Science Last Fortnight

Exploring Gold

Prospecting using modelling

The African continent is known for its mineral resources which constitute around 30% of the Earth's remaining mineral resources. The 21st century witnessed large scale exploration for these resources in this region. Some of the world's largest gold deposits are localized around the Birimian Supergroup of West Africa. However, exploration activities around the Kumsai Basin are limited: Lack of geological understanding of the area and late discovery of these deposits in the 1990s had deterred detailed exploration for gold in this area.

Recent exploration activities in this area have provided geological understanding and identification of prospective areas. And what is even more important, it has provided insights about the factors controlling gold mineralization. This, in turn, has helped develop a conceptual model for determining the prospectivity of gold resources.

A team led by researchers from IIT Bombay, in collaboration with an Australian research group, carried out a detailed study on the prospectivity of orogenic gold mineral systems in the Kumsai Basin. They developed a knowledge-driven model based on a Fuzzy Inference System to identify the process of mineralization. Fuzzy Inference System based models were generated by identifying the key components of the mineral systems and integrating these individual outputs to generate a continuous scale prospective map. This map reclassified high, moderate and low prospectivity areas.

The model was tested on known and unknown gold prospective areas to evaluate the capture efficiency of the model. The high and moderate prospectivity areas show strong spatial correlation with elongated features indicating a strong structural control on gold mineralization in the study area.

This knowledge-driven model reflects the main mineralized trend effectively. This demonstrates that reliable input data on processes and components leading to the mineral deposits can be used to predict the prospectivity of known deposits without considering the spatial distribution of known gold deposits.

Ore Geology Reviews, **78**, 692–711

Plutonium Trapped

Using the vetiver plant

Radioactive isotopes vary in their half-lives. Some survive for mere seconds, while some others have half lives of hundreds or millions of years. Plutonium-239 is one such isotope having a half life of 24,100 years. It is a hazardous radionuclide having carcinogenic and toxic properties. It poses a serious environmental challenge and threat to biological systems.

Besides naturally occurring radioactive isotopes in the soil, air and water, nuclear weapon testing, discharge from nuclear installations, occasional nuclear accidents like Chernobyl and Fukushima, also add to the woes. Disposal of nuclear waste is a challenge even with given technologies.

Last fortnight, Shraddha Singh and others from the Bhabha Atomic Research Centre, Mumbai, reported a phytoremediation method for Pu-239 radionuclide using *Vetiveria zizanoides*, commonly known as the vetiver plant or *khus khus*. Vetiver is a subtropical grass having large biomass and a dense root system which makes it favourable for phytoremediation. According to them, this is the first demonstration of the uptake potential of vetiver plants for the remediation of Pu-239 in hydroponic and in various soil conditions.

In 2000, a group of American scientists demonstrated the ability of Indian mustard (*Brassica juncea*) and the sunflower plant (*Helianthus annuus*) to remove Pu-239 from hydroponic conditions. Another study in 2014 by Sunita Sharma and team recorded the remediation capacity of vetiver plants in radionuclides like Cs-137 and Sr-90 and heavy metals namely As, Cd, Cr, Cu, Hg, Ni, Pb, Se and Zn. But plutonium uptake by vetiver has not been recorded earlier.

Now Shraddha and team report that the uptake potential of the plant is higher in hydroponics (66.2% in 30 days), but limited in soil. Addition of chelating agents like citric acid and diethylene triamine pentaacetic Acid (DTPA) into the growing medium increases the uptake in soil too.

As a chelating agent, DTPA was found more effective than citric acid. The Pu-239 – chelating agent complex raised the translocation index by 8 times and 6 times in water and soil respectively.

The findings provide a remedial mechanism for a highly toxic contaminant found in our surroundings, with little cost, and high efficiency. Plants possess a natural ability to eliminate, detoxify or immobilize environmental contaminants by means of various biological processes. In addition, plants help improve soil quality and soil carbon sequestration. For cleaning a large stretch of contaminated area, it is a suitable method.

