Science Last Fortnight

Low-Cost Water Purification
Removing arsenic and fluoride

Arsenic and fluoride in drinking water are a worldwide concern. Exposure to these chemicals poses a threat to health. However, existing techniques to remove them from water involve high costs and yet offer low removal efficiency. Last fortnight, scientists from the Indian Institute of Technology, Roorkee, reported an alternative technique to remove both from water more economically.

The researchers optimized an electrocoagulation reactor for removing arsenic and fluoride in water. They achieved a maximum removal of both in synthetic water at neutral pH. And removal was rapid at a current density of 10 A/m^2, run time of 95 min and inter-electrode distance of 1 cm. Sodium chloride, used as supportive electrolyte, removed 98.51% arsenic and 88.33% fluoride. The metal hydroxides, generated *in situ*, act as coagulant in aqueous solutions, and provide active sites for the adsorption of polluting species.

The scientists evaluated this technique to purify the natural ground water collected from the Rajnandgaon district. And they found that the concentration of arsenic and fluoride could be brought down to below the maximum permissible limit.

The operation cost of the reactor – cost of electrode material and electricity – is only Rs 23 per cubic meter of water, much cheaper than earlier methods. Entrepreneurs, in areas affected by arsenic and fluoride in groundwater, can now mass produce this efficient and low-cost technology.

J. Environ. Management, **190**, 102–112

Nature's Fertilisers
Beneficial bacteria bearers

Prolonged use of fertilisers can lead to the loss of beneficial soil microflora, water pollution and health hazards including increased propensity to stomach and bone disorders and cancers. Consequently, there is a pressing need for environment-friendly substitutes to chemical fertilisers. Rhizobacteria, to promote plant growth by improving nutrient bioavailability, has been suggested for reducing chemical fertiliser use. However, biofertiliser formulations have short-shelf life.

Last fortnight, scientists at the IIT Dhanbad, in collaboration with the Ural Federal University, reported biofertiliser formulations with better shelf life. They used biochar and flyash as carriers for two Rhizobacteria species.

They tested the efficacy and shelf life of formulations based on fly ash and on biochar by assessing soil fertility as well as the growth of tomato plants. Tomato seeds treated with these bioformulations had a significantly higher rate of germination and yielded plants with higher biomass, leaf-length, number and size of flowers and fruits.

In contrast to flyash as carrier, biochar was found to be better suited to ameliorate soil fertility. The bacteria-based fertilisers in biochar increased the shelf life, for as long as 240 days! With improved shelf-life, it can now be marketed as a substitute for chemical fertiliser.

In an agrarian economy like India, it makes sense to use agricultural and industrial waste. It can also be an eco-elegant approach to resolving soil fertility and food productivity problems.

J. Environ. Management, **190**, 20–27

Conservation of Keoladeo
Mathematical models

The Keoladeo National Park is a Ramsar site. These wetlands, the erstwhile duck-shooting reserve of the Maharajas of Bharatpur, were declared a national park in 1982 and a World Heritage Site by the UNESCO in 1985. The park now provides a safe haven for migratory waterfowls and it is the only regular wintering place for the endangered Siberian crane. But how do we assure the stability of this ecosystem?

Last fortnight, Atasi Patra and others from the Birla Institute of Technology and Science, Pilani, Rajasthan, reported a series of three mathematical functional response models to tackle the problem.

The first model is based on the prey–predator model. The researchers considered floating vegetation, fishes, waterfowl and other species useful to birds, as 'good' biomass and wild grasses such as *Paspalum distichum*, *Pseudoraphis spinescens*, and *Hydrilla verticillata*, which deplete the dissolved oxygen level in water bodies as 'bad' biomass. Good biomass acts as prey and bird population as predator. It was seen that, when the growth rate of good biomass is greater than a threshold value, the positive equilibrium is globally stable and the model was found to be ecologically well behaved.

The second model took into consideration the degradation of wetlands due to bad biomass. The first model was extended to study the impact of bad biomass on good biomass, and consequently on bird population. It was found that, if no efforts are made to control the growth of bad biomass in the wetland, good biomass will reduce and, consequently, the survival of bird populations will be threatened.

The third mathematical model was on the management of the wetland park. In this functional response model, the second model was extended to evaluate the outcome of the effort on bad biomass, and, consequently, on good biomass. It was found that, if the density of the effort increases, good biomass increases and bad biomass decreases and, consequently, the density of bird population increases. The scientists showed, theoretically as well as numerically, that, even if the wetland is in bad health, by intervening with suitable effort, the density of bad biomass can be lowered, increasing good biomass and bird population.

Depending on initial conditions, all three models have multiple steady states under different community regions. Development of such models can be useful in making policy decisions for the conservation and management of wetland ecosystems.

