

## Science Last Fortnight

### Potassium for Productivity *Coastal soils of eastern India*

Potassium, an important soil macro-nutrient, is required in relatively large amounts for plant growth. The availability of potassium in the soil, and the capacity of soil to buffer its concentration are parameters that determine the effective available potassium for plant nutrition.

Recently, scientists from the Uttar Banga Krishi Viswavidyalaya and the Bidhan Chandra Krishi Viswavidyalaya, West Bengal reported analysing potassium in representative coastal soils from eastern India. They collected twelve surface soil samples from agricultural lands in coastal West Bengal.

The samples showed wide variation in physicochemical properties. The team estimated labile potassium ions, equilibrium activity ratio for potassium ions and the potential buffering capacity of potassium ions – indices of potassium ion availability in soils. They found that about half of the samples had high levels of potassium – sufficient to support cropping for a long period.

This approach to evaluating potassium dynamics in coastal soils helps predict potassium ion availability to plants. The approach makes it easy to assess potassium ion dynamics in saline soils and is useful for managing potassium ions.

Data on the nutritional components of soils in agricultural areas need to be analysed for efficient nutrient management. Agricultural departments can collaborate with agricultural universities to provide a detailed soil nutrient map. Such steps could reduce unnecessary use of fertilisers in the country.

DOI: 10.1016/j.geoderma.2018.07.014

### Jasmonic Acid *For lead poisoned plants*

Jasmonic acid is a popular growth regulator and mediates immune reactions in plants. It is known to provide protection to plants under various abiotic environmental stresses caused

by heavy metals. But its potential to decrease lead toxicity has not been investigated. Lead is a non-biodegradable toxic metal and accumulates in soil. Uptake of this metal adversely affects the growth and metabolic activities of plants.

Last fortnight, Renu Bhardwaj and team from the Guru Nanak Dev University, Amritsar collaborated with Parvaiz Ahmad from Srinagar and scientists from Saudi Arabia to report that jasmonic acid helps reduce lead toxicity in tomatoes.



Image: David Besa via Wikimedia Commons

They treated the soil with different concentrations of lead solution. Then, they measured shoot and root length 30, 45 and 60 days after seed germination. The researchers observed that shoot and root length decrease with increasing concentrations of lead at different growth phases. With 0.75 millimolars of lead, shoot length decreased by 45%. Root length decreased by 65% in sixty days.

The team grew tomato seeds pre-soaked with different concentrations of jasmonic acid. They found that soaking seeds in jasmonic acid significantly decreased the uptake of lead. As little as 100 nanomoles of jasmonic acid gave maximum improvement in growth in plants treated with 0.75 millimolars of lead concentration. The results indicate that the jasmonic acid treatment improves growth in plants affected with lead treatment.

What could be the mode of action? The team investigated the effect of lead uptake on metabolic processes - photosynthesis, respiratory activities and metal tolerance. They found that lead treatment lowered pigment con-

centration, increased production of hydrogen peroxide and reduced gaseous exchange.

Jasmonic acid treatment improved photosynthetic efficiency, osmolyte content and antioxidant enzyme activity. Uptake of lead was also regulated.

The results are encouraging since heavy metal contamination in soils is increasing due to industrialisation. To enhance crop productivity in polluted soils, we may need to check whether what is true of tomato is true for other crops too.

DOI: 10.1016/j.scitotenv.2018.07.164

### Diagnosing Tuberculosis *With gold-copper nanoshells*

Tuberculosis kills nearly a quarter of a million people in India every year. Diagnosing the infection early can reduce morbidity and mortality as well as prevent the spread of the disease.

Though several diagnostic tests are available, they are expensive and call for expertise. Moreover, most available tests detect antibodies. Even those merely exposed to the pathogen develop antibodies and give false-positive results.

Suresh Kumar Kailasa from the S.V. National Institute of Technology, Surat worked with researchers from the Republic of Korea to develop a dot-blot immunoassay. A dot-blot assay is simpler than the Western blot assay and does not require separation of proteins for testing.

To develop the test, the researchers used the CFP-10 antigen, the most abundant antigen of the tuberculosis bacteria.

First, they produced the CFP-10 protein and CFP-10 antibody in a prokaryotic expression system. They coupled the CFP-10 antibody to gold nanoparticles.

Since copper and silver offer light-scattering signal enhancement, they checked if gold nanoparticles enhanced with copper or silver nanoshells would give better signal intensity. So, they put the CFP-10 protein on a

nitrocellulose membrane and incubated it with the gold nanoparticles, tagged with the CFP-10 antibody and enhanced with copper or silver nanoshells. They noticed that copper nanoshells increased optical signal intensity to more than twice that with silver nanoshells alone.