Ecotoxicol. Environ. Safety, **132**, 140–144

Bowled by Nano-Gold

Endotoxin detection

Consumption of food contaminated with bacteria often leads to food poisoning. This is due to the presence of an endotoxin released by bacterial cells. A heightened reaction to endotoxins can lead to life threatening systemic septic shock in some cases.

There are, of course, methods for regular monitoring of food samples. However, most methods used for endotoxin detection are either expensive or lack precision. In the last fortnight, Mukherjee and his team from the Vellore Institute of Technology, Vellore, collaborated with the Indian Institute of Science, Bengaluru, to improvize an endotoxin detection method using gold nanoparticles.

Previously, antibodies and aptamers have been coupled with gold nanoparticles for the colorimetric detection of endotoxin. In this study, the scientists attached different sizes of gold nanoparticles with cetyltrimethylammonium

bromide (CTAB). The premise is simple: endotoxin contains a negatively charged region that will interact with positive charge supplied, in this case, by CTAB. Interaction between the moieties would increase the size of the nanoparticle sphere, often causing aggregation, leading to changes in its photometric properties.

To refine this approach, the researchers synthesized CTAB coupled gold nanoparticles of three different sizes: 15, 30 and 40 nm and tested them for endotoxin detection. The size of functionalized gold nanospheres increased, by almost 6 fold, in the presence of endotoxin. This altered the intrinsic fluorescence of the nanoparticles which could then be detected through fluorometry. Sensitivity of the detection was highest for nanoparticles of the order of 15 nm with lower limit of detection around 0.5 nM.

Fats and proteins interfere with the detection. The CTAB capped gold nanoparticles could assess the presence of endotoxin with great precision once these were removed. Researchers believe that given the ease of detection, CTAB capped gold nanoparticles can be employed for routine monitoring of endotoxin in the food industry.

J. Luminescence, **178**, 106–114

Are these Grapes Safe?

The picture tells it all...

Grapes have been in existence for thousands of years. Referred to as the Fruit of the Gods, they are popular and cultivated both for the fruit and for making wine. The crop is highly susceptible to fungal attacks. Uncontrolled application of fungicides has resulted in the presence of pesticide residues. When grapes are consumed without pre-treatments, they become the fruits of the gods of death and disease.

Malay Kishore Dutta and team, distributed in institutions in the National Capital Region and Maharashtra, developed a simple method to identify pesticide contamination at field level. Imaging methods using different wavelet domains distinguish the treated and untreated lots. Images of the pesticide treated and untreated samples are converted to gray scale images. The region of interest is marked and differences in wavelet domains identified. The discriminatory wavelets identified are subjected to statistical features.

The Support Vector Machine classifier tool, distinguished untreated grapes and pesticide-treated grapes. The tool revealed that diagonal coefficients discriminated between samples. A lab analysis of the pesticide residues in the selected samples confirmed the results.

Image processing as a non-destructive analytical tool can go a long way in assessing food quality. It finds application in the food industry, especially perishable commodities, where regular checks are mandatory. The process is cost effective and efficient and can develop as a real time application.

LWT-Food Science and Technology, **72**, 368–376

Holy Cow Provides Elixir

Milk as chemotherapeutic!

The goodness of milk has been elaborated in Indian scriptures, as a 'youth elixir'. Now, researchers have discovered a method of using cow milk along with a herbal drug which is capable of curing and curbing cancer.

A group of scientists from the D. Y. Patil University, N. S. N. Research Centre, and Walchand College of Arts and Science, Maharashtra, synthesized a therapeutic graphene quantum dot (GQD) using milk. A quantum dot is a tiny 2–4 nm sized semiconducting particle which is capable of emitting light.

The researchers pasteurized milk by heating it in a microwave oven and processed it for 5 hours to generate GQDs. Formation of GQDs was monitored by a fluorescent emission at 375 nm. GQDs were then loaded with berberine, an anticancer drug. To observe the size, shape and loading of the drug on GQDs various spectroscopic techniques were used.

