Science Last Fortnight

Mystery of Mud Banks

During the southwest monsoon, the coastal waters of Alappuzha, in Kerala, draw attention because of the occurrence of fluid mud: mud banks. A large number of fish and prawns throng the shore along with the mud bank formations. 'Chakara', as the local people call it, is a seasonal gift of abundance from the sea. Though the phenomenon proves a boon to local fisher folk, the factors behind mud bank formation continue to be a mystery.

Image: Liju Coolbean

Recently, scientists in Goa and Kochi, from the National Institute of Oceanography and the Naval Physical Oceanographic Laboratory, conducted a detailed study on mud bank formation. They selected mud bank reported regions for their field experiments and conducted weekly profiling of physico-chemical and meteorological parameters for over seven months. From the time-series data on meteorological and oceanographic parameters at three locations, the team drew insights into the mud bank triggering mechanism.

During the southwest monsoon, ambient wind and wave strengths are generally high. These initiate strong bed-sediment movement through frictional coupling. Occasional atmospheric low-pressure events enhance this process by supporting the suspension of bottom sediments, creating fluid mud.

Once the fluid mud is formed, the prevailing onshore upwelling current disperses it through a depression channel network towards the coast. The accumulation of a sufficient quantity and thickness of fluid mud near the coast creates the mud bank condition. Nutrients from the mud bank attract micro- and macro-organisms including fish, creating a rich ecosystem, resulting in huge fish catch with low effort.

The scientists say that extensive data is required to confirm whether the process is the same in other regions, where the occurrence of mud banks is reported. Besides Kerala, this rare phenomenon is observed only along the coastal waters of South America. Collecting data from turbid fluid mud regions in such hostile wind and wave conditions is a major challenge, say the scientists.

Estu. Coast., **41**(4): 1021–1035

Encroachment in Banni Grasslands

Behaviour change in rodents

The Banni grasslands of Gujarat are important tropical grasslands in Asia. The grassland has a long tradition of supporting livestock and wildlife. Of late, woody vegetation and manmade intervention in the name of afforestation, have encroached on the Banni grasslands.

Last fortnight, scientists from the National Centre for Biological Sciences, the Wildlife Conservation Society, and the Ashoka Trust for Research in Ecology and the Environment, Bengaluru, reported their study on the effect of bush encroachment in the Banni grasslands. The team found that this affected the foraging behaviour and community composition of rodents. Rodents play a significant role in maintaining biodiversity and are 'keystone' species of the grassland.

In Banni about 45% of the grassland is encroached upon by *Prosopis juliflora*. The team sought to understand the effect of woody cover on nocturnal rodents adapted to open grasslands.

The team selected two areas having dense and sparse cover of woody vegetation. They used Sherman traps baited with wheat plus peanut butter to trap rodents to understand the abundance and species richness in the two sites. They found that in the site with dense cover, there was higher abundance of generalist species, associated with disturbed habitats.

To study the change in foraging behaviour of rodents, the team examined the foraging cost between the sites using the giving-up density theory. The theory says that species tend to quit a food patch with diminishing returns, if the energy spent for searching for food is more than that obtained from the patch.

Using this concept, the team placed 32 food patches consisting of pearl millet mixed with sand, separated by a distance greater than the foraging radius of the largest rodent species, *Tatera indica*. They levelled the soil around the food patch so that they could see the tracks made by the rodents when they visit the patch. Pearl millet seeds remaining in the food patch were sieved and weighed.

From the test results, the team concluded that the rodents had higher foraging costs in the site with high bush encroachment in early summer. This is likely due to higher perceived predation risk and food availability in the dense site.

The team says that higher foraging costs and a shift in the community composition of native prey species could have negative impacts on grassland restoration. Therefore, policy-makers and conservationists need to think twice before implementing grassland afforestation programmes in grasslands.

J. Arid Environ., **153**: 32–38

Oil Spill in Chennai Coast

A curse on the marine ecosystem

On 28th January 2017, about three kilometres from the Chennai shoreline, two cargo ships collided. The accident released about 75 metric tonnes of heavy fuel oil into the

coastal waters of Chennai. Oil spills are a major cause of concern as they contain polycyclic aromatic hydrocarbons – carcinogenic, mutagenic and potent immune-suppressants.

This unfortunate incident provided Indumathi Nambi from IIT Chennai and collaborators Yuling Han and Prabhakar Clement in the USA with an opportunity to study the time evolution of oil spills. They characterised the oil spill using gas chromatography. The collected samples had a relatively large percentage of heavy polycyclic aromatic hydrocarbons.

