

Science Last Fortnight

Raniganj Coalfield

Prospect of hydrocarbon generation

Raniganj Basin, in West Bengal, is the oldest coalfield in India. It produces tonnes of high quality coal every year to meet the nation's energy demands. In the last two decades, some coal fields have gained recognition as sources of liquid and gaseous hydrocarbons. Are Raniganj's coal seams potential sources for oil and gas production, wondered researchers from Dhanbad.

Recently, Deepak Singh Panwar and others from ISM, IIT collaborated with A. K. Singh from CIMFR to assess the hydrocarbon generating potential of Raniganj coal.

For geochemical analysis, the team collected 15 coal samples from the Kalidaspur block of the Raniganj coalfield. The samples had vitrinite, woody terrestrial materials transformed into coal by temperature and pressure. The samples were dominated by organic and reactive plant materials, suggesting the potential for producing liquid hydrocarbon.

The researchers crushed and screened the coal samples and analysed them using Rock Eval Pyrolysis, a technique, where the samples are decomposed at a high temperature in the absence of oxygen to measure the amount of hydrocarbon released. The hydrocarbon yield of the coal samples varied from 167 to 195 weight per cent, indicating that the samples had a fair amount of oil and gas.

The team then proceeded to measure thermal maturity.

'The maximum hydrocarbon was released during pyrolysis between 431°C and 446°C. This indicates mature coal, carrying liquid and dry gas', says Deepak Singh Panwar.

The researchers also checked the reflectance property of the vitrinite. Vitrinite reflectance is sensitive to temperature. This is related to the hydrocarbon generation capacity of the source rock.

'The vitrinite reflectance of the samples varied from 0.5% to 0.7%.

This suggests the high volatile bituminous character of the samples', says A. K. Singh, CSIR-CIMFR.

These results indicate that the Raniganj coal seams are suitable for oil and gas production.

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Assessing Seismic Vulnerability *Strengthening damaged buildings*

On 4 January 2016, an earthquake of magnitude 6.7 hit Manipur, damaging many multi-storey buildings in Imphal. How do we cost-effectively strengthen such buildings?

Trishna Choudhury from the Thapar Institute of Engineering and Technology, Punjab collaborated with researchers from IIT Guwahati to tackle the issue. They took the New Market building, Imphal, as case study. The three-storey building was bubbling with commercial activity before the earthquake. But now it is severely damaged and unsafe.

The team examined the material used in the construction and found that its cohesiveness in columns was too low to withstand tremors. The concrete had voids and cracks.

The researchers suggest strengthening the damaged columns with good quality concrete jacketing. This is economical and can be implemented quickly to make the market usable again.

Assuming the strengths of the recommended materials, the team then modelled the building numerically. They factored in ground motion and storey displacement as an engineering demand parameter.

The researchers then conducted nonlinear static and dynamic analyses of the original and strengthened buildings. The building's capacity increased more than two times after strengthening.

'The concrete jacketing reduced peak moment ratio in all columns by more than 50%', says Trishna Choudhury, Thapar Institute of Engineering and Technology, Punjab.

'The repaired structure will be more resistant to earthquakes than the

original', says Hemant B. Kaushik, IIT Guwahati.

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Reducing Fertiliser Leaching *Modified rice straw biochar*

Fertilisers are often washed away or leached by irrigation and rainwater. So a part of applied nutrients is unavailable to crops. And agricultural productivity remains low, in spite of increased inputs.

Jayanta Bhattacharya and students from IIT Kharagpur now suggest an ecofriendly solution. To restrain the leaching and runoff of fertilisers, biochar has been mooted as a solution. India, the second largest producer of rice, has huge availability of waste rice straw which could be converted to biochar. But biochar from rice straw has a high amount of negatively charged ions that reduce the adsorption of the negatively charged ions of fertilisers.

The team thought of complexing rice straw biochar with positively charged cationic groups. They produced biochar by pyrolysing rice straw. Then they treated the biochar with ferric chloride and potassium hydroxide. This was not adequate to retain iron and potassium in the biochar.

So they subjected the chemically treated biochar to steam pressure and, using X-ray diffraction, they found that potassium and iron ions are indeed complexed in the pores of the biochar.

The researchers then compared the pyrolysed biochar and complexed biochar for sorption efficiencies and timely nutrient release.

They poured fine sand into five acrylic tubes. In two, they put rice straw biochar. In two others, they put the biochar complexed with iron and potassium. A tube without biochar served as control. Then they added a layer of soil on top. They wetted the soil to 80% water holding capacity and pumped the nutrient mixture into each tube.