Cancerous cells create an acidic environment due to a faster metabolic rate. The berberine-GQD complex releases the drug only in the vicinity of acidic cancerous cells. An acidic pH of 5.8 ensured the drug was released over a period of 72 hours. The scientists could monitor the localization of the drug in cells using fluorescence microscopy, highlighting the property of QD complex as 'nanoprobes'. High concentrations of nanoprobes were found to be biocompatible, compared to other currently available bioimaging molecules.

Ease of synthesis and the promising results given by GQDs generated from milk make it an attractive alternative as opposed to the toxic therapies currently available. Additionally, such an amalgamated approach as chemotherapeutic and bioimager opens up a new avenue for a chemistry based synthesis of cancer therapeutics.

Material Science & Engineering C, **16**(67), 467–477

Eggshell Membrane Magic

The benefits of eggshell membranes

Eggs are a powerhouse of nutrients such as proteins, vitamins and minerals. On an average, a person consumes 150–200 eggs annually. That's over a trillion eggs worldwide! And the shells are usually thrown away.

Eggshell is an inexpensive, natural source of calcium. And the membrane attached to the shell is rich in fibrous proteins. Many of its components are known to offer benefits.

The membrane is used as a natural source of collagen, glucosamine, chondroitin and hyaluronic acid, a potential biomaterial for tissue engineering applications, particularly for connective tissue repair.

In the last fortnight, Mahesh Kumar Sah and Subha Narayan Rath, from IIT Hyderabad reviewed the role of eggshell membranes in tissue engineering and regenerative medicine. They spell out a wide variety of uses of the membrane.

The semi-permeable behaviour of membrane could be used for developing dialysis and filtration units. Soluble eggshell membrane protein can be cross-linked with another collagen to form new and improved fibres with higher stability and antibacterial properties. The approach could be utilized to fabricate novel biocompatible fibres that support osteo-regeneration, i.e. remodelling membrane after processing through soluble eggshell protein membrane. The affinity and utility of

membrane for Cu and Mg metal ions play a vital role in bone tissue engineering application and cancer therapy.

The processing of membrane/soluble eggshell protein into hydrogels/organogels and composites will make it useful in various tissue engineering and biomaterial applications. The hydro/organogel forms appear promising enough to open up the development of effective drug delivery for targeted therapy. The soluble eggshell protein, with further modification, could be utilized as bio-ink with promising regenerative impact.

Eggshell membrane is an easily available, biocompatible, contaminant free, eco-friendly material that can be used as such or after modification. Based on the composition, the soluble eggshell membrane, with ease of processing, may have a great potential in clinical practice. The problem that remains to be conquered, for industrial scale utilization of this massive and valuable resource, is collection of the shells that are thrown away.

Material Science & Engineering C, **67**, 807–821

Temperature Matters

Cryo-grinding of black pepper

Black pepper, the king of spices, is indigenous to India, and, more specifically, to the Western Ghats. Aroma, pungency and colour make it a favourite at dining tables. Apart from flavouring and preserving food materials, black pepper is used in pharmaceuticals, insecticides and in cosmetics.

Like many other spices, pepper is available in powdered form in the market. Grinding makes it easy to transport, store and to mix with other ingredients; the increased surface area improves the availability of flavouring components and nutrients. But if grinding is not done with care, the powder loses its characteristic qualities.

Many studies have effectively demonstrated how cryogenic grinding – grinding at low temperature with the aid of liquid nitrogen or liquid carbon dioxide – improves retention of volatile oil content, an important active flavouring component, colour, particle size, and total surface area and that the energy costs are worth incurring. But these studies focused mainly on particle size and the sensory attributes of the black pepper powder; they paid little attention to other powder characteristics required for particle engineering.