The scientists used petroleum biomarkers, hopane and sterane, complex organic compounds derived from former living organisms, for the chemical fingerprinting of the water samples. The biomarkers helped pinpoint the source of the spilled oil.

Based on ambient temperature and wind conditions, the scientists inferred that volatilisation processes played a significant role in degrading and reducing the amount of oil spill. Volatilisation and evaporation were, perhaps, the major weathering processes immediately after the spill, say the researchers.

To understand the time evolution of the spill in a marine environment, the scientists measured the density of the oil and monitored the viscosity for several days. The viscosity values increased with time as the emulsification process transformed spilled oil into heavy, semi-solid emulsions.

The scientists observed that the seawalls and groins installed along the Chennai shoreline to manage coastal erosion problems controlled the oil transportation and deposition patterns. A large amount of oil was trapped within the relatively stagnant zone near the seawall–groin intersection region.

It is important to monitor and track the long-term environmental impacts of the Chennai oil spill residues on the Bay of Bengal coastal ecosystem, as the effects continue for a long time after the accident. The study provides clues for focused action for the remediation of the spill and to reduce long-term effects.

Sci. Total Environ., **626**: 795–806

Biodegradation of Azo Dyes

K. pneumoniae for biotreatment

Kanpur, the former 'Manchester of the East', was the first textile industrial town of India. The textile mills established during the British rule flourished in the city after independence and generated employment. They also generated large quantities of effluents with toxic dyes, polluting the environment.

Conventional physico-chemical treatments are expensive, have high sludge production rates, and produce toxic by-products. On the other hand, biotreatments are inexpensive and eco-friendly.

Researchers from IIT Kanpur have isolated a bacterium that degrades azo dyes and aromatic amines in textile effluents. The scientists used nutrient broth for isolating the bacterial strains, to which sludge from a local dyeing industry was added. Methyl orange was used as model dye for screening the decolourising microbes. Then the team cultured them for a fortnight and inoculated them onto nutrient agar plates.

They then grew the isolated strains in an enrichment medium, consisting of methyl orange, cosubstrates such as glucose and yeast to increase microbial degradation abilities. The researchers could thus select a strain which had the maximum decolourising potential. Using DNA sequencing they identified the strain: *Klebsiella pneumoniae*.

The scientists used sulphonated azo dyes to test the efficiency of the bacterium. They observed that 95% of the azo dyes were decolourised in less than a day and that the bacteria decolourised only in the presence of cosubstrates.

They also observed aromatic amines. This, they hypothesised, may be due to limited oxygenation. So they used an aquarium pump to aerate the decolourised cultures. The aromatic amines were mineralised within a day.

The decolourised cultures and degradation products were analysed using UV visible spectroscopy and high-performance liquid chromatography.

Finally the team evaluated the toxicity of the treated water on *Cicer arietinum*. They concluded that the biodegraded products were not toxic to the plant.

The researchers proposed a mechanism for the process: an electron transport-linked reduction of dyes in the outer membrane of the bacterial cell where it makes contact with the dye. The reducing equivalent possibly shuttles between the dye and an NADH-dependent azoreductase, present in the cell.

The research shows that *Klebsiella pneumoniae* has the potential for degrading toxic dyes. But it is pathogenic to humans. Further studies are needed to identify the metabolic pathways and the microbial components responsible. These can perhaps be isolated for use in dye degradation.

J. Environ. Eng., **144**(6): 04018035

Detecting Pathogens in Water

With nanogold and colistin

A large number of water-borne diseases are caused by bacteria that upset the gastrointestinal system, leading to diarrhoea, nausea, vomiting, dehydration and, often, death. According to a WHO report, nearly 38 million Indians are affected by water-borne diseases and, every day, 4000 children die.

To test whether water is safe, there are many methods. But the current methods of detecting bacteria in water are cumbersome and technically challenging, and often fail to detect low levels of pathogenic organisms in water.

Last fortnight, researchers from the Institute of Microbial Technology and the Panjab University, Chandigarh, reported developing a simple, cost-effective and rapid assay to detect bacterial contamination in water samples.

The assay depends on the interaction of gold nanoparticles and colistin – a peptide antibiotic used to detect pathogenic organisms. The method consists of just adding colistin and gold nanoparticles to water samples. The results are visualised based on colour change.

In bacteria-free potable water, the positively charged colistin binds and neutralises gold nanoparticles leading to aggregation of the gold nanoparticles. The colour of the sample changes from red to blue. In the presence of bacteria, however, colistin binds to lipopolysaccharides present in the bacterial cell wall. This renders the gold nanoparticles free in solution without aggregation. And the solution remains red.

