Science Last Fortnight

K–T Mass Extinction

Volcanism or asteroid impact?

The most well-known and largest exitnction in the Earth's history, the Cretaceous–Tertiary (K–T) extinction, took place about sixty five million years ago. There are many hypotheses given for the K–T extinction: asteroid impact, volcanic eruptions, long-term environmental changes... A better understanding is needed to crack the puzzle.

Recently, IISER scientist, Jahnavi Punekar, along with American and Swiss scientists, reported the beginnings of a resolution to the conflicting hypotheses.

Intense volcanism can increase atmospheric temperature. Volcanism may also release dust, blocking sunlight. And that results in rapid cooling. It also increases atmospheric carbon dioxide, a greenhouse gas that leads to warming. The scientists unravelled the complex changes by examining planktic foraminifera from samples of sediments in the sea. The variations in the diversity of these microscopic creatures during the Late Cretaceous period provide us a clue into the environmental effects of volcanic eruptions.

The isotopic variations of planktic foraminifera from the Indian Ocean, Cauvery basin, Tethys and South Atlantic Oceans revealed four major climate and faunal events in the K–T extinction. First, about 80 million years ago, there was a cooling tendency with increased nutrient input, perhaps due to enhanced upwelling, coastal erosion and/or volcanic activity. This led to diversification of the planktons. Later, due to intense volcanic activity in the Ninety East Ridge, the climate warmed. Increased water mass stratification sustained the diversity. This stage ended with a minor extinction event, especially for the subsurface species. The cooling that happened in the next stage increased dissolved carbon dioxide and consequently, the stress on marine calcifiers, leading to reduced specialized species populations. Only those able to tolerate the ongoing environmental changes from volcanism, both at the Deccan Traps as well as in the Ninety East Ridge, survived. In the last and fourth stage, massive volcanism led to rapid climate warming, acid rain and ocean acidification. This resulted in the carbonate crisis – stressful environments for these microscopic species – and mass extinction.

The results imply that the environmental effects of volcanism are adequate to account for the mass extinction 65 million years ago.

'There is stratigraphic, geochemical, sedimentary and fossil evidence that indicates the asteroid impact at Yucatan predates the mass extinction by about 100 kyr. This is a key issue in this ongoing debate over the cause of the K/T mass extinction', say the scientists.

Palaeogeogr. Palaeoclimatol. Palaeoecol., **478**: 121–138

Altering River Ecology

Effect of roads and culverts

The Kunur River, in West Bengal, has many headwater streams, the smallest parts of the river. The stream network is extensive and the catchment is long and irregular in shape. Population density is high in this region. So, many headwater streams have been altered due to urbanization and agriculture. Transport networks, necessary to interconnect regions separated by streams, criss-cross the river. These transport networks – paved and unpaved roads made with quarried laterite – disturb the natural landscape and dendritic drainage pattern of the area.

Recently, Suvendu Roy and A. S. Sahu from the University of Kalyani, West Bengal, reported their research on the potential interactions between the unpaved roads and headwater streams in the Kunur River. They used spatial analysis with multiple buffers and found a rapid growth in road density and road-stream crossing during the last five decades.

Many unpaved roads here are close to the headwater streams. Unpaved roads have higher erosion, leading to deposition of coarse sediments in the stream water. Subsequently, the distance between streamlines and roadways decreases.

The study found that the central part of the basin and downstream area faced further problems. Road-stream crossing structures induce higher velocity of water flow. This leads to downstream scouring, formation of stable bars, and increased drop heights at culvert outlets. This affects river biota.

Transport lines closer to streamlines have greater potential to disturb the fluvial system laterally and longitudinally. This, in turn, affects the physical structure of the stream network. The team suggests consideration of this factor in transport network planning. Regular monitoring and maintenance of crossing sites help to reduce the road-stream interactions. This helps protect the natural landscape and also save expenditure on overcoming ecological damages later.

J. Environ. Manage., **197**: 316–330

Arsenic in rice

Mitigating through deficit irrigation

Irrigation is the primary source of arsenic contamination in rice. Researchers from the Bidhan Chandra Krishi Viswavidyalaya and Integrated Science Education Research Center, West Bengal have now come up with a method for reducing the arsenic load in the rice ecosystem by appropriate water management system.

The researchers conducted a water management study to assess the role of irrigation in arsenic uptake by rice plants. Arsenic load in soil and various plant parts were monitored while controlled amounts of water were supplied at regular intervals. The team considered four irrigation regimes: continuous ponding, intermittent ponding, saturation and aerobic environments.

