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AMPHOS 21
SCIENTIFIC AND STRATEGIC ENVIRONMENTAL CONSULTING

Model and App of Hydrophobic Meshes Used in Oil Spill Recovery

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Table of contents

Introduction: Oil Spills

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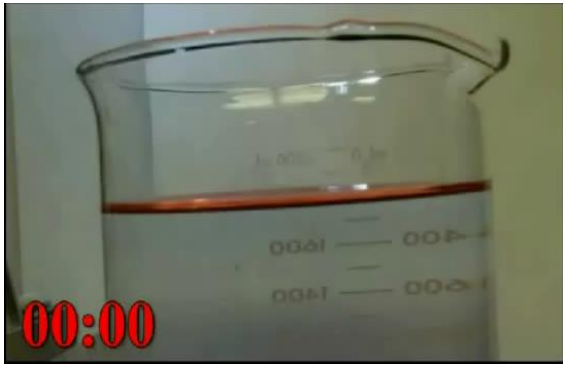
- Aquatic environments are often polluted by oil coming from extraction wells, tankers, pipelines, storage tanks or refineries.
- The oil spill is best dealt with as soon as possible, before some components volatilize, dissolve, sink or emulsionate with the water.
- The main clean - up techniques are:

Destructive Methods	In-situ burning Dispersion Bio-remediation
Recovery Methods	Skimmers Sorbents **Hydrophobic Meshes**

Introduction: Hydrophobic Meshes

- Hydrophobic Meshes are steel meshes coated with some material that repels water while attracting oil.
- They act like filters: oil is recovered while the water is retained.



Song et al. *Self-Driven One-Step Oil Removal from Oil Spill on Water via Selective-Wettability Steel Mesh.*

Introduction: Hydrophobic Meshes

- **Advantages:**
  - Oil is recovered without water content: possibility of recycling the spilled oil without processing
  - Continuous operation
  - Good recovery efficiencies and capacities
  - The only energy input is pumping the oil away
  - Clean
- **Disadvantages:**
  - Operation limited by mesh depth in the water: if the mesh is to deep, water will intrude.

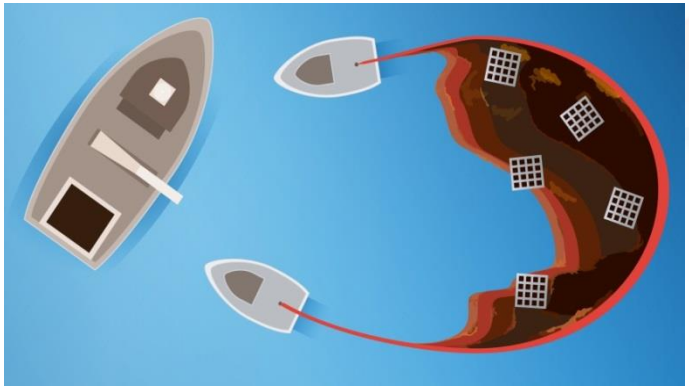
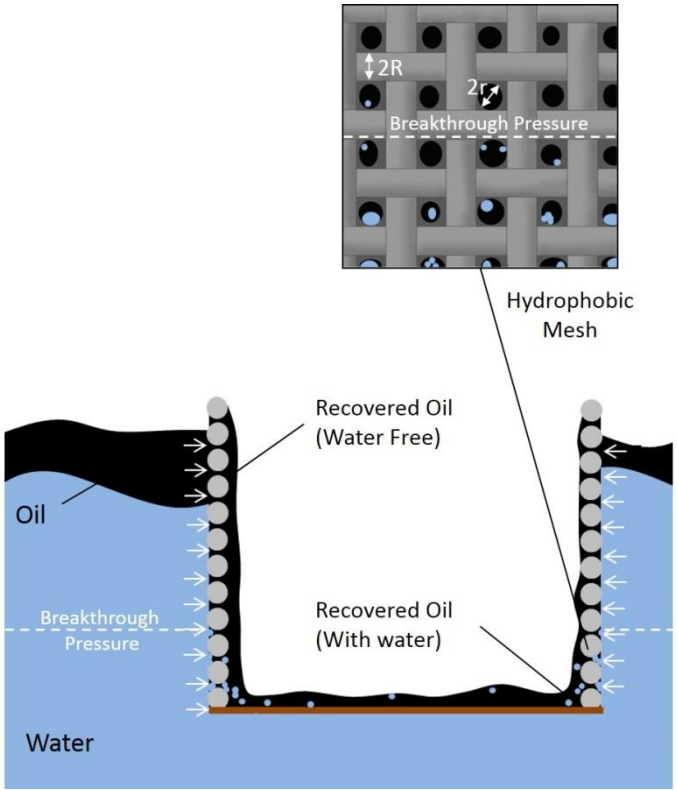


Image credit: COMSOL

Hydrophobic Mesh Model



- The Hydrophobic Mesh App simulates a mesh that is submerged in an oil-water mixture.
- The oil flows through the pores of the mesh, and the water is retained outside due to selective wettability.
- Main parameters:

  - Mesh opening radius (*r*)
  - Fluid height (*h*)

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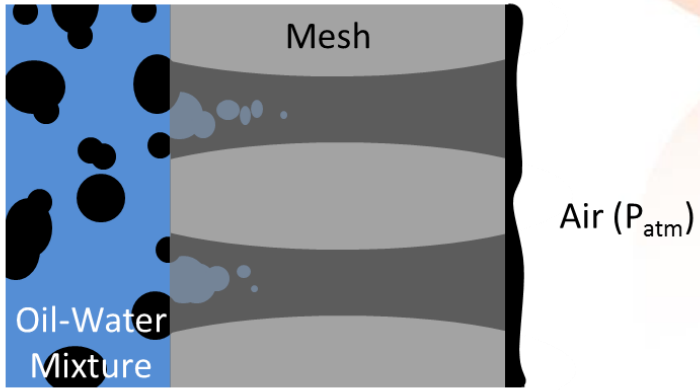
Hydrophobic Mesh Model

- The Hydrophobic Mesh is a two-phase flow model where the mesh is conceptualized as a porous medium.
- These equations are implemented in COMSOL using the coefficient form of PDE module with multiple dependent variables.



