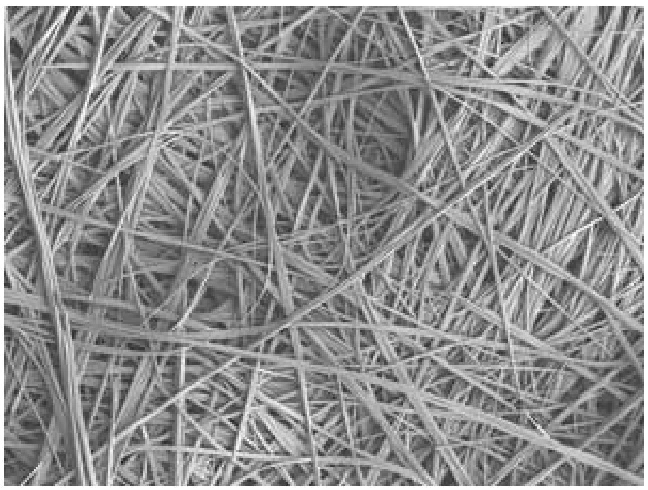
Nanotechnology providing the tools to clean up oil spills

October 11 2016



As the nanofibers form, they trap crude oil in a tangled net that floats above the water. Credit: A*STAR Institute of Bioengineering and Nanotechnology

Oceanic oil spills are tough to clean up. They dye feathers a syrupy sepia and tan fish eggs a toxic tint. The more turbulent the waters, the farther the slick spreads, with inky droplets descending into the briny deep.

Now technology may be able to succeed where hard-working volunteers have failed in the past. Researchers at the A*STAR Institute of Bioengineering and Nanotechnology (IBN) are using nanoscience to turn an oil spill into a floating mass of brown jelly that can be scooped up before it can make its way into the food chain.

"Nanoscience makes it possible to tailor the essential structures of materials at the nanometer scale to achieve specific properties," says chemist Yugen Zhang at IBN, who is developing some of the technologies. "Structures and materials in the nanometer size range often take on distinctive properties that are not seen in other size ranges," adds Huaqiang Zeng, another chemist at IBN.

Jelly slick

There are many approaches to cleaning an oil spill, and none are completely effective. Fresh, thick grease can be set ablaze or contained by floating barriers for skimmers to scoop out. The slick can also be inefficiently hardened, messily absorbed, hazardously dispersed, or slowly consumed by oil-grazing bacteria. All of these are deficient on a large scale, especially in rough waters.

Organic molecules with special gelling abilities offer a cheap, simple and environmentally friendly alternative for cleaning up the mess. Zeng has developed several such molecules that turn crude oil into jelly within minutes.

To create his 'supergelators', Zeng designed the molecules to associate with each other without forming physical bonds. When sprayed on contaminated seawater, the molecules immediately bundle into long fibers between 40 and 800 nanometers wide. These threads create a web that traps the interspersed oil in a giant blob that floats on the water's surface. The gunk can then be swiftly sieved out of the ocean. Valuable crude oil can later be reclaimed using a common technique employed by petroleum refineries called fractional distillation.

Zeng tested the supergelators on four types of crude oil with different densities, viscosities and sulfur levels in a small round dish. The results were impressive. "The supergelators solidified both freshly spilled crude oil and highly weathered crude oil 37 to 60 times their own weight," says Zeng. The materials used to produce these organic molecules are cheap and non toxic, which make them a commercially viable solution for managing accidents out at sea. Zeng hopes to work with industrial partners to test the nanomolecules on a much larger scale.

Unsalty water

Scientists at IBN are also using nanoscience to remove salt from seawater and heavy metals from contaminated water.

With dwindling global fresh and ground water reserves, many countries are looking to desalination as a viable source of drinking water. Desalination is expected to meet 30 per cent of the water demand of Singapore by 2060, which will mean tripling the country's current desalination capacity. But desalination demands huge energy consumption and reverse osmosis, the mainstream technology it depends on, has a relatively high cost. Reverse osmosis works by using extreme pressures to squeeze water molecules through tightly knit membranes.