When they analysed the arsenic content of dried soil, root, shoot, leaf and grain samples under these irrigation practices, they observed that imposing deficit irrigation during the vegetative stage significantly reduced arsenic load in rice grain and soil. The arsenic load of rice grain was 25% less in intermittent ponding than under continuous ponding. Intermittent ponding did not affect grain yield significantly.

Sarkar and team found that the arsenic content in both water and soil influenced the arsenic load of rice grain. But water has a 10% higher impact on the arsenic load of the grains.

Interestingly, deficit irrigation and polishing of rice resulted in a significant reduction in the arsenic content to lower than the toxic level – less than 0.2 mg per kg.

These results promise relief for rice farmers in arsenic affected areas and reduce the anxieties of rice eaters.

J. Environ. Manage., **197**: 89–95

Cluster Beans

Guar gum for safe water

The cluster bean – *Cyamopsis tetragonolobus* – is a common Indian vegetable. Rich in proteins, minerals and vitamins, it is good for cardiac and bone health. It also maintains blood pressure and blood sugar levels in the body.

Photo credit: Neeta Shrivastava

Though cluster beans are not a great favourite in the Indian cuisine, guar gum – a polysaccharide from the seeds of the cluster bean – has a global market value of more than USD 700 million. It finds use in the food, cosmetic, pharmaceutical, paper manufacturing, mining and explosives and oil & gas industries due to its gelling, thickening, binding and flocculation properties. And now, scientists have found a new use: water purification.

Thombare and team from the Indian Institute of Natural Resins and Gums and the Birla Institute of Technology, Ranchi, used the flocculation and binding properties of guar gum to remove suspended solids from water.

Conventionally, alum, polyaluminium chloride and other inorganic coagulants are used to remove suspended impurities from water. However, these inorganic coagulants and aluminium pose health hazards. The team cross-linked guar gum hydrogel – a polymer – with borax and found that it is useful to remove suspended impurities from water.

In addition to settling suspended impurities by flocculation and gelling, the borax cross-linked guar gum polymer removes dye and pigment residue from water by adsorption. When this polymer is used with alum salt, it adsorbs aluminium and potassium and reduces the toxicity of these inorganic chemicals. The team analysed the structure of the product and its properties using various analytical methods and optimized the guar gum-borax cross-linking process for the best results.

The synthesis of borax cross-linked guar gum is a one-step method. The polymer is convenient, economic and safe for large scale water purification, especially in areas where cheaper water purification technology is needed. Social entrepreneurs may now use these research results to develop commercially viable products for water purification.

Carbohydr. Polym., **168**: 274–281

Axing Antimony

A beady solution

Antimony is used in everyday items like plastics, paper, paints and textiles. And it finds its way to ground and surface water sources. Antimony is a persistent, bioaccumulative and toxic chemical, with many adverse effects on human health. However, it is seldom in the limelight.

Researchers have suggested the use of chitosan and chitosan-inorganic oxide composites to remove antimony from water. However, not only do these disintegrate under acidic conditions, their effectiveness as antimony removal agents is not very high.

A team of researchers from the Bhabha Atomic Research Centre Facilities, and the Homi Bhabha National Institute have now developed chitosan beads cross-linked with nano-titania and produced a stable material with increased capacity to absorb and remove antimony from water.

The researchers chemically synthesized beads of nano-titania impregnated with chitosan and cross-linked them using epichlorohydrin. The team tested the cross-linked nano-titania–chitosan beads for efficiency in the removal of antimony from water. Since both titania and epichlorohydrin participate in the removal of antimony from water, the beads become very efficient by providing greater surface area. They find that the sorption and swelling properties of the beads can be easily controlled by varying the amount of epichlorohydrin used in the preparation of the polymer.

The procedure for the production of the beads is simple and the product is stable over varying physical and chemical conditions. According to the team, these beads show potential for large scale applications.

J. Haz. Mat., **334**: 160–167

New Use for Mesquite

Invasive species to purify water

Phenols from industrial effluents are environmental pollutants. They are cytotoxic, mutagenic, genotoxic and carcinogenic and thus pose public health hazards. Conventional physicochemical methods of waste water treatment are expensive and generate hazardous by-products. Phytoremediation is a low cost method for environmental clean-up, but takes a long time for producing any significant improvement.

So, recently scientists started borrowing the technique that plants use, in a bid to speed up the process. Horseradish peroxidase, for example, is an enzyme that can overcome the problem. But the process requires high purity for detoxification and that is costly.

