Science Last Fortnight

Efficient Solar Still

Nanotechnology for pure water

Consuming contaminated water can cause cholera, jaundice, diarrhoea... Pollutants – fluorides, nitrates and heavy metals – also take a toll on public health. To prevent these issues, effective, robust and cheaper water purifying methods are needed.

Last fortnight, researchers from the Anna University, Chennai in collaboration with the Aston University, the United Kingdom reported developing a simple, cost-effective method to purify water.

They impregnated paraffin used in solar stills with three nanoparticles – titanium oxide, cupric oxide and graphene oxide. This increased thermal conductivity and reduced heating time. It is also increased latent heat, improving water distillation.

One square metre of such a solar still produces over a thousand litres of purified water. The cost analysis demonstrated that this innovation cuts cost by more than half.

According to a WHO fact sheet, around 80% of stomach ailments in India come from consuming polluted water. Now, we have a cheap method to purify water.

Besides making water from lakes, seas, and even sewage, potable, nanoparticle-impregnated paraffin also serves as efficient storage for harvested solar energy. The method could also be further developed to produce solar energy storage devices for other purposes.

J. Clean. Prod., **192**: 9–29

Polycyclic Aromatic Hydrocarbons

PM2.5 adds to burden of disease

The burden of disease, attributed to ambient air pollution by particles of diameter less than or equal to 2.5 microns, is rising. These fine particles stay long in the air and trigger asthma, heart attack, bronchitis and other respiratory problems. The high levels of ambient PM2.5 pollution are primarily from incomplete combustion of fossil fuels, biomass and waste.

As if to add fuel to fire, the same sources produce polycyclic aromatic hydrocarbons – PAHs – which affect the respiratory tract, pharynx, lung, alimentary tract, liver and kidney, and cause skin cancers. The PAHs also affect the developmental, reproductive and immunological systems.

Effects of both PAHs and PM2.5 on health have been studied independently. Now scientists from the National Environmental Engineering Research Institute, Nagpur and collaborators from Nigeria, report their combined effect.

They estimated the cancer and non-cancer burden of disease, in disability-adjusted life years, attributable to ambient PM2.5-bound PAH exposure in the Nagpur district, Maharashtra. This is a measure of overall disease burden, expressed as the number of years lost to ill-health, disability or early death.

Nagpur district is a coal mining region and has two coal-fired power stations. The city's vehicle fleet uses fossil fuels. In the surrounding villages, fuels such as animal dung, crop residues, wood and coal are used for cooking and heating. All these conditions are ideal to produce fine particulate matter bound to polycyclic aromatic hydrocarbons.

Sivanesan and team selected urban, peri-urban and rural areas for their study. They collected airborne PM2.5 samples from the sites, using an air sampler, and analysed the composition using gas chromatography. The average concentration of total PM2.5-bound PAHs was substantially highest in rural areas followed, in decreasing order, by urban and peri-urban areas.

Then the scientists calculated the disability adjusted life years using the average concentration of total PM2.5-bound PAHs, by combining measures of life expectancy as well as the adjusted quality of life during a burdensome disease. The calculations led to about 49,500 disability-adjusted life years for Nagpur. The burden of diseases, in decreasing order of severity, was developmental (mostly cardiovascular) impairments, cancer or lung cancer, immunological and reproductive abnormalities.

Though Nagpur is considered the second cleanest and greenest district in India and meets national ambient air quality standards, a substantial amount of years of healthy life time is lost. The estimates of the burden of disease in Nagpur demonstrate the need to revise current Indian national ambient air quality standards. Policy decision makers would do well to pay heed.

Chemosphere, **204**: 277–289

Reducing Nitrate Leaching

Biochar in agriculture

Nitrates leach from the soil due to rain and irrigation and drain into rivers, oceans and groundwater. Though a key input for agriculture, nitrates become an environmental pollutant and a public health problem. Moreover, leaching of nutrients decreases soil fertility, wastes fertilisers applied by farmers and reduces crop yields.

Narendra Kumarand Lenka and team from the Indian Institute of Soil Science, Bhopal and the Indira Gandhi Krishi Vishwavidyalaya, Raipur took up the matter and came up with a solution: biochar.

Many studies prove that biochar application increases agricultural productivity and reduces greenhouse gas emissions from soils. But there is no optimum range prescribed for its use for each type of soil and the type of biomass used for making biochar.

The team took three types of soil samples – from a thick forest, fertile agriculture land and non-fertile agriculture land. They conducted the experiments using a column study in the laboratory. They used biochar, equivalent to 0, 11.2, 22.4, and 44.8 mg per hectare, in the columns. The biochar was made from corn stalks.