An emerging alternative solution mimics the way proteins embedded in cell membranes, known as aquaporins, channel water in and out. Some research groups have even created membranes made of fatty lipid molecules that can accommodate natural aquaporins. Zeng has developed a cheaper and more resilient replacement.

His building blocks consist of helical noodles with sticky ends that connect to form long spirals. Water molecules can flow through the 0.3 nanometer openings at the center of the spirals, but all the other positively and negatively charged ions that make up saltwater are too bulky to pass. These include sodium, potassium, calcium, magnesium, chlorine and sulfur oxide. "In water, all of these ions are highly hydrated, attached to lots of water molecules, which makes them too large to go through the channels," says Zeng.

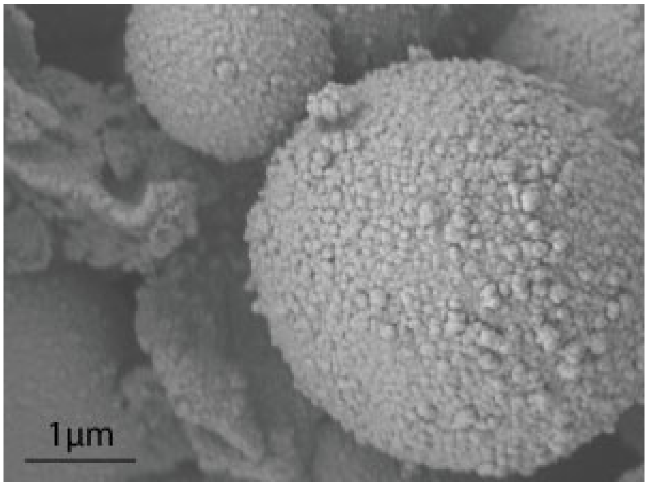
The technology could lead to global savings of up to US$5 billion a year, says Zeng, but only after several more years of testing and tweaking the lipid membrane's compatibility and stability with the nanospirals. "This is a major focus in my group right now," he says. "We want to get this done, so that we can reduce the cost of water desalination to an acceptable level."

Stick and non-stick

Nanomaterials also offer a low-cost, effective and sustainable way to filter out toxic metals from drinking water.

Heavy metal levels in drinking water are stringently regulated due to the severe damage the substances can cause to health, even at very low concentrations. The World Health Organization requires that levels of lead, for example, remain below ten parts per billion (ppb). Treating water to these standards is expensive and extremely difficult.

Zhang has developed an organic substance filled with pores that can trap and remove toxic metals from water to less than one ppb. Each pore is ten to twenty nanometers wide and packed with compounds, known as amines that stick to the metals.



Porous nanoparticles can remove toxic heavy metals from contaminated water to trace amounts within seconds. Credit: Agency for Science, Technology and Research (A*STAR), Singapore

Exploiting the fact that amines lose their grip over the metals in acidic conditions, the valuable and limited resource can be recovered by industry, and the polymers reused.

The secret behind the success of Zhang's polymers is the large surface area covered by the pores, which translates into more opportunities to interact with and trap the metals. "Other materials have a surface area of about 100 square meters per gram, but ours is 1,000 square meters per gram," says Zhang. "It is 10 times higher."

Zhang tested his nanoporous polymers on water contaminated with lead. He sprinkled a powdered version of the polymer into a slightly alkaline liquid containing close to 100 ppb of lead. Within seconds, lead levels reduced to below 0.2 ppb. Similar results were observed for cadmium, copper and palladium. Washing the polymers in acid released up to 93 per cent of the lead.

With many companies keen to scale these technologies for real-world applications, it won't be long before nanoscience treats the Earth for its many maladies.

Provided by Agency for Science, Technology and Research (A*STAR), Singapore