ASIA PACIFIC

CHINA

Nanoparticles for water treatment

Magnetic nanoparticle clusters have the power to punch through biofilms to reach bacteria that can foul water treatment systems, according to scientists at Rice University, USA, and the University of Science and Technology of China. The nanoclusters developed through Rice's Nanotechnology-Enabled Water Treatment (NEWT) Engineering Research Center carry bacteriophages—viruses that infect and propagate in bacteria—and deliver them to targets that generally resist chemical disinfection. Without the pull of a magnetic host, these "phages" disperse in solution, largely fail to penetrate biofilms and allow bacteria to grow in solution and even corrode metal, a costly problem for water distribution systems.

The Rice lab of environmental engineer Pedro Alvarez and colleagues in China developed and tested clusters that immobilize the phages. A weak magnetic field draws them into biofilms to their targets. The research is detailed in the Royal Society of Chemistry's *Environmental Science: Nano*. "This novel approach, which arises from the convergence of nanotechnology and virology, has a great potential to treat difficult-to-eradicate biofilms in an effective manner that does not generate harmful disinfection byproducts," Alvarez said.

Biofilms can be beneficial in some wastewater treatment or industrial fermentation reactors owing to their enhanced reaction rates and resistance to exogenous stresses, said Rice graduate student and co-lead author Pingfeng Yu. "However, biofilms can be very harmful in water distribution and storage systems since they can shelter pathogenic microorganisms that pose significant public health concerns and may also contribute to corrosion and associated economic losses," he said.

The lab used phages that are polyvalent—able to attack more than one type of bacteria—to target lab-grown films that contained strains of Escherichia coli associated with infectious diseases and Pseudomonas aeruginosa, which is prone to antibiotic resistance.

The phages were combined with nanoclusters of carbon, sulfur and iron oxide that were further modified with amino groups. The amino coating prompted the phages to bond with the clusters headfirst, which left their infectious tails exposed and able to infect bacteria.

The researchers used a relatively weak magnetic field to push the nanoclusters into the film and disrupt it. Images showed they effectively killed *E. coli* and *P. aeruginosa* over around 90 percent of the film in a test 96-well plate versus less than 40 percent in a plate with phages alone. The researchers noted bacteria may still develop resistance to phages, but the ability to quickly disrupt biofilms would make that more difficult. Alvarez said the lab is working on phage "cocktails" that would combine multiple types of phages and/or antibiotics with the particles to inhibit resistance.

https://www.cemag.us

INDIA

Water purification membrane

A team of researchers from Indian Institute of Science (IISc) Bangalore has improved upon the water purification membrane they developed in 2014. The membrane allows higher flow rate across it and kills nearly 99 per cent of *E. coli* present in water. The results of the study were published recently in the journal Nanoscale. Instead of creating a membrane with sub-micron pore size, a team led by Prof. Suryasarathi Bose, the corresponding author of the paper from the Department of Materials Engineering, IISc produced a more permeable structure by creating pores that are bigger in size and more interconnected.

Bigger and more tortuous pores were produced by mixing equal amounts of two polymers — polyethylene (PE) and polyethylene oxide (PEO). Since PEO is soluble in water unlike PE, pores tend to form when the membrane containing PEO is dipped in water. Earlier, the researchers used tiny amount of PEO and sheared it at high speed to produce tiny droplets of PEO to create smaller pores. "We took equal amounts of PE and PEO so we get more tortuous pores upon removal of PEO. This is not possible if we take tiny amounts of PEO," says Prof. Bose.

Besides being tortuous, the pores are also asymmetrical — the pore dimensions are not uniform throughout. At some places, the pores get so narrow that they tend to be as small as the micro holes that the team produced two years ago. Explaining the logic behind having asymmetrical pores, Prof. Bose says: "If the pores are asymmetrical then bacteria and other contaminants will have a tougher path to pass through, so they will get trapped." The pores are also well connected thereby increasing the ability of water to pass through the membrane. When two polymers are mixed and subjected to post processing application like hot pressing the initial PEO droplets tend to become bigger. The bigger droplets of PEO tend to leave bigger pores. "To prevent this and control the morphology we added maleated polyethylene. The maleated polyethylene does not allow the droplets to get bigger," Prof. Bose says. "Maleated polyethylene basically interacts with PE (polyethylene) on the one hand and reacts with PEO on the other hand. So it is a kind of interfacial stabilising agent and doesn't allow the morphology to coarsen."

