Developing Sustainable Water Purification Technologies

The NEWT Center

Scientia

DEVELOPING SUSTAINABLE WATER PURIFICATION TECHNOLOGIES

A significant proportion of the world's population has little to no access to clean water, and the water consumed by industrial activities continues to grow. Researchers from the Nanotechnology Enabled Water Treatment (NEWT) Center, which is headquartered at Rice University, are developing cutting-edge purification technologies that can provide communities with access to clean and safe drinking water. They are also creating new wastewater treatment methods that allow the reuse of industrial effluent, to minimise freshwater withdrawals by industries. Instead of conventional methods that use large amounts of chemicals and energy, NEWT technologies are chemical free, and often utilise solar energy.

Responding to Water Shortages

Many people across the globe do not have access to clean water, and there remains a vital need to provide communities with potable water supplies. Seawater and other saline or compromised water sources are often readily available, but these supplies are typically unsuitable for consumption, given their high concentrations of salts, microbes, toxic metals, and other contaminants. Such water sources need to be purified before they can be used.

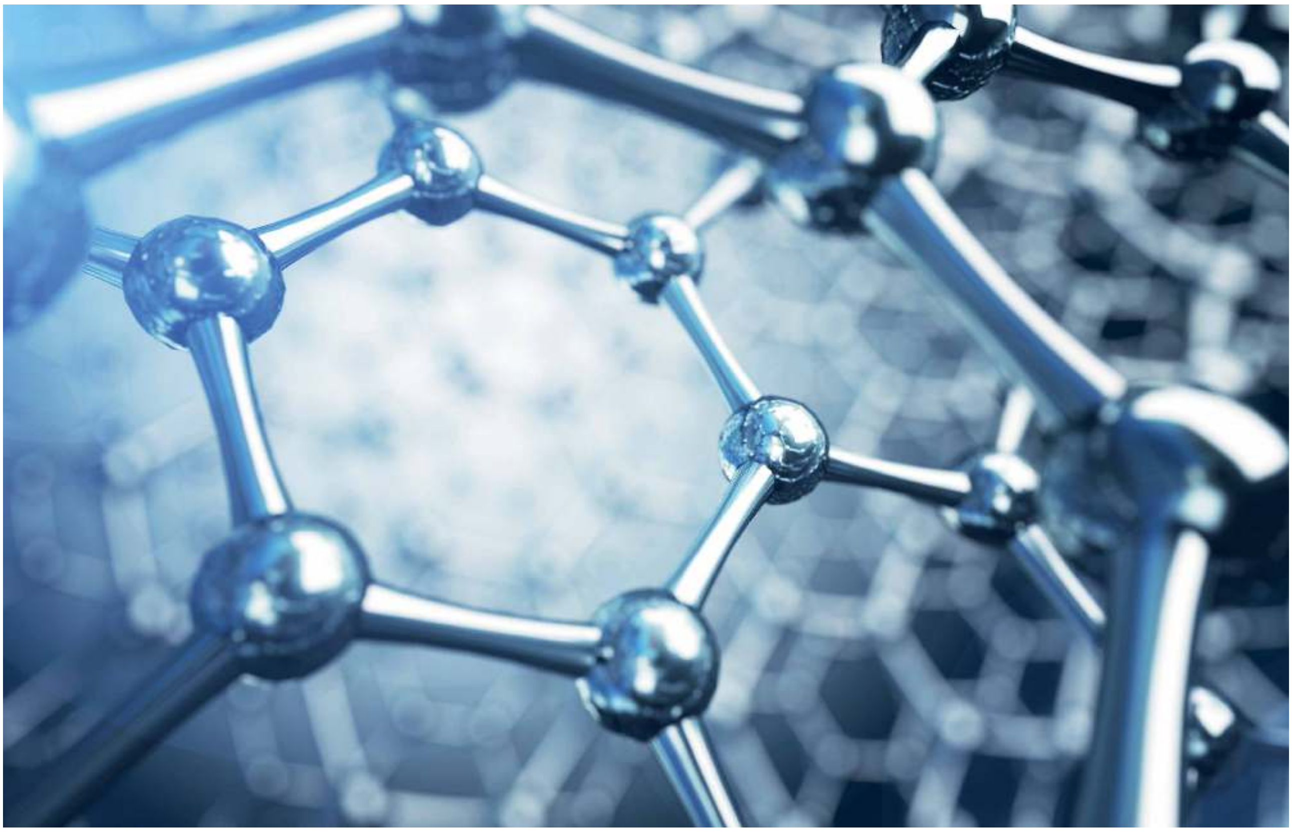
Multiple research teams from the 'Nanotechnology Enabled Water Treatment' (NEWT) Center are working to tackle these urgent problems. Funded by the US National Science Foundation, the Center is made up of researchers from Rice University, Arizona State University, Yale University, and the University of Texas at El Paso, with expertise spanning diverse disciplines, including environmental engineering, chemical engineering, materials science, chemistry and physics. NEWT's vision is to enable access to water of suitable quality almost anywhere in the world by developing next-generation, easy-to-deploy modular treatment systems enabled by nanotechnology.