The assay signal could be detected by naked eye. The test was more sensitive than other spectroscopic methods and could detect even picogram/ml levels of the protein.

The team also tested urine samples spiked with the CFP-10 protein. Once satisfied with the results, they screened urine samples from tuberculosis patients. They noticed that the test was more specific to samples from patients with active tuberculosis than to those with latent tuberculosis.

The authors claim that the test is specific to the CFP-10 protein of the tuberculosis pathogen. However, another study reveals the immunological cross-reactivity of the CFP-10 of tuberculosis bacteria with that of leprosy bacteria. We may need to check if the test works for related mycobacterial infections as well.

DOI: 10.1016/j.bios.2018.08.068

### Crystal Violet

#### *Diverse adsorbents for removal*

Crystal violet is a common cationic dye extensively used by the paper, dye and textile industries. It is a major pollutant in industrial wastewater. The dye is highly toxic to life forms. Various physical, chemical and biological processes have been employed to remove dyes from wastewater. Among these, adsorption is better because it is efficient, easy to use and cheap. Most adsorbents are also reusable.

Last fortnight, two teams of scientists, one led by Gaurav Sharma of the Shoolini University, Solan and another by Chandni Puri at the National Physical Laboratory, New Delhi reported their findings targeting this problem. Moving independently, they used different materials and strategies.

Gaurav Sharma and his team<sup>1</sup> used an acacia gum-based nanohydrogel as adsorbent to suck out the poisonous dye from contaminated water. Gum arabic is a natural, highly

branched polymer. So it has large surface area for adsorption. It is an easily available, non-toxic adsorbent, selective to cations. But it has weak mechanical strength. So, the scientists grafted acrylamide onto the gum polymer by microwave method, using ammonium persulphate as initiator and methylene bisacrylamide as crosslinking agent. This imparted mechanical strength to the nanohydrogel adsorbent and generated more active sites for adsorption.



Image: LHcheM via Wikimedia Commons

The gum-based adsorbent removed 76% of crystal violet. One gram of the nanohydrogel removed more than 90 milligrams of the dye. The nanohydrogel adsorbs more efficiently at low temperature. 'The stability of the nanohydrogel is greater at low temperature. More efficient adsorption at low temperature may be because of this property', explain Gaurav Sharma and his colleagues. The key features of the nanohydrogel are its applicability at alkaline medium and at moderate temperature.

Chandni Puri and her team at the National Physical Laboratory, New Delhi used a different approach<sup>2</sup>. They used montmorillonite, a clay mineral with high cation exchange capacity and large surface area. They added graphene oxide to montmorillonite. This increased the number of active functional groups.

The dye removal efficiency of the clay-based adsorbent was 96% of the initial dye concentration. One gram of the clay nanocomposite removed more than 700 milligrams of crystal violet dye.

Chandni Puri and Gajjala Sumana attribute the high efficiency of clay-based adsorbents to the functional groups on the surface as well as inside the pored network of the nanocomposite. The nanocomposite is more efficient at high temperature. 'Higher temperature removes water molecules from active sites on clay, providing space for the adsorption of dye molecules', says Chandni Puri. The key features of the nanocomposite are its applicability at neutral pH medium and at high temperature.

Adsorption kinetics and thermodynamic studies by both groups revealed that adsorption reactions in both cases were spontaneous. However, the process was exothermic with the gum-based adsorbent, while it was endothermic with the clay-based adsorbent. This suggests that, in the gum-based nanohydrogel, the adsorption mechanism is physisorption, and in the clay-based nanocomposite, it is chemisorption. Both materials demonstrated reusability.

The clay-based nanocomposite and gum-based nanohydrogel are two entirely different materials at molecular level and are applicable for dye removal in different environments. The clay nanocomposite was more efficient at removing crystal violet dye from warmer waters at neutral pH. The gum-based nanohydrogel, on the other hand, was more effective in cooler environments and in alkaline water. Both materials hold promise for environmental detoxification. Upscaling and translating the research for field applications in appropriate environments are the necessary next steps.

<sup>1</sup>DOI: 10.1016/j.carbpol.2018.09.004

<sup>2</sup>DOI: 10.1016/j.clay.2018.09.012

### Geopolymer Concrete

#### *Blast furnace slag and rice husk ash*

Cement is extensively used in building construction materials. The cement industry is one of the most important producers of greenhouse gases. It also causes landscape degradation. With rapid urbanisation, it poses environmental threats. An alternative to conventional concrete is temperature cured geopolymer concrete. It has high strength,

reduced energy requirements and emits 80% less carbon dioxide. The use of such low cost industrial by-products can help address environmental concerns.