Antibacterial studies through direct contact of E. coli with graphene oxide resulted in 100-fold reduction in E. coli colony forming units at the end of 12 hours of contact with the membrane. According to him, graphene oxide has very sharp edges and this helps in piercing and destroying the bacterial cell wall. Also, the amine group of graphene interacts with the phosphate group of the lipids present in the cell and generates reactive oxygen species that eventually destroys the cell membrane. Since polyethylene is inert, the researchers had to render suitable surface modification to anchor graphene oxide on to it, which otherwise would have been very difficult. Lab studies have revealed that there is unimpeded permeation of water across the membrane suggesting that anchoring the graphene oxide on the surface does not clog the pores.

http://www.thehindu.com

Water treatment system and analysis kits

Indian Institute of Technology (IIT) Madras signed a Memorandum of Understanding (MoU) with TANSTIA-FNF Service Centre on Monday (March 20) for the technology transfer of 'Point of use Water Treatment System and Water Analysis Kits'. The T-FNF Service Centre will take this technology to small industries. IIT – Madras has not patented the technology and is giving it away almost free of cost. Prof. Krishnan Balasubramaniam said, "IIT professors are committed to societal development at various levels. This is a grassroots level project that benefits day-to-day entrepreneurs who make a living. While the institutions can develop new technologies, it is organizations such as TANSTIA that can take it from the laboratories to the grassroots."

Prof. Ligy Philip of the Department of Civil Engineering, along with her students Dr. R. Elangovan and Mr. D. Kumaran, developed two water testing kits, one for 14 parameters and another for 24 parameters. The 14 parameters test kit can be used for (i) pH, (ii) total hardness, (iii) chlorides, (iv) dissolved solids, (v) calcium, (vi) sulphate, (vii) nitrate, (viii) fluoride, (ix) alkalinity, (x) magnesium, (xi) acidity, (xii) phosphate, (xiii) residual chlorine and (xiv) bacteriological quality.

The kits have already been tested extensively in the field. United Nations International Children's Emergency Fund or UNICEF sponsored several training programs in Krishnagiri district where the testing kits were distributed to 176 panchayats.

A simple, easy-to-make and easy-to-use domestic water filter has also been developed. The research project was funded by International Development Research Centre (IDRC), a public corporation created by the Canadian Government. The 'Point of Use' water treatment system will remove turbidity, organic matter, colour and odour besides most bacteriological contamination. The filtered water is collected in a container with proper lid, tap and chlorine tablet is added to remove microbes. The maintenance of the system is very simple. 'Point of Use' systems are installed at a single water connection like under kitchen counters or bathroom sinks.

https://indiaeducationdiary.in

Reverse osmosis-based water purifier

Concerned over wastage of water from the RO water systems, two ex-students of Indian Institute of Technology (IIT)-BHU were successful in developing cost and energy efficient water purifier called 'Aquvio'. The patentable technology was developed two years ago. In Aquvio's cost and energy saving Reverse Osmosis-based water purifier, only 30% of water is rejected and 70% is available for drinking purposes. Recognising the potential of Aquvio, IIT-Kanpur granted a seed funding of Rs 20 lakh to the company run by these ex-IIT-BHU students.

The duo--Naveen Kumar and Rohit Kumar Mittal--who had developed Aquvio in just two years, were successful in getting 60 Aquvio water purifiers installed across schools and colleges in Varanasi. Four such water purifiers were also installed at an Army unit in the holy city. Naveen said, "Aquvio's water filters significantly reduce the amount of water wasted as compared to modern RO water systems. In water purifiers available in the market, 70% of the water is drained out, which is nothing but a wastage in the current scenario of water crisis in our country. In Aquvio's cost and energy saving Reverse Osmosis-based water purifier, only 30% of the water is rejected and 70% is available for drinking purpose. Aquvio water purifiers also consume less power". He said, "The technology used in Aquvio has already been patented. This patented technology only ensures that out of four litre of water only one litre gets drained and the remaining water is available for drinking purpose. It significantly helps in saving water", he further said.