After 24 hours, they collected leachate from the other end and determined the concentration of nutrients. The adsorption capacity of the

complexed biochar for nitrate, phosphate and ammonium ions was significantly higher than that of pyrolysed biochar.

For batch sorption experiments, the team took pyrolysed and complexed biochar in polystyrene bottles and poured single as well as mixed nutrients into the different bottles. After shaking the samples for 24 hours, they collected the remaining solution and analyzed nutrient concentration.

Compared to pyrolysed biochar, complexed biochar showed significantly higher sorption capacity in single nutrient phase for all three nutrients. In mixed phase, sorption capacity for nitrate was reduced to nearly half in both types of biochar. The sorption of phosphate and ammonium ions was the same as in single nutrient phase.

The amount of fixed carbon, volatile content, calcium and potassium was higher in the complexed biochar. 'But sodium and magnesium content was higher in untreated biochar', says Subhash Chandra, IIT Khargpur.

The chemical treatment and complexing positively charged iron and potassium with rice straw biochar using high pressure steam are easy to adopt by farm-based agro industries. So farmers who are blamed for burning rice straw and causing pollution can now use the waste to improve nutrient availability to their crops.

Moreover, it can also reduce urea as most of the urea gets leached out of the soil, eventually.

'We have already started field trials', says Isha Medha, Zelence Industries Pvt. Ltd, Kharagpur.

'And the electrostatic properties of the complexed biochar can be used to develop filters for wastewater treatment', says Jayanta Bhattacharya, IIT Kharagpur.

Farmers adopting the technique can have multiple markets for their products.

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Indian White Shrimp Optimising Protein Feed

The Pacific white shrimp is the most popular species for aquaculture in India. But focussing on a single shrimp species is dangerous for the

industry – epidemics can wipe out entire populations causing enormous losses. So, as an alternative, researchers are exploring farming the Indian white prawn, *Penaeus indicus*, which is adapted to brackish waters. And one of the first steps is to standardise feed.



Image: Gayandream via Wikimedia Commons

Christina Lalramchani, Central Institute of Brackishwater Aquaculture, Kakdwip recently took up the challenge of finding the optimum amount of protein for the Indian white prawn for the best yield. For their experiments, Christina and her colleague, Sanoy Das, selected ponds at the Kakdwip Research Centre of ICAR-CIBA.

Each pond was about 600 square metres in area and about one and a half metres deep. To reduce chances of infection and infestation, the team sundried the ponds for 30 days. The ponds were then filled with filtered brackish water and disinfected with bleaching powder. After seven days, lime was added to the ponds to improve phytoplankton growth and the water was fertilized. The ponds were then stocked with post larvae and fed with varied levels of protein: 30%, 35% and 40%.

The researchers found that the growth of the shrimp was slightly higher when fed 30–35% protein feed. Though the food conversion ratio was higher in shrimp fed with 40% protein, the harvest had lower biomass.

'Increased protein feed only leads to more expenses', says T. K. Ghosal, ICAR-Central Institute of Brackishwater Aquaculture.

Water, in ponds that received 40% protein feed, had higher organic carbon content and soil pH decreased.

Different types of bacteria were also higher in ponds where shrimps were fed 40% protein.

'Increasing protein beyond 35% increases chances of infection and implies greater losses', says K. Ambasankar, ICAR-Central Institute of Brackishwater Aquaculture.

'We plan to conduct studies on the nitrogen–phosphorous budget in the aquaculture of the Indian white shrimp', says C. P. Balasubramanian, his colleague.

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Malaria Menace Measuring measures

The malarial drug, chloroquine, has been hitting news headlines recently as a solution to the coronavirus epidemic. This gives us reason to look at the age-old epidemic, malaria.

Dewesh Kumar and Dilip Kumar from the Rajendra Institute of Medical Sciences, Ranchi, teamed up with institutes across Iran, Turkey and the United States, to collate data and analyse the status of malaria in India. They investigated the influence of various factors including seasonality and control efforts implemented by the Indian national malaria control programme on the epidemics between January 2009 and December 2015.

Generally, after each epidemic, preventive measures, such as larvicidal techniques, mosquito net distribution, fogging and awareness creation, are followed. Recurrence is prevented by fever surveys, and diagnostic techniques like microscopy blood smear which help in early detection and treatment.

The researchers analysed the relationship between the control measures taken and the increase in the tolerance zone in terms of distance range. They also examined possible correlations between the control methods implemented and the recurrence of periodic epidemic outbreaks for 90 days in the same district.