Mathematics and Computers in Simulation, **134**, 54–78

Pesticide Residue on Fruit

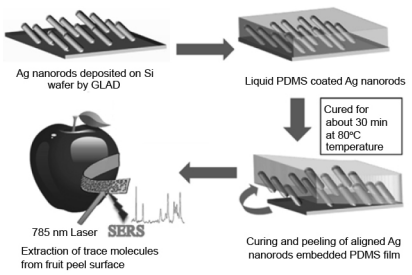
Chemicals on curved surfaces

Pesticides are used in agriculture to increase food security. However, pesticide residue in food raises health concerns. Pesticide residue testing is carried out to ensure compliance with regard to maximum residue levels. Yet it remains challenging for analytical laboratories to detect, identify and quantify many different pesticides.

A research team led by Samar Kumar from IIT, Delhi, developed a simple method for the rapid detection of pesticide residue on the surface of fruit. They used a flexible polymeric material – polydimethylsiloxane – that can conform to the surface of the fruit. Polymethylsiloxane can be examined using Surface-Enhanced Raman Spectroscopy (SERS), a technique which enhances the vibrational spectrum of molecules adsorbed on or in the vicinity of metal particles and/or surfaces. Because of its readiness, sensitivity and least sample preparation requirements, SERS is considered a powerful technique for food inspection.

The researchers embedded silver nanobots (AgNRs) in polydimethylsiloxane. This enhanced portability and mechanical stability. The embedded AgNRs layers showed good adhesion on the polydimethylsiloxane surface as demonstrated by the scotch tape peeling test. These results demonstrate that AgNRs embedded in the flexible substrates are mechanically robust. The team also confirmed that *in situ* SERS signal intensity on flexible substrates under mechanical strain remains almost constant for an induced tensile strain value.

They then tested the AgNRs embedded polydimethylsiloxane substrate. They used a 'paste and peel off' approach to extract pesticide residue from fruits. And checked whether they could detect thiram and chlorpyrifos, commonly used pesticides.



The SERS signals were strong and easily distinguishable. Through enhanced Raman signals on the AgNRs embedded polymer substrate, thiram adsorbed from apple was detected at concentrations as low as 2.4×10^{-9} g/cm^2.

The robustness of the AgNRs arrays based polydimethylsiloxane reveals possibilities for flexible sensors capable of being deployed for onsite, rapid, sensitive, chemical sensing and trace chemical detection on non-planar surfaces.

Sensors and Actuators B: Chemical, **241**, 577–583

Carbon dot-DNA Hybrid Hydrogels

Uniform drug delivery for cancer

Most drug delivery systems involve a burst phase followed by suboptimal levels in blood. Last fortnight, a group of researchers from the Bhabha Atomic Research Centre in collaboration with the Indian Institute of Technology, Patna, and the National Institute of Pharmaceutical Education and Research, have come up with a solution: a carbon dot-DNA hybrid hydrogel to encapsulate the drugs.

Less than 10 nm in size, the carbon dot is a relatively new member of the nanoparticle family and, unlike the case with conventional nano devices, does not face issues of solubility, biocompatibility and biodegradability. DNA is used to create the hydrogel to ensure biodegradability and biocompatibility. The researchers used a DNA sequence rich in cytosine because it has a distinct ability to form an i-motif structure, ideal for hydrogel formation in acidic conditions.

The researchers compared the drug release profile of the hydrogel and found that the drug was released faster in an acidic environment. Thus, DNA's pH sensitivity ensures that the drug is released only in regions with high acidity, a common environment for cancer cells.

They encapsulated doxorubicin, an anticancer drug, in the hydrogel by incubating in an aqueous solution. The drug is attached to hydrogel both by electrostatic interactions as well as through intercalation into the DNA. This ensured high loading efficacy. The loading could be easily visualized: doxorubicin loaded hydrogel looks orange in white light and pink in UV. The fluorescent nature of both the carbon dot as well as the drug load makes it easy to visualize the drug loading and release.

When HeLa cells were incubated with the drug alone and hydrogel encapsulated drug, they found that the hydrogel affected cell viability less, initially. This higher survival indicated that the initial burst phase was restricted and the drug was released in a slow and sustained manner.

The researchers believe that such hydrogel-based drug delivery systems are a promising strategy not just for cancer but also for the treatment of other diseases.

Carbon, **114**, 169–176

Algorithm to Find Disease Genes

Genes in DNA carry information about how our body is made and how it functions. Mutations in these genes may lead to genetic diseases: cystic fibrosis, sickle cell anaemia, Parkinson's disease, some types of cancers, etc. The challenge for scientists is to find which genes are affected in each of these diseases.