Aquvio has two water purifiers that can filter huge quantities of water (100 litre per hour and 50 litre per hour) and are fit for use in corporate offices or schools/colleges. Aquvio has been recognised by Startup India Standup India, a Government of India initiative, Naveen said.

http://timesofindia.indiatimes.com

RUSSIA

Hybrid nuclear desalination technique

Scientists from the National Research Nuclear University have developed a new technology and technological schemes for a pretreatment unit taking into account data on the composition of pollutants, salinity and performance of water treatment systems. It is based on the reagent methods with hydrodynamic activation of the process of pollutant withdrawal in coagulation, flocculation and adsorption, which reduces the unit's size and cost. Moreover, the majority of the sparingly soluble salts can be removed in the pretreatment unit, which increases the efficiency of the system as a whole.

From the pre-water treatment unit, salt water flows into the desalination unit, a very energy-intensive process. Hybrid desalination schemes are proposed to reduce the energy consumption of the desalination process. These schemes use distillation and membrane methods in combination, to produce both drinking water and process water. In addition, the project proposes the development of an integrated technological system of water recycling and desalination systems to reduce environmental burdens and improve the energy efficiency of the system as a whole. The results are intended to be used in complex projects of the State Corporation Rosatom, in particular, in relation to nuclear power plants in Egypt, where it is planned to realize a nuclear desalination technology.

https://phys.org

SINGAPORE

Algae treatment of wastewater

Researchers at the National University of Singapore (NUS) believe they can harness that very growth to treat wastewater, and cut the energy used in treatment by as much as 80 per cent. That is because wastewater treatment takes a lot of energy, most of it to bubble air through, or aerate, sludge ponds so bacteria can eat the waste.

Prof Loh and Prof Tong, of NUS' chemical and bioengineering department, started devising their system about two years ago. They were inspired by a previous government grant call asking for research to

improve the energy efficiency of wastewater treatment. They did not get the grant, but kept plugging away at the system.

Now, they have got as far as a lab-bench experimental setup - a 250ml flask full of algae and an identical flask full of bacteria. The liquids in the twin flasks never mix, meeting only in a reactor where a membrane made of plastic fibres lets the necessary gases through.

So far, they have tested on a high-concentration sugar solution that mimics the concentration of wastewater, but have not yet tried it on real wastewater. That is one of the next steps, explained Prof Loh.

Another would be genetically engineering strains of algae that grow faster and thus consume more carbon dioxide, a project Prof Tong is working on. After that, scaling up to a pilot or demonstration plant should be straightforward, as the membranes used are commercially available. They reckon the process could even be a net producer of energy, if the algae are digested at the end of their life to harvest methane gas which is then burned to generate power.

http://www.eco-business.com

EUROPE

IRELAND

New process for water filtration

A new process for water filtration using carbon dioxide consumes one thousand times less energy than conventional methods, scientific research published recently has shown. The research was led by Dr Orest Shardt of University of Limerick, Ireland together with Dr Sangwoo Shin (now at University of Hawaii, Manoa), while they were post-doctoral researchers at Princeton University (United States) last year. Dr Shardt expects this new method which uses CO_2 could be applied in a variety of industries such as mining, food and beverage production, pharmaceutical manufacturing and water treatment.

The research, published in open-access scientific journal *Nature Communications*, indicates that the new process could be easily scaled up, "suggesting the technique could be particularly beneficial in both the developing and developed worlds". The new method could also be used to remove bacteria and viruses without chlorination or ultraviolet treatment. "We are at the early stages of developing this concept. Eventually, this new method could be used to clean water for human consumption or to treat effluent from industrial facilities," Dr Shardt stated.