Membrane Distillation

One purification method that NEWT researchers are working to improve is called 'membrane distillation'. In the process of membrane distillation, hot saltwater is passed over a membrane on one side, while cold, freshwater flows on the other side of the membrane. The membrane is porous, but keeps the saltwater and freshwater streams apart. The temperature difference across the membrane and between the two streams causes hot water from the saltwater side to vaporise through the membrane and join with the colder freshwater stream. The process does not require the use of chemicals and, overall, separates water from saltwater solutions.

The migration of water vapour from the saltwater side to the freshwater side occurs to a greater extent when the difference in temperature across the membrane is higher. When the temperature of the saltwater is high, the extent to which vaporisation occurs is similarly high. Likewise, when the freshwater temperature is low, the extent to which condensation occurs is also high.

These factors do, however, reveal an inherent limitation with membrane distillation. The act of vaporisation lowers the temperature of the hot, saltwater side and the process of condensation increases the temperature of the cold, freshwater side. The membrane also transfers some of the heat energy from the saltwater side to the freshwater side. These and other temperature-related factors subsequently reduce the difference in temperature across the membrane, therefore lowering the volume of water that can migrate across it. To maximise the migration of water



vapour, one would need to maintain a large temperature difference across the membrane.

Harnessing the Sun's Energy

Maintaining the temperature difference can be achieved by heating the membrane itself. Researchers from the NEWT Center found that by adding a layer that can absorb solar energy to the membrane surface on the saltwater side, and then directing sunlight to this layer, they were able to increase the quantity of water vapour transferred. The team's new technology, referred to as 'nanophotonics enabled solar membrane distillation' (NESMD), can thus be powered locally, using free, clean and widely available energy from the Sun.

In the team's NESMD technology, the layer on the membrane that absorbs sunlight is called 'carbon black' – a substance similar to activated charcoal. Sunlight is directed through an array of lenses to the carbon black layer, which absorbs nearly all frequencies of visible light, transferring the energy as heat to the membrane.

NESMD is relatively cheap to operate, since any potential purification plant would not need to heat the entire volume of saltwater. The NEWT researchers hope that their environmentally friendly purification process can be applied at different scales – from whole communities down to individual households, many of whom will not be connected to the national grid.

The team also investigated other energy-absorbing materials for NESMD. In one study, they applied 'silica', the main constituent of sand and glass, covered with gold to the surface of the membrane. The researchers found that the carbon black materials absorb more of the high-energy radiation in sunlight, comprising blue and violet light, whereas the silica-gold materials absorb more of the low energy radiation, corresponding to red and yellow light. Both NESMD membrane compositions performed more effectively than conventional membranes, maintaining the temperature difference needed to prolong vaporisation.

For applications that require large volumes of water 24 hours a day, such as industrial applications, NEWT researchers have also developed 'dual-power membranes'. These membranes harness energy directly from sunlight when it is available, and can then operate on electricity at night. One team of NEWT researchers developed a dual-power membrane comprising a nanolayer of boron nitride on a stainless-steel wire cloth, which demonstrates superior performance, making it suitable for industrial applications.

Another group of researchers fabricated a dense, non-porous 'pervaporation' membrane from a polymer called Nexar™. The team found that their membrane exhibited a salt separation performance superior to commercial pervaporation membranes, and equivalent to that of commercial membrane distillation membranes.

In another study, NEWT scientists used egg-shell waste to develop a highly efficient dual-power membrane. Specifically, they used the egg membrane, found just inside the

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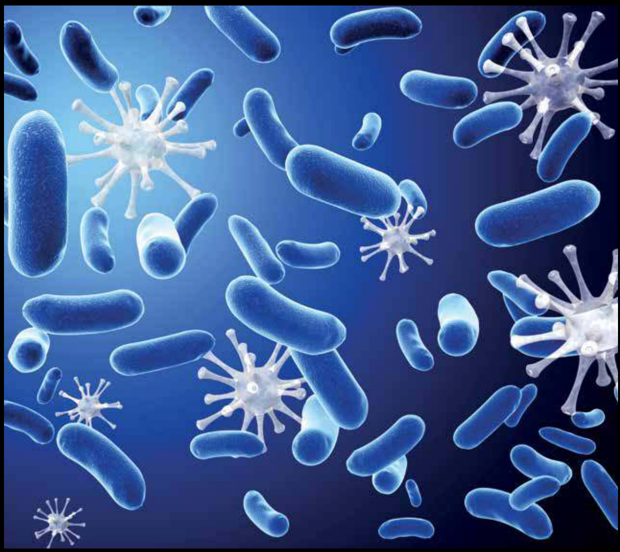

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