Now, in the last fortnight, Bhupendra M. Ghodki and T. K. Goswami from IIT Kharagpur have reported a design of a cryo-grinding technology to obtain high quality pepper powder. They considered numerous other variables that influence powder characteristics: intrinsic variables like moisture content, shape and size and extrinsic variables like rotor speed and speed rate. They also addressed environmental variables such as relative humidity, and temperature of surrounding atmosphere which influence intrinsic variables.

As the grinding temperatures increased from –120 to –80, –40, 0 and 40 degrees on the Celsius scale, flowability, crucial to prevent problems like agglomeration and sticking, also increased. The remaining variables were negatively correlated. Availability of mineral composition of the powder also significantly increased with the reduction in the grinding temperature.

This quantitative investigation and comprehensive theoretical understanding of the powder properties of black pepper in terms of flowability, particle size, morphology, moisture, water activity, etc. will aid in cost reduction, capacity and process optimization of transportation, storage and grinding operations. Moreover, the findings can be immensely useful for the design of equipment for feeding, conveying, processing, handling, mixing, packaging, storing and transporting, say the scientists.

Powder Technology, **299**, 168–177

Coffee to Pass Infrared Test

Inline monitoring of roasting

Coffee comes in a variety of colours and blends. Each region boasts of its unique taste which is largely determined by the sugar content and the process of roasting. Even though coffee roasting is carefully controlled and sugar content is dedicatedly determined in each batch, there is a lack of a method for continuous monitoring to determine end points of roasting, for quality control purposes. A research team, led by Ricardo N. M. J. Páscoa from Portugal, has now come up with a one step method to determine sugar content and roast colour in coffee blends.

The scientists made use of near infrared scanning method for determining two parameters that can greatly influence coffee flavour among different batches: the sugar content and the colour of the roast. The researchers placed a simple infrared probe outside a coffee roaster that allows direct visualization of the roasting drum through a glass window. They roasted coffee beans from Brazil, Uganda and India in separate batches at different speeds and scanned the contents with near infrared after short intervals throughout the process. And they compared the scan results with established industry parameters for colour and sugar content.

The sugar content decreases rapidly in fast roasts. Scientists found that the changes in spectra are consistent with this. The researchers noticed that the industrially defined parameter for colour change – luminosity – was greatly affected by the roasting temperature. For the same value of luminosity, the sugar content of the different roasts could be partially controlled by tweaking the roast process, especially for light roasts, thus producing sucrose-enhanced natural coffee.

The near infrared scanning technique and multivariate methods used are quite rugged and these can be easily employed for continuous monitoring of coffee roasting in industrial facilities for quality control.

Food Chemistry, **208**, 103–110

From Forest Waste to Biofuel

Babool seeds to produce oil

Agricultural biomass contains compounds that directly serve as fuel and yield energy when burnt. But extracting fuel in the form of oil or gas from biomass is cost intensive. Different crops give different yields of oil. Selectively growing plants for biofuel production can encroach upon agricultural lands. This raises several issues with respect to deforestation and the sustainability of the process.

Scientists have now come up with a solution to the problem. In the last fortnight, Neeru Anand and her colleagues from the Guru Gobind Singh Indraprastha University, Delhi, reported a new source – Babool seeds – for large scale cost efficient production of bio-oil.

Babool seeds are a forestry waste produced to the tune of 60,000 tonnes annually. The researchers determined the fuel yield from this source at different temperatures using a pyrolysis chamber. The seeds collected from the outskirts of Delhi were washed, crushed and separated into three different fractions based on size. This was done to study the effect of particle size on fuel yield.

Each group of varying particle size was then fed into a pyrolysis reactor and heated at temperatures ranging from 400°C to 700°C. The vapours were collected and condensed in a separate chamber allowing the scientists to isolate the bio-oil. The researchers analysed the liquid yield, gas yield and oil yield for each group at different temperatures.

They found that smaller particle sizes of the order of 0.4 mm tend to be more efficient for both oil and gas production. The process was most efficient at 500°C – with a liquid oil yield of 49% and a transport grade bio-oil yield of 38.4%. This is comparable to the oil yield of Jatropha – the primary biofuel crop in India. Given that the method used for fuel extraction – pyrolysis – is inexpensive, and that huge amounts of babool seeds are wasted every year, there is an economic feasibilty to using this new source for bio-oil production.

