

Science Last Fortnight

Electro-Bio-Stimulation

Restoring soils with textile dyes

Tirupur, in South India, an export hub for textiles, has many textile units that use chemical dyes. The dyes pollute soils in the area. The soils, thus, become unfit for agriculture.

Scientists from the Central Electro-chemical Research Institute, Karaikudi, the Dryland Agricultural Research Station, Chettinad, and the University of Vigo, Spain recently proposed an integrated approach to address the problem: electro-bio-stimulation.

Bioremediation is a cost effective method for treating polluted soil environments. However, it may not be useful for soils heavily contaminated with dyes, heavy metals and chlorinated compounds. Moreover, it is slow, compared to chemical and physical methods of remediation.

The team combined electrical and biological principles for quicker and more efficient clean-up of farming soils.

They first isolated four bacterial strains: *Brevibacterium halotolerans*, *Bacillus subtilis*, *Achromobacter* sp. and *Pseudomonas aeruginosa* from textile effluent contaminated soils and petroleum pipelines at Tirupur.

The scientists used three compartments separated by perforated acrylic sheets for their experiments. The soil to be treated was placed in the central one. For the electrical components, they used 0.5% starch as anolyte and 0.1 M acetic acid as catholyte. Starch enhances electrokinetics – applying an electric field dissociates fluid from particles and propels it.

In the electro-bio-stimulation experiments, they added the culture of isolated microbes to starch. The starch now doubles up as food for the microbes and as anolyte. The bacteria bio-stimulate the existing electric phenomena.

The team conducted these experiments on lab scale, using a voltage gradient of 2 V/cm for five days. They found that, for removing pollutants such as chlorides and sulphates, electro-bio-stimulation was more effective

than electrokinetics. This, the scientists say, is due to the bacteria that produce B-cyclodextrin, known to improve the solubility of many compounds.

Once they realised the superior performance of electro-bio-stimulation, they conducted pilot scale experiments for fifteen days using 0.5 V/cm. The scientists then evaluated soil quality using the germination of black gram as indicator. They found germination rates significantly higher in electro-bio-stimulation treated soils.

These experiments show that soils contaminated with textile dyes can indeed be reclaimed for agriculture. The zero effluent policy that has recently come into effect will reduce contamination of soils near textile industries. However, to clean up already polluted soils, we need more policy initiatives.

Sci. Tot. Environ., **624**: 1649–1657

Flower Power to Clean Water

Nanosolutions bloom with microwaves

The textile industry has become the epicentre of large scale water pollution. Scientists have attempted to degrade pollutants using semiconductor photocatalysts. However, the efficiency of these techniques is, so far, not adequate for large scale applications.

Researchers from the National Institute of Technology, Assam recently reported a solution for the problem.

Using a microwave assisted technique they engineered a low-cost, non-toxic semiconductor photocatalyst of zinc oxide. Field Emission Scanning Electron Microscopy and Transmission Electron Microscopy images reveal that variation of microwave irradiation power resulted in nanorods. When reaction temperature was increased from 28°C to 180°C, the nanorods exhibited a more orderly arrangement resulting in flower-like morphology.

Each rod-shaped petal was about 150–200 nm in length. This could be attributed to the nucleation and differences in rates of growth at elevated temperatures. Further increase of microwave power transformed the

nanostructures into dense, uniform nanoflowers with greater petal diameter.

The researchers evaluated the photocatalytic performance using an organic dye – methylene blue – as model pollutant. The dye was successfully decolourised by the photocatalytic action when exposed to solar irradiation. The nanoflower form of zinc oxide showed better photocatalytic performance.

The flower-like structures of the photocatalyst have larger surface area and are porous. These help increase photon absorption and improve the performance, say the researchers.

Using the right temperature and microwave power, the scientists could control the morphology of the nanoparticles. The strategy may be useful in producing nanoparticles of other metal oxides possessing the required morphology.