Last fortnight, Pradipta Maji from the Indian Statistical Institute, Kolkata, with Ekta Shah and Sushmita Paul from the IIT-Jodhpur reported a new gene selection algorithm, RelSim, to identify disease genes. About thirty thousand genes in our DNA make thousands of proteins. These proteins interact with each other to carry out their respective functions. Interacting proteins form a protein–protein interaction network with each protein placed at the nodes. If any of these

interactions malfunctions, it may lead to disease. The scientists combined the information on gene expression profiles and protein–protein interaction networks to create their algorithm.

To test the algorithm, the researchers applied it to many cancer datasets. They could identify several genes significantly linked with the corresponding disease. Then they used the algorithm exclusively on colorectal cancer datasets. And they established that their algorithm can detect more colorectal cancer genes than other disease gene identification methods.

The researchers plan to improve their algorithm further, to make RelSim a useful and powerful tool for identifying other disease-related genes.

Information Sciences, **384**, 110–125

Ethanol from Lignocellulose

Lignocellulosic biomass represents a large feedstock for bioethanol production. However, the costs associated with producing biofuel using lignocellulases represent a limiting factor in the development of a biomass conversion process.

Scientists at the CSIR IICT, Hyderabad, collaborated with scientists in Egypt and Australia to explore *Pongamia pinnata* seed residue as a low cost resource for ethanol production. *P. pinnata* seeds are composed of 30–35% oil which can be processed to biodiesel. The residue after extraction of oil has holocellulose, which can be hydrolysed to sugars and fermented for bioethanol production. So, the researchers used the de-oiled seed residue as feedstock for ethanol production.

Enzymatic hydrolysis of the seed residue using cellulase results in significant yield of sugars. But the scientists explored another possibility: growing microorganisms that produce lignocellulases on de-oiled seed residue. They selected two microorganisms – *Spingomonas echinoides*, a bacterial strain, and *Iprex lacteus*, a white rot fungus. And they found that these organisms were able to produce a wide array of lignocellulase enzymes while growing on *P. pinnata* seed residue. Solid state fermentation using both the strains produced lignocellulases with high activity, 10–50 times greater than that observed in liquid cultures! So the organisms can be useful for the hydrolysis of biomass, while doubling up as a source of lignocellulases.

Pongamia pinnata seed residue is a cheap inedible resource for both lignocellulases and ethanol production. It has the potential to produce ethanol in an efficient manner compared to other costlier resources. And, most importantly, the technique improves the economics of *P. pinnata* biodiesel production.

Renewable Energy, **103**, 682–687

Pomegranate and Grapefruit
Extend storage of fruits of sea

White shrimps, with high protein and low fat content, are nutritive and a commercially important seafood. Its aquaculture in Asia has rapidly increased over the last decade. India now exports frozen shrimps to the USA, the European Union, the UAE and Japan.

Shrimps have short-shelf life due to degrading enzymes. Exporters need to preserve freshness and maintain quality from harvest to delivery. So several preservation methods are in use such as low-temperature preservation, modified atmosphere, chemical as well as biological preservation. But importing countries have strict sanitary standards and zero tolerance to use of chemicals and antibiotics in preservation.

Researchers from the Anna University, Chennai, now report an effective alternative to chemical preservatives: extracts of fruit peels and seeds. They used extracts of pomegranate, grape and grapefruit wastes. Shrimp samples were treated with four different extracts: (a) pomegranate peel, (b) pomegranate seeds, (c) grape seeds, (d) grapefruit seeds and left to dry at ambient temperature for a few minutes in an aseptic condition.

Samples were then packaged using different methods. Some were packed in vacuum pouches containing different transmission rates of O_2 and CO_2. Some were subjected to packaging with various percentages and combinations of gases and stored at 3°C.

Different parameters including bacterial load, sensory evaluation of colour and odour were recorded every third day for 24 days of storage. Samples treated with extracts of pomegranate peel and grapefruit seeds combined with modified atmospheric packaging without oxygen and increased CO_2 were found to have very good quality and great antibacterial property.

Such fruit-based extracts which are biosecure, eco-friendly and cost-efficient will have a better market than chemicals for preserving the fruits of the sea.

LWT-Food Science and Technology, **77**, 217–224

Chicken Sausage with Sugars
Fermentation by L. plantarum

Antioxidants are endogenous compounds in food. They increase nutritional benefit and preserve lipid components from deterioration. Lactic acid bacteria are an important natural source of antioxidants, used in industrial fermentation. The ability of the lactic acid bacteria, *Lactobacillus plantarum*, to produce desirable effects in sausages depends on the processing of food such as heating which may kill the bacteria and their sensitivity to curing salts, spices and other ingredients used.