Last fortnight, Vandana Mishra and her team from the University of Delhi, came up with an innovative low-cost method for detoxifying phenols and chlorophenols. The researchers extracted crude peroxidase from the mucilaginous leaves of mesquite (*Prosopis juliflora*) and compared it with horseradish peroxidase for phenol detoxification. They found that even low purity peroxidase from mesquite leaves is effective in removing phenols. The phenolic detoxification activity of mesquite peroxidase is greater than that of horseradish peroxidase. Moreover, the enzyme is active under a

wide range of pH and temperature and shows high residual activity.

Root elongation experiment on the seeds of *Vigna mungo* and *Allium cepa* revealed a high root length on mesquite treated post-reaction mixture. This growth bioassay shows that stress-related responses are significantly reduced with mesquite peroxidase treatment.

Photo credit: Thamizhpparithi Maari

Thus, mesquite peroxidase is far more efficient and effective than horseradish peroxidase. Hence, a tree that is considered an invasive, can become a sustainable resource for the management of phenols in the environment.

J. Haz. Mat., **334**: 201–211

Removing Melamine from Milk

Molecular imprinting technique

Melamine is used to produce plastics, kitchen ware and adhesives. Like proteins, it is rich in nitrogen and is, therefore, used to adulterate milk and milk products including infant foods. This is alarming as ingesting melamine-contaminated food can induce health issues such as kidney stones, kidney failure and bladder cancer.

Last fortnight, scientists from the University of Kerala proposed a method for monitoring melamine contamination in milk. They synthesized a magnetic molecularly imprinted polymer for melamine by surface imprinting on magnetic nanoparticles. Using X-ray diffraction and Fourier Transform Infrared spectroscopy they analysed the characteristic spectrum of the polymer. The polymer showed good recognition for melamine and was used in the solid phase extraction and determination of melamine from adulterated milk samples.

The research group claims that the binding process is very fast and can be used to free food samples from melamine contamination. Moreover, the magnetic molecularly imprinted polymer is fabricated easily at low cost and is reusable. The researchers say that, due to these unique features, the prepared polymer has potential for applications in solid phase extraction of melamine from complex matrices.

Food Chem., **227**: 85–92

Dopamine Sensor Electrode

Useful in lithium ion batteries

The everyday complaint, 'the thrill is gone from my life', from Mr Chaturvedi, rings a bell for Dr Bhaskara. He suspects that dopamine deficiency is the problem.

Dopamine deficiency causes various disorders related to the nervous system such as depression, Parkinson's disease, etc. Recently, scientists at the National Institute of Technology, Karnataka, in collaboration with researchers in Malaysia, developed a sensor that can detect levels of dopamine to help diagnose such problems.

The team fabricated a nanocomposite of vanadium pentoxide embedded on graphene oxide. They first synthesized vanadium pentoxide nanoparticles using a melt quenching technique. Then, applying a simple hydrothermal approach, they created vanadium pentoxide/graphene oxide nanocomposites. High-resolution transmission electron microscopy exhibited a layered structure of graphene sheets embedded with spherical amorphous nanoparticles of vanadium pentoxide.

This nanocomposite was then drop-casted over the polished glass carbon electrode surface. This modified electrode shows excellent dopamine sensing performance and can detect dopamine molecules even at concentrations as low as 0.07 μM. The layered structure of the composite allows rapid transfer of electrons between the biomolecules and electrode substrate. Chronoamperometry confirmed high selectivity and sensitivity for dopamine even in the presence of high concentrations of interfering molecules such as uric acid.

The team further tweaked this nanocomposite material to develop an improved cathode for lithium-ion batteries. They bound the nanocomposite and carbon black with polyvinylidene fluoride. Using X-ray diffraction studies and Raman analysis, they found that the graphene oxide is partially reduced to graphene in the nanocomposite. This led to improved electrical conductivity of the cathode. The layered structure provides a larger surface to volume ratio, shortening electron travelling distance and resistance. This prevents structural degradation of the electrode. The nano-sized pores of the composite enable better diffusion of electrolytes and lithium ions.

This study lays the foundation for the production of dopamine detectors in clinical settings. It also offers scope for developing cost effective, high energy density batteries for portable electric equipment.

Appl. Surf. Sci., **410**: 336–343

Composites from Rice Husk

Superhydrophobic silica particles

Superhydrophobic surfaces are extremely hard to wet. When droplets hit a superhydrophobic coating, they just bounce back. Superhydrophobic coating is self-cleaning, anti-adhesion and anti-biofouling.