The research by Drs Shardt and Shin demonstrates an alternative membraneless method for separating suspended particles that works by exposing the colloidal suspension to CO_2. "The demonstration device is made from a standard silicone polymer, a material that is commonly used in microfluidics research and similar to what is used in household sealants. While we have not yet analysed the capital and operating costs of a scaled-up process based on our device, the low pumping energy it requires, just 0.1% that of conventional filtration methods, suggests that the process deserves further research," said Dr Shardt.

"What we need to do now is to study the effects of various compounds, such as salts and dissolved organic matter that are present in natural and industrial water to understand what impact they will have on the process. This could affect how we optimise the operating conditions, design the flow channel, and scale-up the process," he continued.

https://www.eurekalert.org

GERMANY

Cleaning wastewater effectively

Researchers from the Fraunhofer Institute for Ceramic Technologies and Systems IKTS in Hermsdorf, were able to significantly reduce the separation limits of ceramic membranes and to reliably filter off dissolved organic molecules with a molar mass of only 200 Dalton. Even industrial sewage water can thus be cleaned efficiently.

Dr. Ingolf Voigt, Dr.-Ing. Hannes Richter and Dipl.-Chem. Petra Puhlfuerss from the Fraunhofer IKTS have achieved the impossible. "With our ceramic membranes, we achieve, for the first time, a molecular separation limit of 200 Daltons – and, thereby, a whole new quality," says Voigt, Deputy Institute Director of the IKTS and Site Manager in Hermsdorf. The challenge was to produce pores which were as small as possible, with all of them having more or less the same size. "We achieved these results by refining sol-gel technology says Richter, Head of Department at the IKTS.

The second hurdle was to make such membrane layers defect-free over larger surfaces. The Fraunhofer researchers have succeeded in doing this, as well. "Whereas only a few square centimeters of surface are usually coated, we equipped a pilot system with a membrane area of 234 square meters, which means that our membrane is several magnitudes larger," explains Puhlfuerss, scientist at the IKTS.

Commissioned by Shell, the pilot system was built by the company Andreas Junghans – Anlagenbau und Edelstahlbearbeitung GmbH & Co. KG in Frankenberg, Germany and is located in Alberta, Canada. The system has been successfully purifying waste water since 2016, which is used for the extraction of oil from oil sand. The researchers are currently planning an initial production facility with a membrane area of more than 5,000 square meters. The innovative ceramic membranes also offer advantages in industrial production processes: they can be used to purify partial currents directly in the process as well as to guide the cleaned water in the cycle, which saves water and energy.

http://www.innovations-report.com

UK

Algae water treatment

Replacing chemical treatments with algae farming could make wastewater treatment cheaper and more sustainable, according to researchers at Bath University who are testing the method in partnership with Wessex water. The method is particularly suited to removing phosphorus from sewage, an increasing problem for water treatment.

The Bath team, led by chemical engineer Tom Arnot and Prof Rod Scott of the Department of Biology and Biochemistry, is trying an approach that turns the problems posed by phosphorus into an advantage. Phosphorus-containing wastewater

streams are fed into shallow ponds that have been seeded with algae, and phosphorus acts as a fertiliser encouraging the aquatic plant to grow. This reduces the level of phosphorus in the water. Some of the water and algae mixture is then removed into a settling pond, and the "polished" water, whose quality is suitable for it to be released into rivers and ponds, is separated, leaving the algae behind. The treatment pond is refilled with more wastewater.

The method is currently under test with a small pond at Beckington sewage treatment works. Known as a high rate algal pond (HRAP), it is seeded with algae that can be used as a feedstock for bioplastics, biofuels and agricultural fertiliser. The pond, with a surface area of 60m^2, treats around 3000l of wastewater per day, and is removing 80 to 96 per cent of phosphorus content. The team is hoping to confirm that HRAPs such as this are practical in the inconsistent light and temperature conditions of the UK weather, and believe this method may be particularly suited to smaller sewage treatment works that serve communities of around 1000 people, of which Beckington is a good example.