Renewable Energy, **96**, 167–171

Stabilizing Omega-3 Fatty Acids

Improving human health

Omega-3 fatty acids are polyunsaturated fats which have many positive effects on our health. The World Health Organization estimates that 80% of cardiovascular diseases are avoidable by following a healthier diet. Increased health awareness and higher incidence of cardiovascular disease has raised the demand for omega-3 fatty acid containing health foods.

Among omega-3 fatty acids, docosahexaenoic acid, or DHA, is considered the most important. DHA is easily oxidizable which makes it unstable and sensitive to environmental stresses. This poses the problem of degradation during transportation and storage. In fact, bioavailability of DHA is poor due to degradation even after consumption.

Karthik and Anandharamakrishnan, researchers from CSIR-CFTRI, Mysuru, utilized nanotechnology based emulsions to protect the DHA from oxidation. Nanoemulsion based delivery of omega-3 fatty acids is becoming increasingly popular because of its ease of preparation, small particle size, relatively high stability and high bioavailability. Despite these advantages, selection of nanoemulsions must be carefully considered to ensure good physical and chemical stability and high bioavailability.

The scientists tested different types of nanoemulsions such as Tween-40 (T-40), sodium caseinate and soya lecithin to stabilize the DHA. The highest physical stability and least oxidation of DHA were observed with T-40 nanoemulsion. Moreover, it also ensures gradual delivery and increased digestibility of biologically active and functional omega-3 fatty acids. Therefore, omega-3 fatty acids can be protected and stabilized better with T-40 nanoemulsion.

Many national and international health organizations recommend that consumption of 250 mg DHA per day improves human health. Therefore, nanoemulsion based delivery of omega-3 fatty acids can be employed to meet the recommendations to improve human health.

J. Food Engineering, **187**, 92–105

Leather for Enzyme

Waste utilization meets value addition

The leather industry produces large quantities of degradation-resistant wastes and this poses a problem of waste disposal. A major proportion of pre-tanning leather waste comprises animal fleshing that contains about 40–50% of protein. Recent investigations show that enzyme and fermentation based techniques can help in recovery and utilization of commercially important products from waste animal fleshing.

Recently, researchers from the Sathyabama University, Chennai, and the Central Leather Research Institute, Chennai, collaborated with scientists in Seoul and Hong Kong to study protease production from animal fleshing using a newly isolated bacterial species – *Clostridium limosum*.

Proteases have multiple uses, particularly in pharmaceutical, leather and textile industries. *C. limosum* can produce such enzymes by utilizing animal fleshing as a substrate. To identify the optimum conditions for protease production, the researchers incubated animal fleshing with *C. limosum* in an anaerobic atmosphere for 120 hours at different pH and temperatures. After every 24 hours, a small quantity of media was drawn to estimate the amount of protease produced. The researchers found that the protease yield was highest at 40 degrees and mildly acidic pH of 6. The enzyme was then isolated through column chromatography and assessed for purity using gel electrophoresis and high pressure liquid chromatography. The isolated enzyme was inhibited by metal chelators and stimulated by zinc and magnesium salts, indicating that it is a metalloproteinase. By manipulating purification strategies, the researchers could purify the enzyme 58 fold.

The present approach not only stabilizes leather waste but makes it more prone to microbial degradation by decreasing organic content. It also creates value addition by facilitating the production of a commercially important product. Scientists say that such useful waste disposal strategies can help in the cost-efficient management of industrial wastes.

Bioresource Technology, **217**, 150–156

Reports by: **Bobby P. Mathew, Manali Datta, K. T. Mufeeda, G. Sharath Chandra, H. M. Mahadeva Swamy, Rekha R. Warrier** and **Sarah Iqbal**

scienceandmediaworkshops@gmail.com