As source of nitrate, they used potassium nitrate. And they conducted

the leaching experiments for fifteen consecutive weeks, with an interval of one week.

The team noted that adding biochar, at a 44.8 mi/hectare equivalent, led to reduction in nitrate leaching – up to 27% in forest soil, 23% in fertile soil and 6% in non-fertile soil.

However, when biochar was reduced to 22.4 mg/hectare level, leaching did not reduce in fertile soils. At 11.2 mg/hectare equivalent, the scientists noticed higher leaching even in the forest soil. The non-fertile soil showed higher water holding capacity with addition of increasing amounts of biochar.

The study clarifies the amount of biochar necessary to reduce leaching of nitrates in the various soil types of Central India.

Catena, **167**: 422–428

Potential Carbon Loss

Clearfelling rubber plantations

Monoculture rubber plantations occupy over seven thousand square kilometres in India – more than the area that the State of Sikkim occupies. Normally, some three decades after planting, latex yield declines and farmers clearfell all the trees in a plantation. This practice destroys habitats, threatens biodiversity and releases a significant amount of carbon, causing environmental problems.

Last fortnight, scientists from the Assam University in collaboration with the University of KwaZulu-Natal, South Africa developed models to predict biomass and carbon loss from clearfelling of mature plantations.

The team demarcated 25 m × 25 m quadrants in a 35 to 40-year-old rubber plantation, in Assam. They measured the height of the trees and the girth at 2 m from ground level. Then, they categorised the trees into six different diameter classes. Nine trees were selected from each class. These 54 trees were felled. The team excavated roots to a depth of one metre. The fresh biomass of stem, leaf, branch and root were measured separately. 500 g of subsamples were collected from each component for dry matter estimation. The researchers extrapolated the data to calculate dry matter for the whole tree.

Image: S. Suresh Ramanan

After collecting field data, the team developed allometric models to determine biomass using diameter and height as predictor variables. These models predict unquantifiable variables – the biomass of a tree – by measuring a quantifiable variable such as diameter or height. Based on the coefficient of determination and mean absolute error percentage, the team selected the best model for biomass determination.

Since sequestered carbon contributes to 50% of total biomass, the team multiplied the calculated biomass by a factor of 0.5. Thus, they found that clearfelling mature rubber plantations can lead to a loss of more than a hundred tonnes of carbon per hectare!

It is now up to scientists to develop better plantation management activities to tackle carbon loss from mature rubber plantations. There is a need to develop plantation tree-based agroforestry systems for sustainable land use.

Biomass Energy, **115**: 88–96

Sugarcane Quality Deterioration

Causative bacteria identified

Sugarcane is a major source for sugar production. The post-harvest sucrose loss of this crop, due to the inordinate delay between harvesting and milling, is of prime concern to the sugar industry.

Recently, scientists from the Indian Institute of Sugarcane Research, Lucknow, found the cause of this reduction in sucrose. They identified the bacterial species responsible for the loss.

To investigate what lay behind the loss, they collected cane juice samples from different sugarcane fields. They isolated several bacterial colonies from the juice and screened their morphological and biochemical characteristics. They found that 34 of these bacteria could ferment/cleave sugars.

The team then identified these bacterial species, using eight different species specific primers in a polymerase chain reaction. Among them, only one primer showed a positive result for all the bacterial samples. The scientists identified it as *Leuconostoc lactis.*

Leuconostoc lactis was predominant in cane juice from all locations. This bacterium utilises sucrose for energy needs, by secreting several enzymes to breakdown cane sugars. The scientists claim that this is the first time *L. lactis* has been found associated with sugarcane.

Image: Amaresh Chandra, ICAR

The findings will help develop control strategies against this species to reduce post-harvest losses and to enhance sugar production in the Gangetic belt. Action needs to be taken to screen sugarcane from other parts of India for the identification of similar species.

Sugar Tech., **20**: 492–496

Rutin from Sweet Orange

Anti-biofilm potential

Many infectious bacteria form biofilms – cells embedded in a slimy layer. This layer of complex carbohydrates protects bacteria from antibiotics, causing chronic diseases that are often fatal. Scientists have been experimenting with mechanisms to disrupt bacterial biofilms to enable treatment with antibiotics. A team of researchers from the Bharathidasan University, the CSIR-Central Leather Research Institute and the King Institute of Preventive Medicine and Research, Tamil Nadu have now come

up with a cost effective solution – rutin from the peels of the sweet orange, *Citrus sinensis.* Rutin is a flavonoid present in citrus fruits.

