption profile in the liquid film around the oil-absorbing absorbent and adsorbent mass were studied. The results of the model were compared with experimental data and model the absorption kinetics of uptake kinetics was studied primarily with the catchy closer.*

**Keywords:** oil pollution, simulation, absorbent, perlite

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### INTRODUCTION

Today, oil pollution means damage to the planet and its inhabitants. Because the water in the seas and oceans in addition to part of the food chain in the world, about 90% of Earth's oxygen supply.

Sea pollution sources include solid waste, sanitary wastewater, ballast water of ships, wash water of ships, oil spills from nozzles, flanges, fittings and pipelines, ships collision with each other and with pipelines.

Oil pollution in the waters is followed by many physical and biological consequences. Sea surface oil slicks to prevent the passage of light into the depths of the sea water, reduce photosynthesis of aquatic plants and algae that are producing oxygen, and are therefore critical factor is the amount of oxygen is reduced and causes the changes in the aquatic environment. In addition the dangers of mortality of sea creatures, remain the possibility of pollution in the food chain and in human diseases such as cancer can be somewhat born pollution.

Ecological effects of oil pollution depends on several factors such as the type of oil, weather conditions and oceanographic, physical geography of the area, the water cycle and the seasons, the presence of other pollutants, a variety of plant and animal life of the area depends on how much oil leak.

As soon as the meeting of oil into the sea, in the form of a thin layer is going to be and volatiles evaporate. The evaporation depends on the temperature, wind, pressure has evaporated. Oil compounds that have a boiling point below 200 ° C during the first few hours evaporate the oil compounds that boiling point below 270 ° C, evaporation of several days [1]. Some cyclic compounds such as benzene and Xylene petroleum particularly with small molecules are dissolved in water. Because of the toxicity of these substances, in the event of liquidation, even in small amounts, will cause damage to the health of aquatic and marine organisms are destroyed. Oil polarized, UV radiation from the sun, are oxidized. When the oil spill is large, the water droplets in the oil seeps and oil viscosity are increased. This wave causes fragmentation of large patches of the emulsified oil come to the surface. The idea is to use mechanical means to recycle oil spills from sea level is very useful but it is the restrictions. In general, stating that mechanical recycling efficiency depends on the position of the oil spills. For example, when wind and currents, waves, floating canvas loses its effectiveness. If the speed of the spots over 5 m / s, usually a small amount of oil stains can be recycled.

The use of scattering is very common dealing with oil pollution in the water. The role of these substances in the decontamination of oil spills is that the water level to fall apart, it turns out smaller particles. These particles penetrate deep into the water and diluted. Then breaks down and eventually disappear by microorganisms in water.

What is certain is that concentration of marine pollution can be found in sediments that gradually decomposes pollutants and toxic heavy metals in sediments disappear only accumulate and remain in the environment.

In Iran, although the current context of the Persian Gulf, but the oxidation of petroleum hydrocarbons and other pollutants leak due to biological degradation and ultimately leads to the depletion of dissolved oxygen bed, and finally was led to decrease the sediments and deposits of oxidation environment gradually restored to an environment. This event causes the heavy metals and toxic materials is released in connection with sedimentation of solid phase to a liquid phase. Thus, these elements are entered again in the Persian Gulf and the availability of marine species and marine ecosystems are affected.

By comparing the amount of oil contamination in sediments and other areas, it is clear that the large accumulation of sediment is related to the contamination and the percentage of granulation tissue. With increasing distance from shore and depth, the amount of fine particles also increased in the sediment and thus pollution by small particles is carried to a greater extent.

So, in this paper, it is tried to examine the hydrodynamic behavior of the marine environment and factors affecting the oil patch on it, and how to attract the spot by industrial spherical absorbent model. For modeling, the momentum and mass transfer phenomena and laws in k-ε model was used to investigate the disturbance. Then, process modeling and simulation is described.

## MODELING

### The governing equations of fluid flow

Most important engineering flows are disturbed, the turbulent flow region is not only important in theory. Experiments on fluid systems have shown that the so-called critical Reynolds number below the smooth flow of adjacent layers of fluid on both're rustling. In quantities higher than the critical Reynolds number, a series of events that eventually leads to serious changes in the flow behavior. In this case, the random and erratic behavior and even with the fixed boundary conditions is completely non-permanent. The main reason for the transition to turbulence created in the flow attributed to disturbances. Transition to turbulence is strongly influenced by factors such as pressure gradient, surface turbulence, rough walls and heat transfer.