Last fortnight, scientists from the ICAR-Central Avian Research Institute, Izatnagar, devised a novel approach to protect *L. plantarum* throughout the process of sausage preparation, including heat processing. White Leghorn was deboned, minced and mixed with *L. plantarum* using dextrose and starch as substrates in different formulations. There were two controls: one containing only meat and the other with meat and *L. plantarum*. Both control and treatment formulations were divided into two parts. One was used for making an emulsion, with spices and condiments added, which was cooked at more than 100°C. The other was fermented with *L. plantarum*. After fermentation for 24 hours, ingredients were added and the meat was cooked.

The researchers performed antioxidant, pH and free fatty acid analyses on the meat, with and without fermentation. And they evaluated the microbiological quality and sensory properties of the fermented sausages.

The antioxidant profile and sensory scores of *L. plantarum* fermented sausages, with added dextrose and starch, performed better than those of conventional sausages. *L. plantarum* also protects the ingredients with the antimicrobial effect it exerts due to the addition of sugars. This potential of *L. plantarum* could find industrial applications for making healthier minced meat.

LWT-Food Science and Technology, **77**, 249–258

Unmanned Aerial Vehicle

Solar energy to power conversion

The Unmanned Aerial Vehicle (UAV) is in demand for use in intelligence and surveillance operations. Aviation fuels used to power aircrafts are petroleum based and contribute to greenhouse gases. Moreover, aircraft engines are too noisy for surveillance. So, the power has to come from the battery. However, battery power is restricted.

Last fortnight, B. S. Karthik Reddy and Aneesh Poondlaa from the VIT University, Vellore, Tamil Nadu, proposed a conceptual design for a solar powered UAV. They built an experimental plane using lightweight balsa wood and carbon fibre rods. The gross weight of the plane was 2 kg. They chose a 3 S battery, which consists of 3 lithium-polymer batteries connected in series and used it as a single unit. For a constant safe charging voltage of 12.4 V for the 3 S battery, 24 solar cells were connected. The solar cells are arranged in series on top of the wing, and supplied the required voltage for charging the battery. And the battery power was supplied to the motor such that it shuts down during constant level flight, to save energy. The central part of the wing containing solar cells is perpendicular to the fuselage, and parallel to the ground for maximum efficiency.

The researchers analysed the energy efficiency, exergy and power conversion efficiency to work out the feasibility of the design of a solar powered UAV. The energy needed to power the entire plane was conceptually analysed. They also analysed exergy, the maximum work possible during the process for equilibrium with the surroundings. The energy and exergy efficiencies were calculated for a solar wing by considering the mixed effect of both temperature and wind speed.

And then they tested the results of the analysis with experimental flights. It was observed that energy efficiency, exergy and power conversion decrease slowly during morning, remain low in the afternoon and start rising in the evening due to high ratio of output to input voltage. Higher global solar radiation and lower outdoor temperature were favourable for both exergy and power conversion efficiency. The energy efficiency was found to be always higher than that of exergy and power conversion. The UAV built by the team could fly for more than 6 hours using only solar energy which can be further increased by storing the excess energy in the battery.

These findings can be utilized for meeting the demand for an unlimited inexhaustible source of energy for UAVs, thus decreasing greenhouse gas emission to a large extent.

Renewable Energy, **104**, 20–29

Risk Analysis of Nuclear Plants

The risk associated with nuclear power plants is a major concern all over the world. Existing risk calculation methodologies address risks associated with a single reactor. The Fukushima accident has raised the need for second-thoughts on this method, especially when the site hosts multiple nuclear plants. Nuclear power generating sites around the world are mostly twin or multiunit sites. With no acceptable methodology to assess the risk posed by multi-unit nuclear plant sites anywhere in the world, Mahendra Prasad and team from BARC, Mumbai, proposed a holistic framework to do this. The strategy was to integrate the risk from all units, dependencies on external events and operation time of individual units.

The team has put forward two analytical approaches. The first one combines the risks associated with each unit considering them as constant values while the second approach combines the risks considering them as random variables.

The first method takes into account core damage frequency and operational years of each of the units. The probability of core damage resulting from internal as well as external events of each unit was also separately considered.

The result of a case study on hypothetical data shows that site level core damage frequency is not a sum of effects of all units but around 18% higher than unit level effect.

By using the second method, this effect was found to be 50% higher than the risk effect of a single unit. The scientists comment that the second method is technically correct as it relies on data on failure rate and the failure probability of components.

The new methodology takes into consideration external dependencies as well as the combined effect of all the units within the site. And it confirms that installing nuclear reactors of advanced design at the site, along with the old reactors, reduces the combined risk of the site.

Nuclear regulatory authorities, the world over, now have a new risk assessment methodology to consider for making nuclear sites safer.

Progress in Nuclear Energy, **96**, 56–61

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