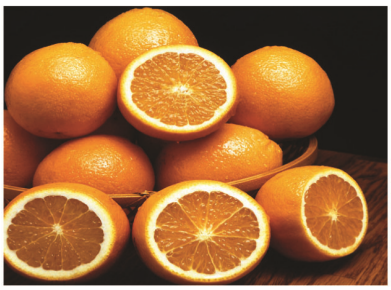

Image: Agricultural Research Service

The scientists dried and powdered *C. sinensis* peel and extracted the components with different organic solvents. An ethyl acetate extract, they found, gave maximum yield of rutin. They also characterised the extract's components using chromatography and spectroscopy. The antimicrobial activity of rutin and gentamycin were assessed by broth microdilution assay. The results indicated that rutin has moderate antimicrobial properties.

They used a biofilm-producing organism, *Pseudomonas aeruginosa*, as model. This bacterium causes chronic otitis media, cystic fibrosis, as well as lung and kidney infections.

The biofilm was quantified and measured using a spectrophotometer. From absorbance values, biofilm inhibition was calculated mathematically. The team inferred that there was maximum biofilm attenuation of 50% by rutin at 200 micrograms per litre.

They used checkerboard titration to test the synergistic effects of rutin and gentamycin on the biofilms. The biofilms were grown on glass slides in 24 well plates and incubated with rutin–gentamycin. The team, then, evaluated the thickness of the biofilms using a confocal laser scanning microscope. And found a reduction in the thickness of the biofilms.

Their results show that rutin–gentamycin induced cell wall disruption, higher membrane permeability and reduced cell density. The researchers checked endogenous radical oxygen species in *P. aeruginosa* under rutin–gentamycin treatment, using fluorescent probes. They found that rutin generates reactive oxygen species that lead to oxidative stress in and death of *P. aeruginosa* cell components.

It may be a while before rutin emerges as adjuvant for the treatment of chronic bacterial infections in clinical settings. Meanwhile, sweet oranges can, perhaps, be used as nutraceutical to control the bacterial films that cause chronic infections.

Food Control, **90**: 282–294

Autism Spectrum Disorder

Alterations in immune regulators

Autism spectrum disorder in children is marked by impairments in social interaction, repetitive behaviours and communication abnormalities. It is associated with abnormal brain development. Genetic and environmental factors are known to contribute to this disorder. Now, scientists from the National Institute of Mental Health and Neurosciences report that the immune system also has a role in autism.

They examined 50 children, aged three to twelve, diagnosed with autism spectrum disorders. 30 children with good social quotient and maturity levels without any recent illness were included as control group.

The team collected blood samples from all the children and used the serum portion of the blood for all analysis. They measured the levels of immune cells – T cells, regulatory T cells, B cells, natural killer cells, monocytes and dendritic cells – using cell-specific antibodies. They also compared the levels of cytokines – immune signalling proteins.

The researchers found higher myeloid dendritic cells and cytokine secreting T helper cells in autism. The signalling proteins of the immune system, especially interleukin-6 and interleukin-17A, were predominantly higher among autistic children.

The researchers from NIMHANS suggest that cytokines could be used as biomarker for autism, and, perhaps, for targeted immune-based therapies.

Recent evidence suggests immune modulation by cytokines, during pregnancy, which could impact the development of the neural stem cell, its proliferation and connectivity in the developing child. Could this be the proximate cause of the development of autism? Only future research will tell.

Psychoneuroendocrinology, **94**: 162–167

Superabsorbents

Bagasse, chitin and clay

There are synthetic materials capable of rapidly absorbing liquids, hundred times their weight. But such superabsorbents tend to be non-biodegradable and pollute the environment. Can we create superabsorbents from natural agricultural waste?

Maya Sharma and Anjali Bajpai of the Government Science College, Jabalpur, decided to tackle the problem. Last fortnight, they reported a simple process to fabricate a superabsorbent using sugarcane bagasse, shrimp-shell chitin and clay.

Bagasse consists of lignocellulose while chitin is comprised of cellulose and amino polysaccharide. Microfibrillation is essential for binding the constituents in a composite. The scientists used an ionic liquid for microfibrillation which removed the hemicelluloses and lignin components from the bagasse and reduced the self-assembled chains in chitin. The treatment enhanced interaction among the neighbouring chains of the constituents and helped form uniform voids in the hybrid composite.

The team added Fuller's earth clay to the biopolymer matrix. This enhanced strength and stiffness. The nanocomposite was held together by microwave assisted graft polymerisation in acrylamide.