J. Matlet, **219**: 76–80

Magic Membrane

Drinking water from wastewater

Drinking water scarcity drives research to develop technologies to make dirty water potable. Sophisticated equipment and costly materials make present technologies unaffordable for the majority. Membranes made with polymers hybridised with nanocomposites are easy to produce. However, most have shortcomings when tested on wastewater.

Recently, K. Buruga and J. T. Kalathi of the NIT, Karnataka and collaborators from the Hanyang and Korea Universities, reported fabricating a polymer–clay nanocomposite membrane to purify wastewater. Halloysite is an aluminosilicate clay mineral. The halloysite nanotubes have a hollow, tubular structure with high biocompatibility and good mechanical strength. Besides serving as sieve, they possess inherent antibacterial abilities and display high antifouling properties. The nanotubes also exhibit a unique geometry and surface chemistry, with positively charged lumen and negatively charged surface

to capture contaminants with opposite charge.

The team suspended the halloysite nanotubes in a solvent and sonicated the solution to a homogenous mixture. Polystyrene, which acts as matrix, was added to the mixture. The team uniformly spread the mixture over glass plates. When the solvent evaporates, it leaves a thin membrane with uniform tiny pores.

The team tested the chemical, physical, morphological and performance-related aspects of the membrane. Using different solvents, they found that they could get membranes with different properties.

To ensure high purity of water, they designed a two-staged filtration unit with micropore and nanopore membranes. Both membranes were fabricated using the same protocol but with different solvents. The micropores of $1000\text{--}10^4$ Å facilitated microfiltration whereas $10\text{--}1000$ Å nanopores enabled ultrafiltration.

For real-world application, the team assembled the membranes in an apparatus, with a vacuum pump between the compartments. The wastewater sample was first passed through the microporous membrane. The vacuum pressure created by the pump on the lower compartment forced the micro-filtrate to enter the nanoporous membrane.

The filtered water met the WHO standards for drinking water. The scientists say that the membrane is reusable and provide a simple base-acid cleaning method to retain high performance after multiple uses.

Halloysite is an easily available and naturally occurring mineral, making fabrication low cost. The membranes made by hybridising polymer and halloysite have high mechanical and tensile strength, and are, thus, resistant to harsh environments. The membranes will attract entrepreneurs from the water purification sector, hopes the team.

J. Ind. Eng. Chem., **61**: 169–180

Levodopa from Itchy Beans

Supplement for breast cancer therapy

Mucuna pruriens – velvet or itchy or devil beans – is a traditional herbal

medicine. This nutritive herb is used for treating scorpion bites, infertility, diabetes, Parkinson's and depression. Though the hairy pod causes severe itching, the seeds are relatively rich in the neurotransmitter levodopa, a dopamine precursor. Levodopa is also a natural inhibitor of the prolactin hormone, which plays a critical role in breast cancer progression.

Recently, a team led by Neeta Shrivastava from PERD, Ahmedabad, and scientists at the NIPER, Gandhinagar, reported the molecular mechanism underlying dopamine-mediated prolactin inhibition in breast tumour progression, using *M. pruriens*. 'Re-purposing existing drugs using *in vitro* and *in silico* techniques will reduce the cost and time of drug discovery and development – much required in the Indian scenario', says Neeta Shrivastava.



By Ton Rulkens, Wikimedia Commons

The team first prepared a methanolic extract of *M. pruriens* seeds. After dehydrating the extract into powder using a lyophilizer, they estimated the levodopa content using high performance liquid chromatography. Next, they established the anti-proliferative property of this extract under *in vitro* conditions using different breast cancer cell lines. They also analysed the effect of *M. pruriens* seed extract and standard levodopa over colony forming ability, cell cycle progression, DNA damage and apoptosis in the cell lines. And found inhibition in cell proliferation and cell cycle arrest, followed by apoptosis in the cells treated with seed extract.

Using real time PCR, they quantified the expression of the prolactin gene and followed protein expression using western blot experiments. The

researchers observed that the presence of *M. pruriens* inhibits prolactin protein expression, thus halting cancer progression. This blockade also increased the efficacy of the chemotherapeutic drug, cisplatin, when co-supplemented with the *M. pruriens* extract.