Navier-Stokes formed equations of continuity and at the same time a closed set of four equations with four unknown u, v, w, p. Continuity and Navier-Stokes equations are integrated into turmoil, led to the introduction of these terms mean and fluctuating unknowns in the equation. In this study, the average timelies on the equations of motion, the details of the current state of the abandoned variations. As a result, six additional unknowns in the equation, the average time is achieved as Reynolds stresses [2].

The most common turbulence models are classified as follows [3]:

- Couches classic, based on the average time Reynolds equations
  - ✓ zero-equation model - mixing length model
  - ✓ Equation model - model k-ε
  - ✓ Equation model tensions Reynolds
  - ✓ Algebraic stress model

-Simulates great literature, based on uniform model

Now the mix of classic and k-ε model is widely used and valuable. Based on the basic assumption that a similarity between the viscous stress and Reynolds stress there. Here, just a k-ε model used in this paper is described [4].

### K-ε model

The shear layers of thin two-dimensional, changes are so slow in the direction of flow that confusion can adjust itself to local conditions. If handling properties and ignore the influence of turbulence, the effects of the turmoil on the average in terms of the said mixture. If it cannot be ignored the influence of the movement, such as streams with this rotation, the other a short algebraic relationship is not practical to the mix. K-ε model on practices that are focused on kinetic energy of impact.

It is necessary to begin the kinetic energy of the fluid flow and the rate of deformation elements such as instantaneous average flow equations in two variables average and swinging break. As a result, the average kinetic energy and swinging kinetic energy is shown in the relations 1-2 and 2-2.

$$(1-2) \bar{k} = \frac{1}{2} (\overline{u^2} + \overline{v^2} + \overline{w^2})$$

$$(2-2) \bar{k} = \frac{1}{2}(\overline{u'^2} + \overline{v'^2} + \overline{w'^2})$$

The turbulent kinetic energy and the deformation rate of 3-2 and 4-2 is expressed as [5]:

$$(3-2) K = \bar{K} + k$$

$$(4-2) e_{ij} = E_{ij} + e'_{ij}$$

$$(5-2) e'_{ij} = \frac{1}{2}(\nabla V' + \nabla V'^T), V' = (u', v', w')$$

$$(6-2) E_{ij} = \frac{1}{2}(\nabla \bar{V} + \nabla \bar{V}^T), \bar{V} = (\bar{u}, \bar{v}, \bar{w})$$

The possibility of developing similar transport equations for all qualities which include depreciation rate slimy bulk turmoil. The exact equation contains a large number are unknown and immeasurable,  $\epsilon$ . K- $\epsilon$  standard model has two equation model. One is built for k- $\epsilon$  and one is built on the best understanding of the processes appropriate for that change are the variables. The standard model of the form of 7-2 and 8-2 [6].

$$(7-2) \frac{\partial(\rho k)}{\partial t} + \nabla \cdot (\rho k \bar{V}) = \nabla \cdot \left[ \frac{\mu_t}{\sigma_k} \nabla k \right] + 2\mu_t E_{ij} : E_{ij} + \rho \epsilon^*$$

$$(8-2) \frac{\partial(\rho k)}{\partial t} + \nabla \cdot (\rho k \bar{V}) = \nabla \cdot \left[ \frac{\mu_t}{\sigma_k} \nabla k \right] + C_{1\epsilon} \frac{\epsilon^*}{k} 2\mu_t E_{ij} : E_{ij} + C_{2\epsilon} \rho \frac{\epsilon^{*2}}{k}$$

In the standard model k- $\epsilon$ , values of  $C_\mu = 0/09$ ,  $C_{1\epsilon} = 1/44$ ,  $C_{2\epsilon} = 1/92$ ,  $\sigma_\epsilon = 1/3$ , and  $\sigma_k = 1$  come in a wide range of turbulent flows,  $\mu_t = \rho C_\mu \frac{k}{\epsilon^*}$  are used as well.

The equation 9-2 is used to calculate the Reynolds stresses model k- $\epsilon$  [7].

$$(9-2) -\overline{\rho u'_i u'_j} = 2\mu_t E_{ij} - \frac{2}{3} \rho k \sigma_{ij}$$

The results show that the performance of the model has been good especially for flows where the Reynolds shear stresses is more important. [8].