Hydrophobic Mesh Model

The governing equations consist on a system of two Partial Differential Equations (PDE):

Oil Mass Balance: $$\phi \frac{\partial S_o}{\partial P_c}\frac{\partial P_c}{\partial t} + \nabla(\lambda_o k(\nabla P_c - \nabla P_w)) = 0$$

Water Mass Balance: $$-\phi \frac{\partial S_o}{\partial P_c}\frac{\partial P_c}{\partial t} - \nabla(\lambda_w k \nabla P_w) = 0$$

Solved for P_c and P_w

ϕ:	Mesh Porosity	k:	Mesh Permeability
S_o:	Oil Saturation	λ_o:	Oil phase mobility
P_c:	Capillary Pressure	λ_w:	Water phase mobility
P_w:	Water Pressure		

Hydrophobic Mesh App

- The App predicts the performance of a Mesh under different conditions
- Helpful when
  - Designing a mesh
  - Deciding on operation conditions
- The performance of a mesh is assessed by:
  - The oil recovery rate, or oil flux
  - The purity of the recovered oil
- Both depend on mesh and oil properties, and on the depth at which the mesh is operated.

File ▾ | Hydrophobic Mesh Model

Model | Set Parameters | Single Simulation | Breakthrough Analysis | Pore Analysis

Hydrophobic Mesh Model

The system simulated with this App is a Hydrophobic and Oleophilic Mesh used for oil-water separation.

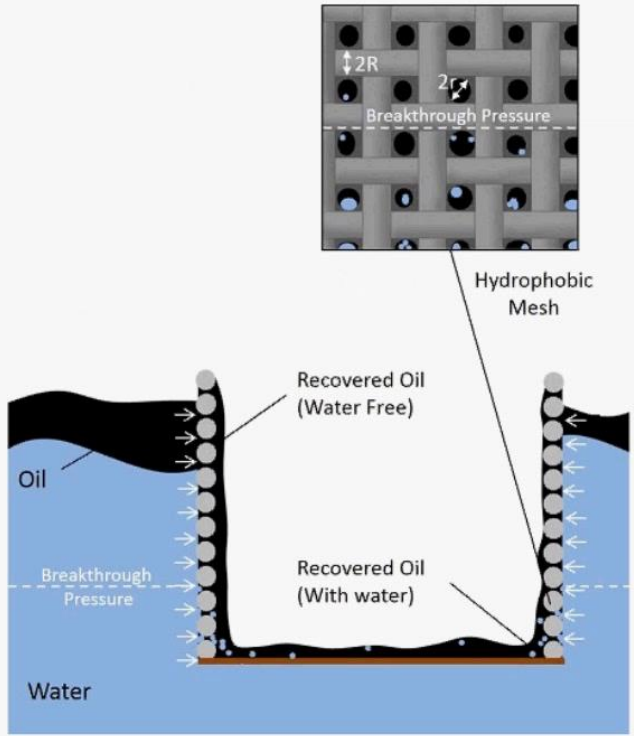
The Mesh is made of steel wires of diameter R, coated with a hydrophobic and oleophilic material. These wires are woven into a mesh with an opening radius r, as seen in the figure to the right.

The mesh is fixed on a container and submerged into an oil-water mixture, such as an oil spill in the ocean. The oil flows through the mesh into the container while the water is retained. The oil in the container is assumed to be pumped away continously.

If the hydrostatic pressure given by the fluid column height (h), is too high, however, water will break through the mesh and into the container.

The main purpose of this app is to study the oil flux and the water content in the oil (or fractional water flow) for different meshes under different conditions.

Open Document



Conclusions

- Hydrophobic meshes are a promising technique and offer many advantages when it comes to oil spill clean-ups.
- These meshes can be modelled as porous media with multiphase flow: a model has been implemented in Comsol Multiphysics using the *Coefficient Form PDE* module.
- The hydrophobic mesh model and app can be a useful tool for researchers, designers and users.
- Future work:
  - Dynamic boundary conditions
  - Coupling to a free fluid model that accounts for the effects of sea waves and currents.

References

- Song, J., Huang, S., Lu, Y., Bu, X., Mates, J. E., Ghosh, A., ..., Megaridis, C. M. (2014). Self-Driven One-Step Oil Removal from Oil Spill on Water via Selective-Wettability Steel Mesh. *Applied Materials and Interfaces 6*, pp. 19858-19865.

- Deng, D., Prendergast, D.P., MacFarlane, J., Bagatin, R., Stellacci, F., Gschwend, P.M. (2013). Hydrophobic Meshes for Oil Spill Recovery Devices. *Applied Materials and Interfaces 5* pp. 774-781.

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