The researchers report that the nanocomposite has a paracrystalline structure – a lattice with short or medium ordering – which assists in high water absorption and reduces possibilities of cracks developing during swelling and shrinking.

The scientists tested the erosion of the material in consecutive swelling–shrinking cycles and report that erosion was highest during the first cycle and negligible in the following cycles.

The highest swelling degree, 15000%, was observed in 15 days.

They also tested the antimicrobial activity of the nanocomposite against *Staphylococcus aureus* and *Escherichia coli* and report that the biomaterial is highly resistant to microbial growth in both dry and wet conditions.

The process for making the bio-based material is low cost and environment-friendly. The material is superabsorbent and highly recyclable. With possibilities for multiple applications, the material will help farmers deliver fertiliser solutions with minimum wastage, and water to crops during drought, hope the scientists.

Carb. Pol., **193**: 281–288

Detecting Carbon Monoxide

Carbon monoxide – CO – is a major culprit responsible for air pollution. It is highly toxic. Even a small concentration of CO can cause severe problems and high concentrations lead to unconsciousness, even death. Researchers have attempted to develop CO sensors using semiconducting metal oxides, but they are only operational at high temperatures.

Recently, scientists from the Amity University, Noida in collaboration with scientists from the National Cheng Kung University, Taiwan, developed a CO sensor by doping copper in octahedral molecular sieve nanofibres.

The team prepared two solutions: potassium permanganate and copper chloride dihydrate in distilled water and manganese sulphate tetrahydrate in water, acidified with nitric acid. They obtained a brownish-black precipitate after 18 hours of boiling the mixture. This was filtered and washed until a neutral filtrate was obtained. Then the team heated the filtrate at 120°C to get copper-doped sieve fibres.

They examined the morphology of the doped nanofibres using a field emission scanning electron microscope. And, using X-ray diffraction, the researchers determined the crystal structure of the copper octahedral molecular sieve nanofibres.

The scientists developed the sensor on an insulated substrate having gold-coated copper electrodes. Gold coating copper electrodes improves resistance and prevents them from getting oxidised.

The sensor was placed inside a sealed desiccator in the presence of air at room temperature and probed to obtain the base resistance of the sensing film. The team monitored the change in sensor resistance in the presence/absence of CO using a computer controlled device. They recorded the responses of the sensor film at different concentrations of CO. The sensor proved highly suitable for detecting CO gas, even at lower concentrations than those harmful to humans.

'We observed a sharp and significant response when the film was exposed to CO and the response remained in saturation as long as CO was present in the chamber. Surprisingly, recovery time was lower than sensing time' says Mittal, Amity University, Noida.

'We ensured the reproducibility of the sensor, using different sets of electrodes multiple times' adds Robin Kumar, Amity University, Noida.

Even after eight months, the copper octahedral molecular sieves showed stable electrical and sensing parameters.

The sensor is cost effective. So, this research could be translated to high-quality room temperature sensors for CO gas detection, and for air pollution monitoring.

Sens. Actuators. B Chem., **266**: 751–760

Game of Bribes

Don't ask too much

The robustness of a policy is a challenge for decision-makers. Myriads of unpredictable factors play yoyo with the efficacy of regulations, especially how they affect the population. Can theoretical models predict the possible outcomes of a new policy?

Supratim Sengupta and team from IISER Kolkata used Game Theory to approach bribery, a pervasive social problem. They analysed the process of harassment bribery in a complex network. Using Evolutionary Game Theory, the team examined the conflicts between a service officer and citizens.

They simulated the complex world scenario with variables like cost of complaining, bribe amount demanded and the asymmetric nature of the interaction, closely resembling the real world.

The findings suggest that a shift in just one variable can lead to a population dominated by corrupt officers.

The structure of the underlying social network in which a citizen is embedded, and the average number of connections each citizen has, can significantly impact the spread of corruption.

For a moderate number of connections, a random social network turns out to be more suitable for honest officers to prevail than more structured social networks. In linear-chain-like social networks, there is an optimal range of connections which increases the likelihood of spread of honest officers.

'Low bribe amounts and moderate to high cost of complaining allow the spread of corrupt officers', says Supratim Sengupta. Thus, ease of complaining would be a means to reduce bribery incidents. But, when faced with such a situation, his advice is not to ask advice from too many people. Having a few advisors from closest connections is a better, long term strategy.

Their work also reveals how changes in individual decisions can affect population-level outcomes in such social conflicts. The group hopes that this is an important step towards improved understanding of the outcome of government policies before implementation.

J. Theor. Biol., **450**(7): 43–52

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