### Kinetics uptake

The amount of oil absorbed by the adsorbent was investigated in the study. One way to analyze the reaction of absorption, adsorption kinetics equations is the most used of these models, pseudo-first and pseudo-second 2-11 and 2-13 that were shown in the relationship. In this relationship, x is the density of the oil,  $k_1$  and  $k_2$  first fixed constant pseudo II.

$$(10-2) -\frac{dx}{dt} = k_1 x$$

$$(11-2) -Ln x = k_1 t$$

$$(12-2) -\frac{dx}{dt} = k_2 x^2$$

$$(13-2) \frac{1}{x} = k_2 t$$

### CFD simulation

At this point, it is trying to be examined with the help of the absorption of petroleum modeling tool within a spherical element adsorbent using CFD simulation. Computational fluid dynamics or CFD is a systems analysis of fluid flow, heat transfer and associated phenomena such as chemical reactions, based on computer simulation.

### Basic assumptions

The oil absorption within a spherical element adsorbent was evaluated. Calculation area is shown in Figure 3-1.

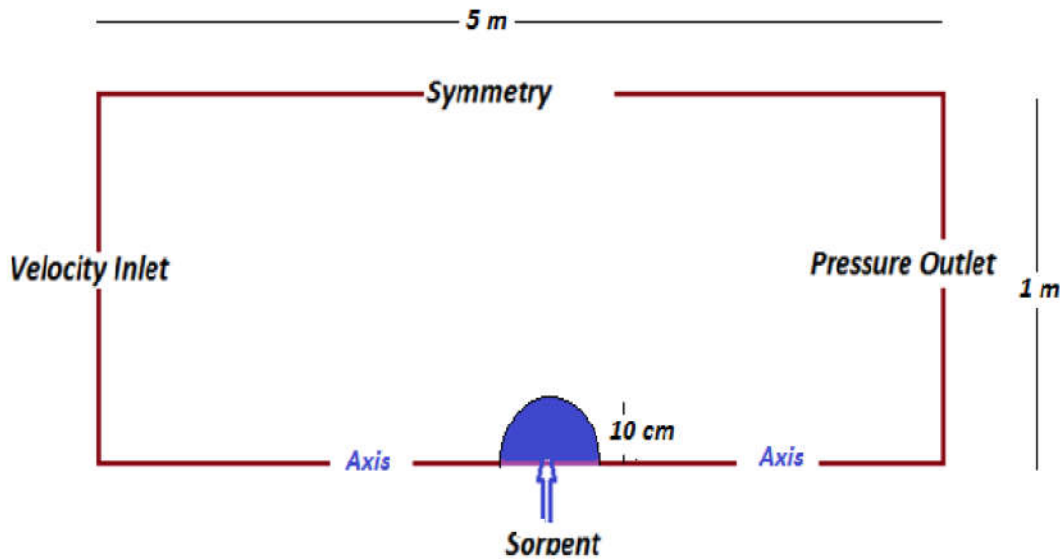


Fig.1-3. Schematic of 1 and boundary conditions used in the calculation of cylindrical coordinates. Oil and water mixture are entered with oil mass fraction 0/02 and computational speed of 1 meter per second into the calculating area. The boundary conditions are considered top of the infinite computing range. Walls were considered as the wall with zero velocity. To obtain the absorption rate, its variation is used the experimental data obtained by Ali Hosseini et al. Assumptions used for the simulation is shown below:

- The changes in the absorption and concentration changes are taken together and are shown in equation 1-3. Although this assumption is true, but is in equilibrium with acceptable accuracy for use in the simulation as well.

$$(1-3) \frac{\partial C}{\partial t} = -\frac{\partial q}{\partial t} \times \rho = -\frac{\partial q}{\partial t} \times \rho_{solid} \times (1 - \varepsilon)$$

In equation 1-3,  $\varepsilon$  porous adsorbent and  $q$  is the mole absorbed per kilogram of adsorbent.

- The experimental values also have been used to gain  $q$  changes in each time. The equation 2-3 was used to estimate this amount at any time [9].

$$(2-3) q = 48.357 \ln(t) - 155.891$$

### Reticulation

In this paper, the software Gambit is used for the grid geometry. It should be noted that four-sided mesh is used for the simulation. Also according to the curved surface of the adsorbent used, mesh is employed with irregular structure. In Figure 2-3 is shown that mesh is used to simulate an adsorbent element.