Researchers from the Amity University, Noida and the Thapar Institute of Engineering and Technology, Patiala used ground-granulated blast furnace slag and rice husk ash for producing sustainable geopolymer concrete.



Image: GST-HBK via Wikimedia Commons

These materials contain more calcium and silica than fly ash which is commonly used in making concrete.

To obtain even particle size, the researchers separately ground granulated blast furnace slag and rice husk ash and sieved them to remove impurities.

They analysed the materials using X-ray fluorescence and found that blast furnace slag had equal amounts of silica and calcium oxide while rice husk ash had more silica oxide.

They then replaced blast furnace slag with rice husk partially, in different proportions. The slag and rice husk ash along with crushed stone and natural river sand were mixed in a pan mixer for ten minutes. These trial mixtures were analysed for their specific gravity.

To improve performance, the researchers added a super plasticiser to the mixtures with an alkali activating solution. The samples were then cast and cured at 80°C for 24 hours in an oven.

They analysed the resulting concrete for compressive strength, split tensile strength and permeation properties.

They observed maximum compressive strength with 85% slag and 15% rice husk ash after 90 days. Permeation properties were extremely

low for the geopolymer with 15% rice husk ash.

The team also noticed high compressive and tensile strength when pressure was applied at various angles.

Using scanning electron microscopy and X-ray diffraction, the researchers examined the mineralogy and microstructure of the concrete. They observed sodium aluminosulphate and calcium silica hydrates in the blast furnace slag-rice husk ash geopolymer mixture. This, they say, made the concrete stronger.

'The optimum content of rice husk ash, as partial replacement of ground granulated blast furnace slag, is 15%', say the researchers.

India, a leading producer of rice, outputs 130 million tonnes of rice husk annually. The study provides a method to use this agri-waste along with waste from the steel industries in the production of environment friendly concrete.

DOI: 10.1016/j.jclepro.2018.08.313

### Nifty Exfoliation

#### *Improving electromagnetic shielding*

From the simplest electrical switching circuits to high-precision wireless receiver systems, electromagnetic interference is one of the recurring snags encountered by radio scientists and engineers. The fidelity of electronic instruments depends on the shielding efficacy of the materials used for insulation and on their capacity to prevent undesired signals from interfering with the system. In order to minimise the influence of external signals on sensitive instruments, scientists use materials with high electrical conductivity as shielding medium.

Although a number of experiments using forms of graphene as shielding material have reported a maximum shielding effectiveness of 52.6 dB, manufacturing high-tensile, flexible materials is a challenge.

Many carbon-based shielding materials have hitherto provided decent shielding efficiency, but traditional methods to obtain large quantities of single-layered graphene, or exfoliated graphite, are arduous and time-

consuming. Furthermore, the formation of residue compromises the effectiveness to a large extent. Nagaraju Sykam and Mohan Rao from IISc Bengaluru used a new method to exfoliate graphite: a single chemical compound to exfoliate graphite within a minute.

The scientists mixed graphite flakes with diluted perchloric acid to produce an intercalation compound – a method to separate layers of graphite. They then used microwave irradiation to remove the intercalated species, thereby producing highly porous exfoliated graphite. This was then cast, compressed, and rolled into very thin sheets of uniform density. The flexible graphite sheet had very good electrical conductivity.

In contrast to the absorptive properties exhibited by other materials, this material acted predominantly as a reflective shield. The absorption coefficient was lower than the reflection coefficient. The researchers concluded that the material has a reflection-dominant profile in the 12–18 GHz Ku-band.

They observed that a 0.5 mm thick flexible graphite sheet had a maximum shielding effectiveness of 79.4 (–dB). The flexible graphite sheet fabricated by this method was better at shielding than any other material hitherto produced. The entire process of fabrication also took far less time and effort.

Applications range from preventing microwave ovens from interfering with the reception of wireless devices in the Ku-band to shielding microwave-sensitive receivers in astronomical observatories, say the researchers. Considering the ease of fabrication, these flexible graphite sheets can be used commercially where flexibility and strength play major roles.