The study successfully tested a well-known antiparkinson drug on breast cancer suppression. The crude form, in particular, gave better results as it works in synergy, remarks Neeta Shrivastava.

The team suggests using levodopa from *M. pruriens* seeds as dietary supplement along with chemotherapeutic drugs for effective breast cancer therapy.

J. Ethnopharmacol., **217**: 23–35

Fighting Neurodegeneration

Is quercetin the answer?

Estimates report that, in India, two in hundred suffer neurodegenerative disorders – progressive cognitive, behavioural and motor dysfunction. These diseases cause serious disabilities in many old people. This may increase with the demographic shift, when the majority of the population becomes older.

Interestingly, there is a common factor in neurological disorders: deficiency of cathepsin D, a protein essential for the health of neurons.

Recently, Phaniendra Alugoju and team, from the Pondicherry University, reported a solution. They chose *Saccharomyces cerevisiae* with *PEP4* proteinase A gene mutation, as their experimental model. This mutation is equivalent to the cathepsin D gene mutation in humans. Both proteinase A and cathepsin D help increase protein turnover after oxidative damage. As a result, the cells are protected from hydrogen peroxide and acetic acid induced apoptosis.

The oxidative and apoptotic stresses progressively increase during aging. If that is the case, antioxidants should reduce the problem, reasoned the researchers.

So they set out to explore the neuroprotective property of quercetin, by using the yeast model. Quercetin is a well-known antioxidant found in fruits,

vegetables, tea and red wine. They cultured wild type yeast and mutant yeast under the stressful conditions by adding acetic acid and hydrogen peroxide to the culture medium and observed the effects.

The results showed the mutant cells to be highly sensitive to induced oxidative and apoptotic stress.

Then the scientists added quercetin to the medium. However, quercetin pre-treatment protected the experimental group from oxidative and apoptotic stress-induced sensitivity. Further, pretreatment also increased viability as well as stress tolerance against oxidant, apoptotic and heat stress.

The scientists say that quercetin could be a potential therapeutic molecule for reducing aging of the central nervous system at the cellular level.

Though these experiments were done on a mutant yeast strain, the results raise hope in the fight against neurodegenerative complications as the *PEP4*/yeast models are a widely accepted model for the purpose.

So the researchers hope that in the future, quercetin could be used in the treatment of neurodegenerative diseases associated with cathepsin D gene mutation.

Curr. Microbiol., **75**(5): 519–530

Monitoring Kidney Function *Electrochemical biosensor*

To prevent chronic kidney disease progressing to renal failure it has to be detected early. However, detecting progression, with available techniques, is tedious, time-consuming and expensive. There is a biomarker for kidney function, cystatin C, a small protein. The protein is broken down by the kidney but a small amount is excreted through urine. As kidney function deteriorates, cystatin C levels in urine increase. However, so far, there is no sensor to detect this.

Recently, Manali Datta and team from the Amity Institute of Biotechnology, Rajasthan collaborated with the CSIR-IGIB, Delhi and an Indian scientist in Nigeria, to propose a new sensor – a screen printed multiwall carbon nanotube electrode with immobilized papain for the rapid and accurate detection of cystatin C.

When cystatin C binds with the immobilized papain, it induces an electric signal which can be measured using cyclic voltammetry and differential pulse voltammetry – good methods to get qualitative results of electrochemical processes in various conditions.

The team used different concentrations of cystatin C to calibrate fluctuations in electronic transitions. The sensor detected chronic kidney disease stages accurately with a small volume of sample in 10 minutes. The scientists tested other biomarkers such as creatinine, albumin and gliadin, to confirm the specificity of the sensor.

‘Diabetic, hypertensive and heart patients are prone to kidney malfunction at later stages’, says Manali. The team hopes this economical, fast and reliable technique, for the early detection and monitoring of progression of chronic kidney disease, will soon find use in clinical practice. ‘Such a point-of-care device to monitor kidney disorder can help stall progression if followed up with simple diet modifications’, suggests Manali.