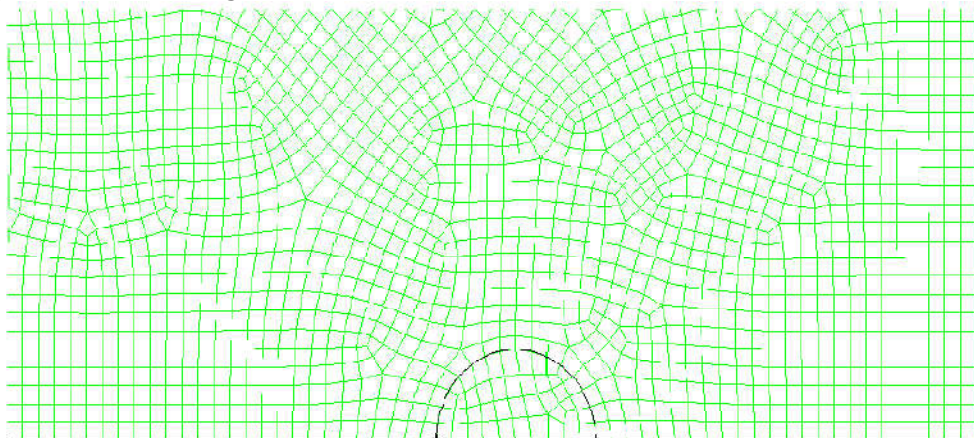


Fig.2-3. Adsorbent element mesh used in the simulation of a spherical (from software Gambit)

After analyzing the absorption of a single adsorbent element, studies were conducted on how to absorb an adsorbent bed. Figure 3-3 and 3-4, respectively, have shown a schematic of the calculated and boundary conditions and mesh used for adsorbent bed of spherical elements.

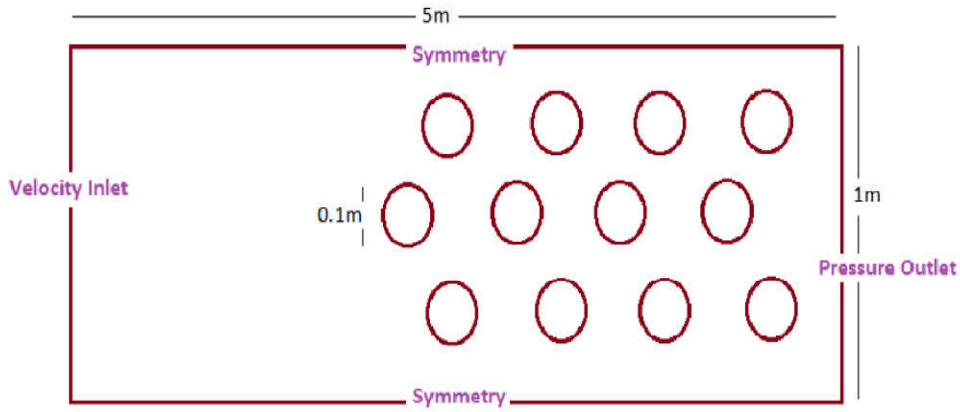


Fig.3-3. Schematic of the calculated and boundary conditions for the admission of third-absorbing spherical elements

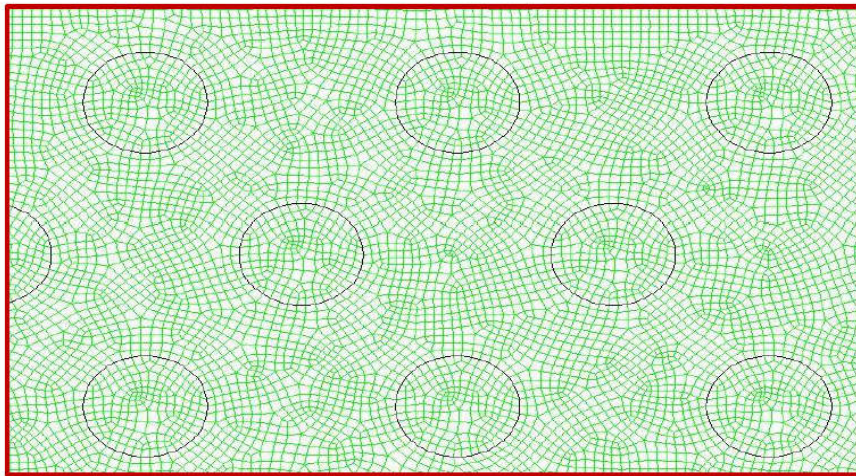


Fig.4-3. multi-element mesh used in the simulation of spherical adsorbent (from software Gambit)

**RESULTS AND DISCUSSION**

**Spherical adsorbent**

**Absorbing absorption bearings**

In Figure 4-1, the absorption rate of the simulation are shown in the spherical adsorbent. It is observed that the absorption of funds from adsorbent is much higher especially on the back faces more turbulence in the flow. Flow around a spherical adsorbent has been slow, leading to smoother absorption. This event can be attributed to the low spherical drag coefficient.

