Oil-catching sponge could soak up residue from offshore drilling

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Drilling and fracking for oil under the seabed produces 100 billion barrels of oil-contaminated wastewater every year by releasing tiny oil droplets into surrounding water.

Most efforts to remove oil from water focus on removing large oil slicks from industrial spills but these aren't suitable for removing tiny droplets. Instead, scientists are looking for new ways to clean the water.

Now, researchers at the University of Toronto (U of T) and Imperial College London have developed a sponge that removes over 90 per cent of oil microdroplets from wastewater within ten minutes.

After capturing oil from wastewater, the sponge can be treated with a solvent, which releases the oil from the sponge. The oil can then be recycled; the sponge, ready to be used again.

The sponge improves upon a previous concept: lead author Dr. Pavani Cherukupally, now of Imperial's Department of Chemical Engineering, had developed an early version of the sponge during her Ph.D. at the U of T. Although the previous sponge removed more than 95 per cent of the oil in the samples tested, it took three hours to do so—far longer than would be useful in industry.

Acidity and alkalinity also presented an issue, as the pH of contaminated wastewater dictated how well the sponge worked. Dr. Cherukupally said: "The optimal pH for our system was 5.6, but real-life wastewater can range in pH from four to ten. As we got toward the top of that scale, we saw oil removal drop off significantly, down to just six or seven per cent."

Now, Dr. Cherukupally, together with U of T and Imperial academics, has chemically modified the sponge to be of potential use to industry. The new sponge works faster, and over a much wider pH range than the previous version.

The results are published today in *Nature Sustainability*.

Spongey secrets

To create the original sponge, Dr. Cherukupally used ordinary polyurethane foams—similar to those found in couch cushions—to separate tiny droplets of oil from wastewater. The team carefully tweaked pore size, surface chemistry, and surface area, to create a sponge that attracts and captures oil droplets—a process known as 'adsorption' - while letting water flow through.

To improve the sponge's properties in the new study, Dr. Cherukupally's team worked with U of T chemists to add tiny particles of a material known as nanocrystalline silicon to the foam surfaces. They could then better control the sponge's surface area and surface chemistry, improving its ability to capture and retain oil droplets—a concept known as critical surface energy.

After use, the sponge could be removed from the

water and treated with a solvent, releasing the oil from its surface.

Dr. Cherukupally said: "The critical surface energy concept comes from the world of biofouling research—trying to prevent microorganisms and creatures like barnacles from attaching to surfaces like ship hulls.

"Normally, you want to keep critical surface energy in a certain range to prevent attachment, but in our case, we manipulated it to get droplets to cling on tight.

"It's all about strategically selecting the characteristics of the pores and their surfaces. Commercial sponges already have tiny pores to capture tiny droplets. Polyurethane sponges are made from petrochemicals, so they have already had chemical groups which make them good at capturing droplets.

"The problem was that we had fewer chemical groups than what was needed to capture all the droplets. I therefore worked with U of T chemists to increase the number of chemical groups, and with Imperial's Professor Daryl Williams to get the right amount of coating."

Oil cleanup

Co-author Professor Amy Bilton from U of T said: "Current strategies for oil spill cleanup are focused on the floating oil slick, but they miss the microdroplets that form in the water."

"Though our sponge was designed for industrial wastewater, adapting it for freshwater or marine conditions could help reduce environmental contamination from future spills."

Dr. Cherukupally will continue to improve the sponge's performance for oil applications and has teamed up with Dr. Huw Williams at Imperial's Department of Life Sciences to investigate how the sponges could remove bacteria from saltwater.

She also wants to use the sponges to treat contamination from gas, mining, and textile industries, and wants to make the technology affordable for use in developing countries—mainly for ridding contaminated rivers of organics, heavy metals, and pathogens.

More information: Pavani Cherukupally et al. Acid–Base Polymeric Foams for the Adsorption of Micro-oil Droplets from Industrial Effluents, *Environmental Science & Technology* (2017). DOI: 10.1021/acs.est.7b01255

Surface-engineered sponges for recovery of crude oil microdroplets from wastewater, *Nature Sustainability* (2019). DOI: 10.1038/s41893-019-0446-4 , nature.com/articles/s41893-019-0446-4

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