They found no single prevention method clearly superior to the rest. The fever survey and anti-larval activity were effective in reducing the chances of epidemics recurring in the same area.

In general, malaria epidemics occurred in greater frequency in the eastern and central parts of India. However, epidemic outbreaks caused by *Plasmodium vivax* were greater in North India during the study period. Summer and fall had greater chances of triggering epidemics than winter.

The researchers note that antimalarial treatment did not decrease the odds of epidemics. They attribute this to the development of drug resistance among malarial parasites.

'We lack data on the development of insecticide resistance among vector populations. So we could not evaluate effects for malaria control', says Dilip Kumar, Rajendra Institute of Medical Sciences, Ranchi.

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Eating Bamboo Shoots Responsible for goitre?

Bamboo shoots are part of Manipuri cuisine. They are tasty and rich in nutrients. But, recently, it has been noticed that where bamboo is consumed, there is higher endemicity of goitre – even in areas that are not iodine deficient.

Laishram Hemchandra Singh, D M College of Science, Manipur, has been concerned about this from the time he worked with Amar K. Chandra at the University of Calcutta. Now he collaborated with his old team, including Indrajit Ray from the Ramkrishna Mahavidyalaya, Tripura to take one more step in their research. The team analysed water extracts of *Bambusa balcooa* shoots from Manipur. They quantified the antithyroidal constituents of the extract – cyanogenic glycosides, glucosinolates and thiocyanates – as 650 milligrams per litre.

To understand the dose response of the extract, they chose thyrocytes from Wistar rats. Thyrocytes secrete the hormones, thyroxine and triiodothyronine.

The researchers evaluated the extract's effects on the enzymes, thyroid peroxidase, that plays an important role in thyroid hormone production, and deiodinase, which facilitates activation or inactivation of the thyroid hormone in thyrocytes. They also examined an enzyme that maintains

ion gradient across cell membranes and is regulated by thyroid hormones.

The extract suppressed the activities of these enzymes in a dose and time dependent manner. At 24 nanograms per microlitre, the antithyroid substances became toxic to thyrocytes.

The extract also reduced a regulatory protein in the thyroid gland and a protein that affects iodine uptake.

The team analysed reactive oxygen species.

'The bamboo shoot extract not only disrupts the activity of thyroid hormone synthesizing factors at both cellular and molecular level, but also disturbs the balance of the oxidative status of thyrocytes', says Laishram Hemchandra Singh, D M College of Science, Manipur.

However, when supplemented with iodine, these effects seem to reduce.

'So those who are fond of bamboo shoot should perhaps increase iodine intake to overcome the threat of goitre', says Amar K. Chandra, University of Calcutta.

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Converting Brick Kiln Coal Ash To eco-friendly fertilisers

The construction sector in India is supported by many brick kilns that traditionally use coal as fuel. The kilns generate high amounts of coal ash waste. Though the ash contains high amounts of carbon and essential plant nutrients, such as nitrogen, phosphorus, potassium and sulphur, it cannot be used as fertiliser since it also contains toxic metals such as lead, cadmium and chromium. A sustainable use of brick kiln coal ash has not been explored yet.

Satya Sundar Bhattacharya, from the Tezpur University and Pradip Bhattacharya from the Indian Statistical Institute have been collaborating to tackle the problem. They had two challenges: decreasing toxic materials in coal ash and enhancing nutrients present, to convert the ash to useful manure.

Earthworms are good bioaccumulators of heavy metals that remain inside their intestine in non-toxic form. So why not try vermicomposting? They set the problem to their Ph D

scholar, Ananya Mondal, and involved other colleagues.

Ananya and team collected coal ash samples from brick kilns in Assam and West Bengal. They mixed the ash with cow dung in ratios of 1 : 1 and 2 : 1. Five hundred kilograms each of the mixture was used for vermicomposting and simple composting. The team used *Eisenia fetida*, adding 10 earthworms per kilogram of feedstock. And analysed the biological and physicochemical properties of the feedstock for 60 days. The accumulation of toxic metals by earthworms reduced the pollution load index in brick kiln coal ash and enriched it with more minerals.

The team tested the compost in agricultural fields for rice cultivation and found that soil quality improved and crop yield also increased.

'Vermicompost using brick kiln ash can replace chemical fertilisers by about 15 to 30 per cent', says Satya Sundar, Tezpur University.



Image: McKay Savage via Wikimedia

Brick kilns have been criticised for contributing to the denuding of agricultural soils. With this method, brick kilns can pay back to agriculture what they took away.