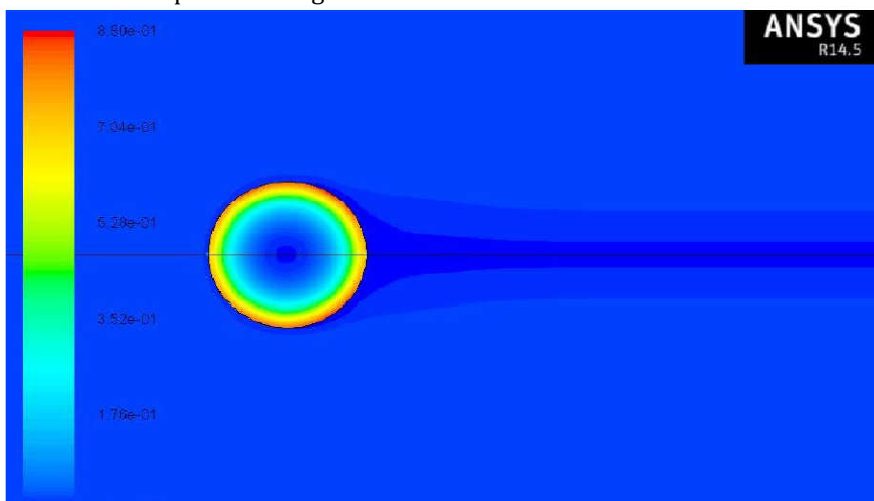


Fig.1-4. Profile within the adsorbent spherical volume fraction of oil after 10 seconds

### Changes in the concentration of spherical adsorbent

The concentration of the adsorbent is shown in Figure 4-2. As you can see, the concentration of the fluid surrounding the adsorbent mass is much greater than oil and the adsorbent is almost completely absorbed.

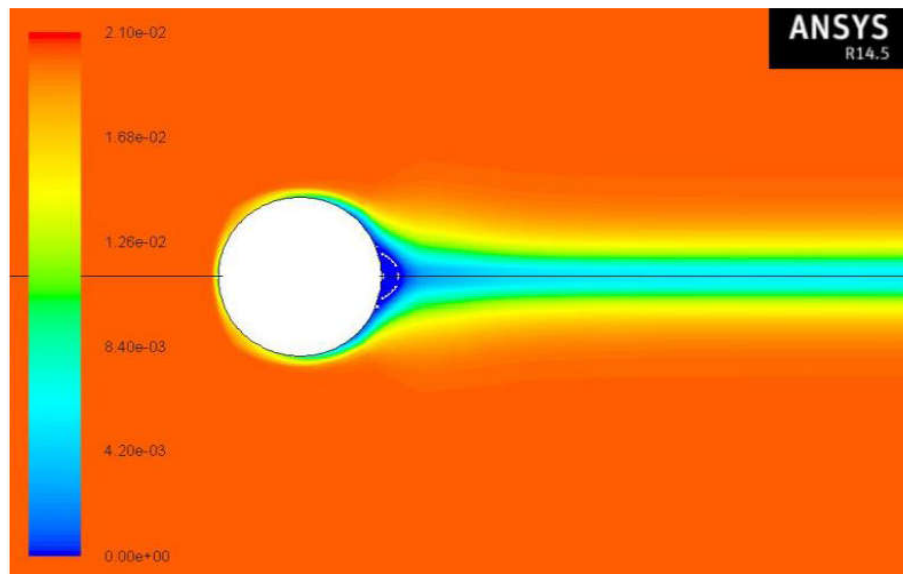


Figure 2-4. Profile of the oil volume outside the spherical adsorbent after 10 seconds

### A pressure series of spherical absorbers

#### Profile spherical pressure in the adsorbent bed

In Figure 3-4, the pressure profile obtained from the simulation is shown within the adsorbent bed. It is observed that the pressure in these areas is greater than in other areas due to the initial impact with the first row of adsorbent particles. The maximum pressure has occurred on the rest of the particles.