Superhydrophobic coatings can be prepared using organic and inorganic compounds as pigments. This process uses the sol–gel and the functionalization method. Researchers from the CSIR-Central Electrochemical Research Institute, Karaikudi, now report water droplet bouncing behaviour and other characteristics in silica particles synthesized from rice husk. These particles have large surface area, thermal stability and high density – properties that are desirable for a superhydrophobic coating.

Silica particles from rice husk can act as support and adsorbent. Researchers also observed that the bouncing behaviour of water droplets over the porous substrate was unusual: the frequency of rebound was less.

The scientists say that the silica particles have several industrial uses. They can be incorporated into aerogels and polyurethane sponges to separate oil/water, in filter paper, and in membranes for fuel cells.

J. Alloys Compounds, **711**: 197–2016

Eco-friendly Corrosion Inhibitor

Aluminium alloys play a vital role in packing materials because they are light-weight, high-strength and non-corrosive. Though aluminium alloys are used in a number of domestic and industrial applications, they are not suitable for high temperature applications because their tensile and fatigue strengths decrease with increase in temperature.

Last fortnight, researchers from the Manipal Institute of Technology, Manipal, reported overcoming this problem. They prepared an aluminium metal matrix composite by reinforcing the aluminium alloy with nano-sized silicon carbide particles. The resulting aluminium composite showed superior wear resistance, surface hardness and low thermal expansion compared to conventional aluminium alloys. This finding can widen the range of use of aluminium alloys to applications in electronic packaging, aeronautics, aviation and automobile industries.

The corrosion resistance is due to the natural formation of an oxide layer on aluminium. Unfortunately, due to the reinforcement, the oxide layer on the aluminium alloy is destroyed. Hence, it is essential to use a corrosion inhibitor. In general, organic heterocyclic compounds are utilized as corrosion inhibitors. However, the compounds are not only costly but also non-biodegradable and toxic. Recent reports say that inulin – a carbohydrate extracted from the chicory plant – has the potential to reduce corrosion. Hence, the scientists used inulin as a corrosion inhibitor. Being of plant origin, it is cost-effective, eco-friendly and non-toxic.

The team performed various tests on the sample and found that the corrosion inhibition action of inulin is due to the presence of electron-rich oxygen atoms and the larger molecular size of the structure. So, a better aluminium alloy is ready to meet the needs of industrial applications.

Carbohydr. Polym., **168**: 337–345

Corrosion Free Steel

The use of oil and gas is increasing and the Oil and Gas industries are happy. But they are unhappy because of a frequent problem: breakdown of pipelines due to carbon dioxide corrosion. At present, industries use pipelines made of alloy steels which are prone to corrosion.

To minimize the corrosion of steel caused by carbon dioxide, the use of corrosion inhibitors is considered the most effective method. So researchers are scrambling to find profitable alternatives to inhibit corrosion.

Last fortnight, researchers from the Indian Institute of Technology, Banaras, in collaboration with Chinese and American scientists, reported three different imidazole derivatives as inhibitors to reduce carbon dioxide corrosion. The team reported the synthesis of the imidazole derivatives in laboratory conditions. They applied them on J55 steel and examined their impedance property, corrosion resistance and formation of corrosion products. The results showed that 40 mg/l of one of the imidazole inhibitors on J55 steel has 93% inhibitory efficiency.

Thus, the imidazole derived inhibitor is a cost effective method to reduce carbon dioxide corrosion. The material can be used in the oil and gas industries to fight carbon dioxide corrosion.

J. Alloys Compounds, **712**: 121–133

Sharper Surveillance

Better security

You are being watched! The world is increasingly relying on video surveillance. Technology to track objects in motion or individuals in a crowd is important to army, police and other security personnel. The existing technology of single stage tracking lacks precision.

Anjana Gupta from the Delhi Technological University in collaboration with a team of scientists from the DRDO and Bharat Electronics Limited recently published a paper that addresses this challenge. They propose a multistage, coarse-to-fine tracking algorithm, which they claim is more efficient than the present state-of-the-art technology.

First, a coarse estimation of object state is done using optical flow. Multiple fragments of the video are generated around this approximation. These fragments are then analysed using three complementary cues to locate the object precisely.

The scientists evaluated the system using various video sequences and found that the mean tracking error is less than 7 pixels. The algorithm has the ability to quickly adapt to environment dynamics because it is coarse grained initially. It has also proved robust and effective for object tracking. Moreover, the tracker also provides solutions for partial or full occlusion, illumination change, background clutter, target rotation, scaling and deformation.

The results of this research show promise for effective surveillance. This solution has the potential for customization and confidentiality. This is not just an improvement but a leap in terms of surveillance and security.

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