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Thermoacoustic Instability Multifractal flame dynamics

Combustion in jet engines and rockets often leads to instability. The complex interactions between the heat-release dynamics of flame and acoustic pressure of combustion chambers lead to unstable oscillations in heat release rate. This results in acoustic fluctuations – self-sustained, large amplitude periodic pressure and heat release rate

oscillations. Such thermoacoustic instabilities can damage and reduce the life-span of mechanical parts and operating systems.

R. I. Sujith's lab at the Department of Aerospace Engineering, IIT Madras has been seeking methods to predict and control this phenomenon. His team, including his earlier students, now researchers in Germany and USA, report that flames in combustion chambers take multifractal forms during such instabilities.

They developed a technique to visualise flame behaviour inside a combustion chamber. They seeded the incoming air of the combustion chamber with some titanium dioxide particles. Titanium dioxide is non-reactive during combustion but the particles scatter light while they pass the plane illuminated by the high-power laser sheet. This can be captured as a Mie scattering image, using digital image sensors.

To detect the flame front, the team used an edge detection algorithm which detects sharp gradients in the pixel intensity of the Mie scattering images to identify and outline the flame front. They used a turbulent combustor representative of a gas turbine combustor for their experimental setup. Here, the flame is stabilised through a buff-body, a circular disk located at a fixed position from the backward facing step of the combustor. The fuel is injected upstream of the buff body. The circular burner suddenly expands into a combustion chamber with a square geometry cross section.

The combustor is illuminated through a quartz window at the top using a laser light sheet and a high speed camera is positioned to capture the scattered laser. The unsteady pressure signals are picked up by piezoelectric sensors.

A photo multiplier mounted with a CH* filter is used to estimate the heat release rate from chemiluminescence during combustion.

Both the pressure signal and the chemiluminescence data are acquired at the same rate as the Mie scat-

tering images captured by the camera in a synchronised manner.

The researchers started analysing the images and found that temporal statistics converged over 100 images.

The researchers noted that, during thermoacoustic instability, large-scale coherent structures emerge. These large-scale structures contain small-scale vortices that roll up and wrinkle flame surfaces. This introduces additional complexity in flame dynamics. During the state of intermittency, the researchers found two distinct spatio-temporal dynamics of the flame – aperiodic wrinkling and periodic rolling.

'The aperiodic wrinkling is due to turbulent fluctuations inherent in the flow. The periodic roll-up, on the other hand, results from the emergence of large-scale coherent structures', says Manikandan Raghunathan, IIT Madras.

The researchers found that flame dynamics have a multifractal nature. To confirm this, they applied the box-counting method on the flame front to compute the multifractal spectrum of the flame.

With these insights into the relationship between flame geometry and thermoacoustic instabilities, aerospace engineers can now formulate strategies to predict and control instabilities in combustor systems.

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Pedestrians Violating Signals Crashes in Kolkata

Kolkata has a population of 4.5 million. Road accidents involving pedestrians at intersections are high here. Besides the ever increasing vehicular density, pedestrian behaviour also influences the number of accidents. What attributes of pedestrians contribute to the phenomenon?

Dipanjan Mukherjee and Sudeshna Mitra from IIT Kharagpur collected crash data for 2011–2016 from the Kolkata city police. They identified nine crucial corridors in the city, based on reports from earlier research. They selected 55 signalised intersections with varied road geometrics, traffic volume,

vehicle speeds, and a range of pedestrian–vehicular interactions. Fifteen did not have zebra crossings.

The team then conducted a road inventory survey, and vehicle speed surveys using speed guns. They also set up video cameras to record pedestrian behaviour. They administered a questionnaire to more than 3000 respondents.

Then the researchers made models and selected the best one using statistical testing. The model showed that overall traffic volume, approaching speed of motorized vehicles and pedestrian–vehicular ratios have significant influence on fatal crashes. Zebra crossings significantly reduced crashes involving pedestrians. Parked vehicles near crossings and other factors that reduced sight distance increased the chances of crashes.

Areas that had many offices or were residential had less chance of accidents at signalised intersections than commercial areas and slums.

Longer duration green lights to ease traffic flow, especially at peak hours, tended to make pedestrians impatient enough to take risks. Students rushing to classes, people bearing loads, or rushing to catch buses, etc. were more prone to disregard signals. Males took more risks.

According to the researchers, pedestrian signal violation in Kolkata is highly site-specific and associated with pedestrian behaviour. However, road design and signal settings need improvement for the convenience of pedestrians, the scientists say.

The insights can help formulate management measures to avoid casualties among pedestrians in Kolkata.

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