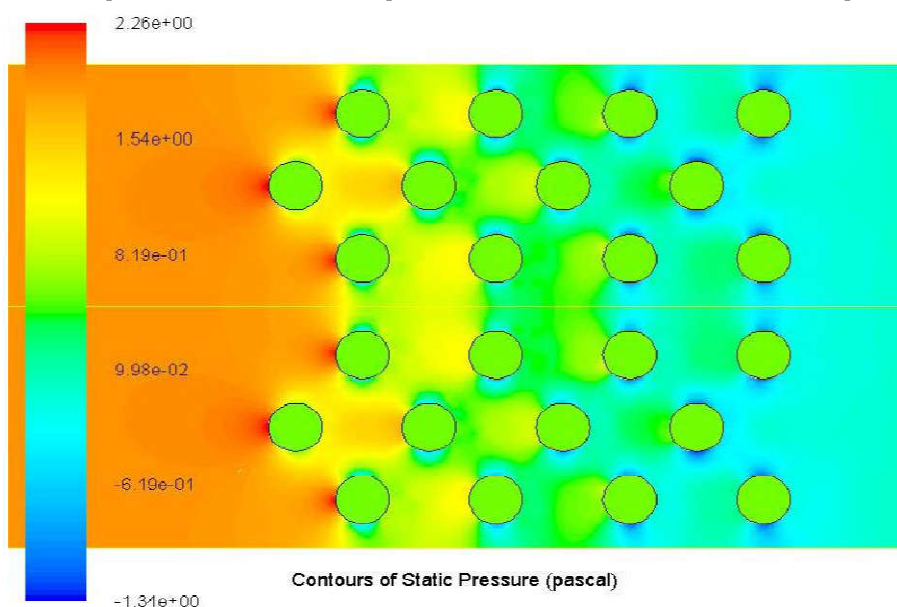


Figure 3-4. Profile of the pressure within the adsorbent bed

#### Profile rapidly in spherical adsorbent bed

In Figure 4-4, profile obtained from the simulation speed is shown within the adsorbent bed. It is observed that due to the initial impact with the first row of adsorbent particles, speed in these areas is less than other areas. The minimum speed and the maximum speed of the particles occurred in the stationary front rows because of the lack of cross-flow absorber.

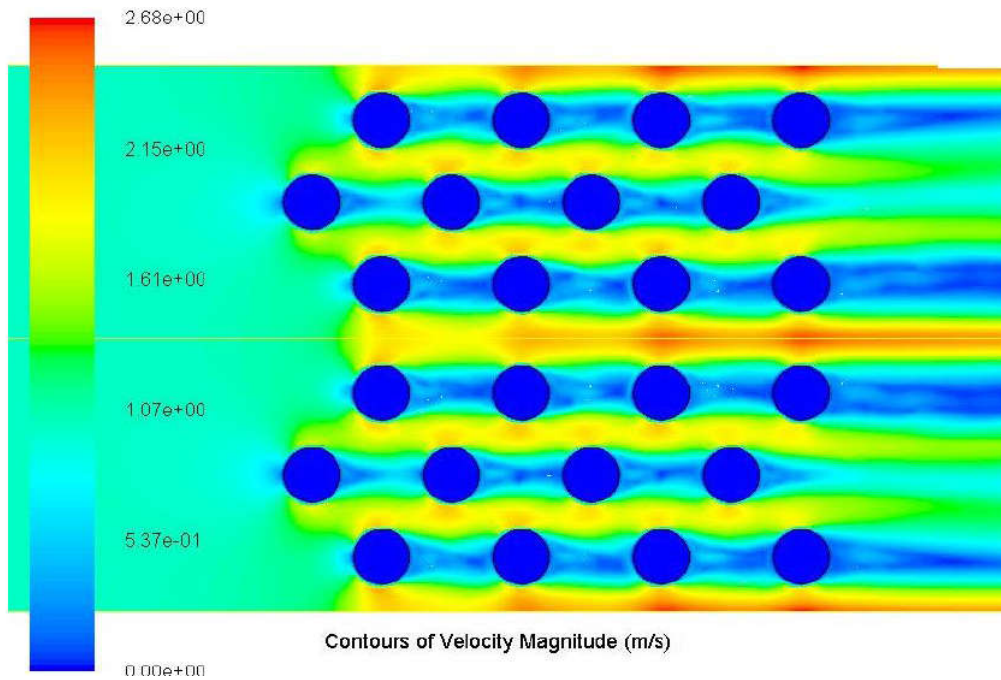


Fig. 4-4. Oil velocity profile within the adsorbent bed

**Concentration changes of oil in the adsorbent bed**

Changes in the concentration of the adsorbent bed can be seen in Figure 5-4. As observed, the concentration of the first layer of adsorbent is less than other layers. Obviously, the amount of oil flowing into the mainstream will decrease significantly after passing the multi-layer adsorbent. Unlike single-gravity conditions, this decrease occurred in very little time.