This method can be used for onsite detection of bacteria in just 5 minutes without any instrumentation. Of course, to do this, the water to be tested has to be filtered to remove impurities.

The researchers successfully applied the method to detect *E. coli*, *Salmonella typhimurium* and *Klebsiella pneumoniae* and a combination of these bacteria in water. Even 10 bacterial cells per ml of tap water and 100 bacterial cells per ml of lake water are detectable with the naked eye, say the researchers.

Safe drinking water is a major concern. Rapid and sensitive detection methods are needed to control waterborne diseases, especially in rural areas. The report offers the possibility of a technology to test water at home.

Sens. Actuator B-Chem., **262**: 603–610

Which Leukaemia Subtype?
Microarray and AI to diagnose

The subtypes of leukaemia, the most fatal of all cancers, are acute lymphoblastic leukaemia and acute myeloid leukaemia. Though similar in morphology, these cancer subtypes respond differently to medicine. If diagnosed wrongly, the patient can die.

Last fortnight Ashok Kumar Dwivedi from the Maulana Azad National Institute of Technology, Bhopal, reported a method to discriminate between the two subtypes of leukaemia. He explored the use of artificial intelligence methodologies to discriminate between the gene expressions in the two subtypes.

He took data from the microarray based gene expression of 46 leukaemia patients. 32 had acute lymphoblastic leukaemia and 14 had acute myeloid leukaemia. The microarray data contained the expression profiles of 7129 genes of each patient.

The researcher tested six available algorithms for automatic classification – artificial neural network, support vector machine, logistic regression, naïve Bayes, classification tree, and *k*-nearest neighbour – to classify the data into leukaemia subtypes.

Ashok found that, among all six algorithms, the artificial neural network could efficiently classify the samples correctly – with only one error of classifying acute myeloid leukaemia as acute lymphoblastic leukaemia. In other algorithms, the errors ranged from 9% to 50%.

The findings indicate that the artificial neural network can efficiently discriminate between the cancer subtypes based on the differential gene expression profile generated by microarray and convert it into useful information for diagnostic purposes. The scientist says that this lays the foundation for a differential gene expression based classification of cancer subtypes to get better medical outcomes.

Neural Computing Network, **26**(12): 1545–1554

Drug-resistance in Leprosy
New drugs in pipeline

Leprosy, an infectious communicable disease caused by *Mycobacterium leprae*, primarily affects skin and nerves, though some forms destroy other organs too. The social stigma associated with the disease worsens the issue.

Leprosy was believed to have been eliminated from India in 2005. But it still exists in some areas and new cases of leprosy continue to surface. In 2015, more than 120,000 new cases were reported from India, accounting for 60% of new leprosy cases the world over. On the verge of its eradication, the world witnessed drug-resistance, notably in India. Before drug-resistance makes leprosy as life threatening as tuberculosis, new drugs have to be discovered.

Mohanty and team from the National JALMA Institute for Leprosy and Other Mycobacterial Diseases, Agra, made an effort to address the issue. They focused on ribonucleotide reductase, an enzyme involved in DNA synthesis, essential for the survival of the pathogen. The enzyme in humans has a different structure and that makes it a good target for treatment. However, the 3D structure of the enzyme is not yet elucidated and this hampered the rational discovery of drugs against the disease.

The enzyme is made up of two subunits. One of the subunits is believed to be directly important for DNA synthesis. Since the protein is absolutely necessary for the survival of the Mycobacterium, it would have conserved sequences. So the scientists used homology modelling to predict the structure of the subunit.

Once they confirmed that the structure was reliable, they looked for potential inhibitors via molecular docking – a simulation technique that predicts effective binding between molecules of interest. They took more than 1800 FDA-approved small molecules with desirable molecular properties. The team identified three molecules – lincomycin, novobiocin and telithromycin – as potential inhibitors of ribonucleotide reductase.

As the three molecules are already approved for use on humans, clinical trials using the three drugs for the treatment of leprosy need to be undertaken to validate the *in silico* studies.

Infect. Genet. Evol., **60**: 58–65

Regenerating Knee Meniscus
Silk-fibroin and egg shell scaffold

The human knee meniscus is cartilage. Though not as hard as the femur bone or the tibia and fibula, it has to bear loads. As a result, the chance of injury to the meniscus is very high. Conventional treatment strategies like compression wrap or meniscectomy cannot heal the injuries completely. Patients risk developing osteoarthritis later in life.

An alternative strategy is tissue engineering: creating a suitable supporting structure and microenvironment

for human meniscal tissue to regenerate. Naturally occurring and synthetic polymers are used to create three dimensional support structures – scaffolds on which cells can attach themselves, grow and proliferate, to repair the damaged tissue.