"In theory, HRAPs could offer an environmentally friendly and sustainable way of removing phosphorus from wastewaters and consequently improving the health of our rivers and lakes without a massive increase in consumer's water bills," said Dimitris Kaloudis, a research associate and operator of the trial. "In this trial, one of the first of its kind, we are looking to establish how the technology performs in realistic scales and conditions as well as to understand and address any challenges that may arise during the course of the trial."

The trial is one of a number being carried out by water and sewerage companies in England and Wales to investigate new phosphorus removal techniques.

https://www.theengineer.co.uk

Seawater desalination breakthrough

Scientists at the University of Manchester have developed graphene oxide membranes with holes small enough to filter out salt. The sieves represent a technological breakthrough in the effort to make desalination more efficient and affordable.

Graphene oxide membranes have been used in desalinatio experiments for years, but never before has the sieve been small enough to filter out smaller particles. One of the major challenges with this process is the natural tendency of graphene oxide membranes to swell in water. This causes their pores to expand, and salt particles to pass through. The scientists, led by Rahul Nair, were able to control the swelling by building epoxy resin walls around the membranes, as noted in the study published in *Nature Nanotechnology*.

"Realization of scalable membranes with uniform pore size down to atomic scale is a significant step forward and will open new possibilities for improving the efficiency of desalination technology," Nair said. "This is the first clear-cut experiment in this regime. We also demonstrate that there are realistic possibilities to scale up the described approach and mass produce graphene-based membranes with required sieve sizes."

https://www.ecowatch.com

NORTH AMERICA

USA

New method for solar desalination

A team of researchers from Rice University in Houston, Texas, has developed a new method for using solar power to desalinate sea water. Part of a federally funded research effort into water treatment, the team has developed a system utilizing a combination of membrane distillation and nanophotonics to turn salt water into fresh drinking water. The team at the Center for Nanotechnology Enabled Water Treatment (NEWT) built on an emerging technology known as membrane distillation, whereby hot salt water is flowed across one side of a porous membrane and cold freshwater across the other, and water vapor is drawn through to the cold side, to create its new 'Nanophotonics-enabled solar membrane distillation' (NESMD) technology.

"Unlike traditional membrane distillation, NESMD benefits from increasing efficiency with scale," said Naomi Halas, leader of NEWT's photonics research. "It requires minimal pumping energy for optimal distillate conversion, and there are a number of ways we can further optimize the technology to make it more productive and efficient."

The technology developed by NEWT integrates engineered nanoparticles, which the team says can harvest as much as 80% of sunlight to generate steam, into the porous membrane, essentially turning it into one sided heating element that heats the water to drive distillation through the membrane. In a study described in the *Proceedings of the National Academy of Sciences journal*, researchers demonstrated proof of concept for the technology based on tests using an NESMD chamber about the size of three postage stamps. The membrane contained a top layer of carbon black nanoparticles, which heat the entire surface when exposed to sunlight.

Qilin Li, Rice University Scientist and water treatment expert, said that the team had already made a larger system of around 70 x 25 centimeters, and that NEWT is hoping to scale the technology up to a modular design where customers could calculate how many panels they need based on their daily water demand. "Direct solar desalination could be a game changer for some of the estimated 1 billion people who lack access to clean drinking water," says Li. "This technology is capable of providing sufficient clean water for family use in a compact footprint, and it can be scaled up to provide water for larger communities."

https://www.pv-magazine.com

Sunlight powered water-purifier

Researchers from the University at Buffalo may have found a solution to purify saltwater and contaminated water at a fraction of the cost. The scientists improved on the common solar still. They improved the efficiency and the freshwater generation rate via a cheap portable device that can convert clean water 2.4 times faster than leading commercial products. Their results are published in *Global Challenges*. "Using extremely low-cost materials, we have been able to create a system that makes near maximum use of the solar energy during evaporation," lead

researcher Qiaoqiang Gan, an associate professor of electrical engineering in the University at Buffalo School of Engineering and Applied Sciences, said in a statement. "At the same time, we are minimizing the amount of heat loss during this process."