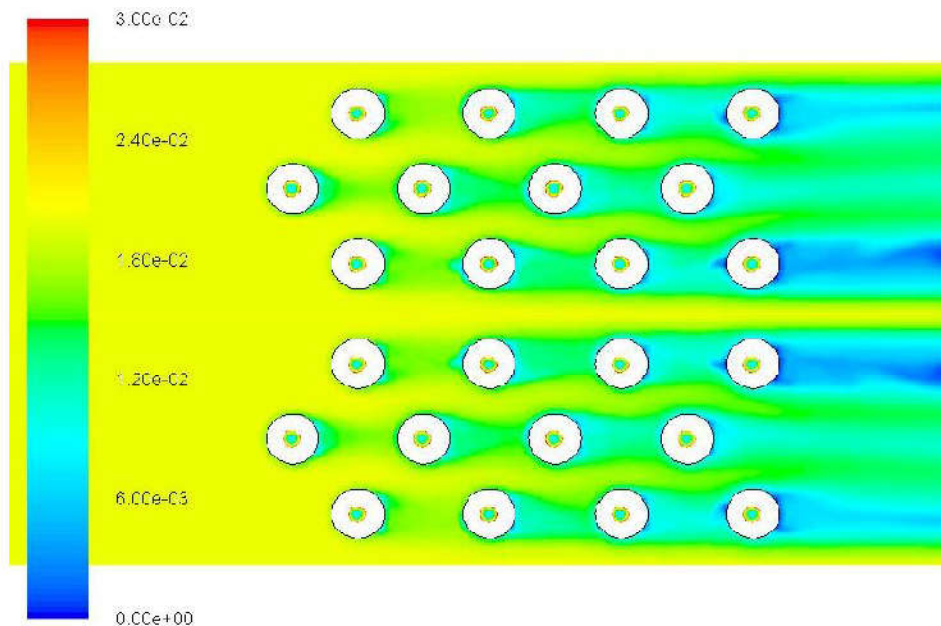


Fig.5-4. Profiles oil volume fraction of the adsorbent bed after 10 seconds

In Figure 6-4, the amount of oil absorbed has been shown in a different time range. As observed with the passage of time, the amount of oil absorbed by the adsorbent spherical will be increased. It is clear that over time, this amount goes toward the center of adsorbent.