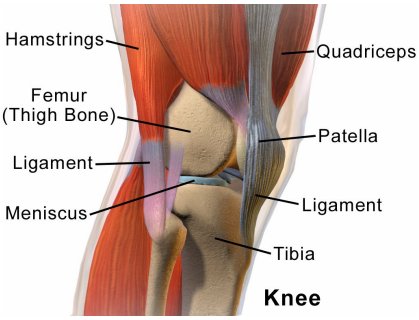

Image: Bruce Blause

Last fortnight, scientists from four institutions in Coimbatore reported developing a 3D scaffold for human meniscus regeneration by combining two polymers – silk fibroin and poly vinyl alcohol – which are often used in scaffold generation. These polymers are non-toxic, biodegradable and durable. And what is more, they could be moulded into different shapes.

Previously, the scientists had tried to prepare scaffolds by combining these two polymers in different ratios. They found that a 3 : 1 blend of silk fibroin and polyvinyl alcohol was the best suited scaffold for growing primary human meniscal cells. They added powdered egg shell membrane which mimics the function of the extracellular matrix present in the intercellular space to the mix. The blend was supplemented with a combination of biomolecules which would help the meniscus cells multiply.

To find out whether these scaffolds were suitable, the researchers collected primary human meniscal cells from patients undergoing meniscectomy and seeded them on the scaffolds. After a few days, they observed meniscal cells on the scaffold.

The scientists then checked whether these scaffolds are toxic to animals. They implanted the scaffold subcutaneously in New Zealand rabbits. 28 days later, they removed the implants surgically.

They observed that cells had multiplied, attached themselves to and infiltrated the scaffolds. Blood vessels and connective tissue had also started to develop on the scaffold. The implants had elicited an immune response in the animals, albeit mild.

So if your meniscus is damaged, here is hope.

J. Biomed. Mater. Res. A., **106**(6): 1722–1731

Formaldehyde Synthesis

Utilising the full solar spectrum

Formaldehyde serves as base material for products such as decorative laminates, wrinkle-proof fabrics and chrome printing. So tonnes of formaldehyde are synthesised worldwide every year. Large-scale synthesis of formaldehyde involves oxidation of methanol using catalytic agents – potassium permanganate and potassium dichromate. While the produce is sufficient, the process is toxic, unstable and generates unwanted by-products such as carbon monoxide, methyl formate and formic acid. An efficient and benign synthesis of formaldehyde is essential considering the scale of its production for industrial and laboratory uses.

A team from the IIT Mandi has now come up with a solution that is not just safe but energy efficient too: a photocatalyst that can turn methanol to formaldehyde under sunlight.

To be deemed proficient, a photocatalyst has to show appreciable absorption over a range of irradiation wavelengths and prevent recombination of charge carriers. The team used titania as base owing to its abundance, low cost and excellent photo-physical properties. But, titania has poor absorption at the visible and near infrared regions of the solar spectrum due to its large band gap.

To overcome this limitation, the scientists embedded gold nanoparticles on a titania matrix. Gold nanospheres offer tunable surface plasmon resonance, a collective oscillation of conduction electrons resulting in absorption of light over a range of visible wavelengths. Such an interface between metal and metal oxide prevents recombination of charge carriers. They confirmed the homogeneity of gold nanosphere dispersion on the titania matrix using transmission electron microscope and spectroscopic studies.

The researchers demonstrated the photocatalytic activity of the titania–gold nanocomposite through the conversion of methanol into formaldehyde. Under ultraviolet radiation, electrons in the valence band jump into the conduction band by absorbing the incident light energy, thereby influencing the catalytic process. This is complemented with gold nanospheres enhancing the charge carrier separation, say the scientists.

On irradiating with visible light, surface plasmon resonances of the gold nanospheres help photo-generated electrons migrate from gold to titania and interact with dissolved oxygen in the reaction mixture, resulting in formaldehyde.

With near-infrared radiation, electrons collide with the ionic lattices of gold nanospheres. Such collisions lead to heating of the matrix environment, resulting in increased photocatalytic activity. The electrons move from metal to matrix, thereby influencing the conversion process.

The scientists say that the efficiency of the titania-gold nanocomposite is enhanced by its synergistic response to sunlight, which comprises of ultraviolet, visible and infrared radiations.

What could be better than simple, non-toxic formaldehyde synthesis assisted by sunlight! Now, it is up to industrialists to capitalise on the method for safe large-scale formaldehyde production.

Surf. Interface, **11**: 98–106

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