The device is a solar vapor generator, which uses the heat from the Sun to evaporate the water and thus separate it from bacteria, salt, and soot. The water vapor is then condensed into drinkable water. "People lacking adequate drinking water have employed solar stills for years, however, these devices are inefficient," says Haomin Song, also at the University of Buffalo and one of the study's leading co-authors. "For example, many devices lose valuable heat energy due to heating the bulk liquid during the evaporation process. Meanwhile, systems that require optical concentrators, such as mirrors and lenses, to concentrate the sunlight are costly."

The breakthrough for the team was to use paper coated in carbon black that absorbs the water and maximizes the amount of sunlight absorption. The device, which is as big as a mini-fridge, floats and uses only surface water, so it can be used on any body of water. The generator, according to the team, can produce between 3 and 10 liters of freshwater a day. Based on the current cost of the material, the device is roughly $1.60 per square meter. It could be brought down even further if they were produced in bulk.

http://www.iflscience.com

Method to clear pollutants from water

A new method developed at MIT could provide a selective alternative for removing even extremely low levels of unwanted compounds. The new approach is described in the journal *Energy and Environmental Science*, in a paper by MIT postdoc Xiao Su, Ralph Landau Professor of Chemical Engineering T. Alan Hatton, and five others at MIT and at the Technical University of Darmstadt in Germany.

The system uses a novel method, relying on an electrochemical process to selectively remove organic contaminants such as pesticides, chemical waste products, and pharmaceuticals, even when these are present in small yet dangerous concentrations. The approach also addresses key limitations of conventional electrochemical separation methods, such as acidity fluctuations and losses in performance that can happen as a result of competing surface reactions.

In the new system, the water flows between chemically treated, or "functionalized," surfaces that serve as positive and negative electrodes. These electrode surfaces are coated with what are known as Faradaic materials, which can undergo reactions to become positively or negatively charged. These active groups can be tuned to bind strongly with a specific type of pollutant molecule, as the team demonstrated using ibuprofen and various pesticides. The researchers found that this process can effectively remove such molecules even at parts-per-million concentrations.

Previous studies have usually focused on conductive electrodes, or functionalized plates on just one electrode, but these often reach high voltages that produce contaminating compounds.

By using appropriately functionalized electrodes on both the positive and negative sides, in an asymmetric configuration, the researchers almost completely eliminated these side reactions. Also, these asymmetric systems allow for simultaneous selective removal of both positive and negative toxic ions at the same time, as the team demonstrated with the herbicides paraquat and quinchlorac. The same selective process should also be applied to the recovery of high-value compounds in a chemical or pharmaceutical production plant, where they might otherwise be wasted, Su says. "The system could be used for environmental remediation, for toxic organic chemical removal, or in a chemical plant to recover value-added products, as they would all rely on the same principle to pull out the minority ion from a complex multi-ion system."

The system is inherently highly selective, but in practice it would likely be designed with multiple stages to deal with a variety of compounds in sequence, depending on the exact application, Su says. "Such systems might ultimately be useful," he suggests, "for water purification systems for remote areas in the developing world, where pollution from pesticides, dyes, and other chemicals are often an issue in the water supply. The highly efficient, electrically operated system could run on power from solar panels in rural areas for example."

Unlike membrane-based systems that require high pressures, and other electrochemical systems that operate at high voltages, the new system works at relatively benign low voltages and pressures, Hatton says. And, he points out, in contrast to conventional ion exchange systems where release of the captured compounds and regeneration of the adsorbents would require the addition of chemicals, "in our case you can just flip a switch" to achieve the same result by switching the polarity of the electrodes.

http://news.mit.edu

Clean Energy Education and Empowerment

The Clean Energy Education and Empowerment Technology Collaboration Programme (C3E TCP) of the International Energy Agency (IEA) aims to raise awareness, share best practices, establish a network for information exchange and commit to action across borders so that more women are encouraged and empowered to become leaders in clean energy. The C3E TCP provides an international platform that will focus on four distinct areas: data collection, career development, recognition and awards programmes and dialogue.

For more information, access:

C3E TCP
E-mail: C3E-TCP@iea.org
Web: https://www.iea.org/tcp/cross-cutting/c3e/