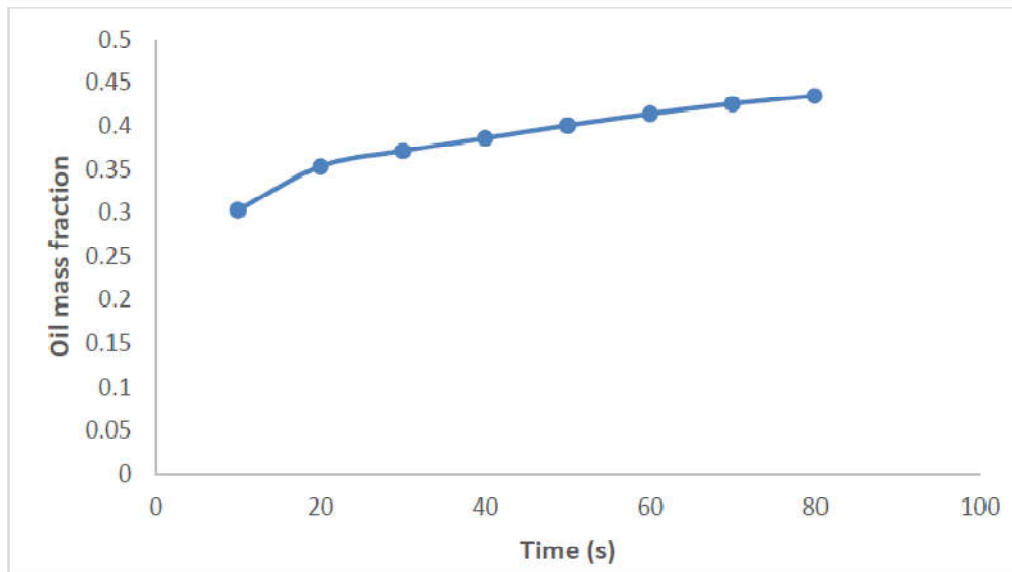
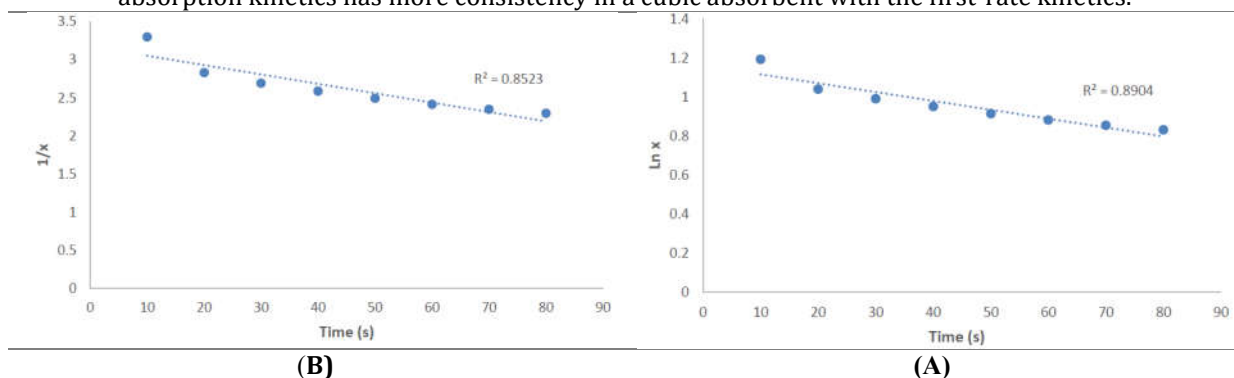


Fig. 6-4. The amount of oil absorbed by the absorbent spherical at various times

Figure 7-4 shows the kinetics uptake to spherical absorbent. Correlation coefficients indicate that the absorption kinetics has more consistency in a cubic absorbent with the first-rate kinetics.



a) Uptake kinetics model primarily spherical oil absorbent and b) uptake kinetics oil absorbent using the quadratic model

## CONCLUSION

The main objective of this research is to study the negative effects of the oil spill in open water like rivers and methods such as absorption is to eliminate it. The fundamental point that must be mentioned is that oil is a name for a wide group of compounds that each have a different effect on the physical conditions and ingredients, and they show different behavior. Depending on the type of view this behavior as well as assumptions made on the system, different relationships to model the oil offered. In this paper, to obtain the absorption rate and its changes from experimental data obtained by Ali and colleagues and to achieve a specific model of CFD tools for modeling was used to absorb oil spills.

At the beginning of modeling, studies were conducted on the absorption of oil combinations in a spherical absorbent element. Studies have shown that absorption of the way around the back and the concentration of absorbing is much greater than the mass of the fluid. The absorption kinetics was studied in spherical mode of absorbing the results showed that uptake kinetics primarily is in a good agreement with data.

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### Abbreviation signs

$\bar{k}$  The middle kinetic energy

$\kappa$  The swinging kinetic energy

$\bar{K}$  turbulent kinetic energy

$\bar{u}$  The average speed in the x direction

$\bar{v}$  The average speed in the y-direction

$\bar{w}$  The average speed in the z direction

$u'$  Speed oscillating in the x direction

$v'$  Speed fluctuation in the y-direction

$w'$  Speed oscillating in the z direction

$e_{ij}$  Deformation rate

$E_{ij}$  The average rate of change

$e'_{ij}$  Deformation rate fluctuations

$V'$  The relative speed between the oil slick and choppy water level

$\bar{V}$  The average relative speed between the oil spill and the water level

$\rho$  Density

$\mu_t$  Viscosity turbulence

$\varepsilon^*$  Depreciation rate per unit mass

x mass fraction of oil in the absorber

C oil concentration in the adsorbent

$k_1$  Sinitic primarily fixed equation

$k_2$  Quadratic equation of fixed Sinitic

q The mole absorption per unit mass of adsorbent

$\varepsilon$  Porous adsorbent

### CITE THIS ARTICLE

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