DOI: 10.1016/j.matlet.2018.08.066

### Self-cleaning Transparent Coating

#### *For solar energy devices*

Solar panel output tends to reduce as atmospheric pollutants slowly settle on them. The loss is estimated to go up to 40% in some cases. To overcome the problem, scientists tried

two self-cleaning approaches: superhydrophobic and super hydrophilic coatings. The performance of superhydrophobic films is seen to slowly reduce with time, reducing transmission to the point that it becomes worse than uncoated glass.



Image: Fernando Tomás via Flickr

So Deepanjana Adak, Indian Institute of Engineering Science and Technology, Howrah took the hydrophilic approach. Most superhydrophilic coatings are found to consist of Titania.  $\text{TiO}_2$ , a photocatalyst, is capable of breaking down organic contaminants under ultraviolet light.

To put a thin layer of  $\text{TiO}_2$  over glass, there are quite a few techniques. But then, the layer has to be highly transparent. It should not peel off from the low iron tempered glass used in fabricating Si solar photovoltaic panels. Raghunath Bhattacharyya, Deepanjana's mentor at the Centre of Excellence for Green Energy and Sensor Systems, suggested a scalable dip coating technique, followed by plasma treatment. Anup Mondal, at the Chemistry Department, and H. Saha and Sugato Ghosh from the Centre collaborated. The team used Pluronic F127, a symmetric triblock copolymer with polyethylene oxide and polypropylene oxide in an alternating arrangement. Not too costly. Adequate for the purpose.

They dissolved Pluronic F127 in ethanol and hydrochloric acid by stirring and then added Tetrabutylorthotitanate, the source for  $\text{TiO}_2$  and stirred. Then, they added water and continued stirring. The process is laborious. But, if you put a little  $\text{SiO}_2$  gel, the  $\text{TiO}_2$  sol that is slowly formed

is stable over months. In fact, you can use the same sol for months.  $\text{TiO}_2$  is now trapped in a micelle-like layer of organic material. One can dip glass, dry it, and heat it to remove organic matter. And you get a very thin layer of  $\text{TiO}_2$  on glass, self-assembled as an interconnected nanoporous structure, which can be annealed on to glass by heating to higher temperatures.

Now, to get a thin layer, how fast or slow should we remove the glass that is dipped in the sol? After a series of experiments, the team determined that 200 mm/min is the best rate. Faster or slower removal reduces transmission of the layer. The transmission is more than 95% while the glass underneath has a transmission of barely 92%.

But  $\text{TiO}_2$  is good at photocatalysis only under ultraviolet light. Can it be improved to work in the visible range as well? The team tried doping the film with nitrogen using a gaseous plasma reactor. A simple trick that extends the activity of the film to at least a part of the visible range. It took many trials to get to the optimum treatment. A little less than three minutes, under 55 Watts RF power, turned out to be the optimum.

Rabibrata Mukherjee from IIT Kharagpur and his student, Poulomi Chakraborty, helped characterise these films. K. M. K. Srivatsa of the NPL pitched in for optical characterisation by ellipsometry.

The team realised that it is a highly porous structure, with just the right roughness to reduce reflections. Porosity was about 80%, but it was tough enough mechanically, as experiments with a nano-indenter proved. It does not peel off even after boiling in water, or after keeping it immersed in saline solution. It has increased ability to photocatalyse pollutants, as shown by studies with the dye, methylene blue.

So here is, hopefully, the beginning of a new technology that is less costly, applicable even to automobile windscreens and the glass facades of buildings.

The Department of Science and Technology that funded the research will now need to push for field trials.

DOI: 10.1016/j.solmat.2018.08.011

## Electricity Load Management

### *Deep learning forecast tool*

Electricity demand goes up and down every day, from season to season and often peaks due to festivals or socio-political events. Balancing the unpredictable demand with supply in a dynamic manner is a headache to electricity departments.

There are linear statistical models such as autoregressive models that can accommodate moving averages and even integrate past data to forecast the future. But they are not successful. One could think of nonlinear methods – support vector machines, artificial neural networks, extreme learning machines, adaptive neuro-fuzzy interface systems ... And algorithms galore – evolutionary, genetic, and a host of others – that learn from past data, extract features, identify parameters that contribute to the changes. None worked. Scientists even tried to combine the different methods. But with no success.

Neethu Mohan and team from the Amrita school of Engineering, Coimbatore now report an effective strategy: mine data to identify dynamic characteristics using dynamic mode decomposition. We can forecast without knowing the parameters that impact the changes. This strategy reduces the costs and computer run time. They tested the strategy using data from Australia and the US. The forecasts turned out to be better than all earlier models.

Electricity departments in India could benefit from this non-funded research.

DOI: 10.1016/j.apenergy.2018.09.190

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