J. Biosens. Bioelectron., **105**: 90–94

Detecting Chlorpyrifos Pesticide *Using ultrasensitive nanoparticles*

Chlorpyrifos, a pesticide, is liberally used, worldwide, on crops such as fruits, vegetables, cotton and tea. This highly toxic chemical enters the food chain. Long-term exposure can lead to cancer, reproductive and neurological disorders, allergic reactions as well as neurodevelopmental impairment in children.

There are many qualitative and quantitative techniques to detect the pesticide. Instrument based techniques provide high sensitivity but are time consuming and costly. They call for trained personnel and are not suitable for on-site application.

Now, Sonul Gandhi and team from the Amity University and the CSIR-IGIB in collaboration with researchers from Russia have worked together to develop a sensitive, specific and economic electrochemical nanosensor. The sensor is made of a fluorine-doped tin-oxide electrode fabricated with gold nanoparticles and immobilised anti-chlorpyrifos antibodies. Fluorine-doped tin oxide coated glass is electrically conductive and ideal for use in a wide range of devices. Gold nanoparticles enhance its sensitivity.

The team found that the nanosensor exhibited high sensitivity and a stable response for the detection of chlorpyrifos, ranging from 1 femtomole to 1 micromole. They successfully tested the sensor for the rapid detection of chlorpyrifos in apple, cabbage and pomegranate. A 5 g sample is crushed, mixed in buffer solution and centrifuged. Only one millilitre of the sample is needed to check for the presence of the pesticide.

This nanosensor can be miniaturized and used as quantitative tool for rapid, on-site detection of chlorpyrifos traces in real samples.

J. Biosens. Bioelectron., **105**: 14–21

Nitrous Oxide Emissions *Reducing through muffler design*

There are extensive global efforts to replace fossil fuel with blended fuel. Blending alcohols, such as methanol, with petrol, can reduce carbon emissions. But that leads to higher temperature which, in turn, leads to increase in nitrogen oxide emission. Researchers are looking for ways to dissipate the temperature of exhaust gases.

Modifying muffler design can reduce exhaust temperature, thought researchers at the KIIT University, Bhubaneswar. In collaboration with the Veer Surendra Sai University of Technology Odisha, they undertook a study to understand the pattern of temperature under perforated and non-perforated muffler design.

First, the team blended methanol with petrol in different proportions to investigate the fuel characteristics. They confirmed that fuel blending does not create any major variation in fuel properties. Then, using solid modelling software, the scientists created a three dimensional solid model of the muffler. They converted the design layouts to a CAD model for computational fluid dynamics analysis, using back pressure, exhaust temperature, gas density and velocity streamline as primary parameters. They carried out this analysis on both perforated and non-perforated

mufflers. And found that an increase in back pressure increases exhaust temperature. The perforated muffler had less back pressure than the non-perforated design. This is because of the availability of the multiple passages in the design which helps the gases expand, say the researchers. The expansion of the gases reduces the temperature – which, in turn, reduces nitrogen oxide formation.

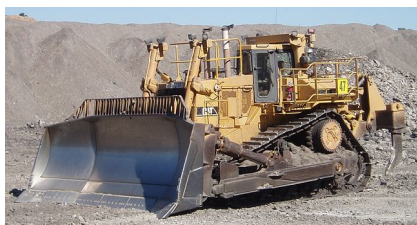
The team recommends that the design be adopted in all ranges of petrol engines. They also have suggestions for further research to reduce emission even more by regulating perforation hole size.

J. Clean Prod., **183**: 869–879

Abrasion-resistant Steel Buckets *Carbide-free bainite*

Mining, agriculture, transport and construction industries use huge steel buckets in excavators and shovels. They are essential components for soil penetration and for handling bulk material. Since they are in direct contact with different types of sands and rocks and, that too, in harsh field environments, such buckets need to be hard, and strong, as well as abrasion and corrosion resistant.

Abrasion-resistant equipment is mostly made with tempered martensitic steel. The tetragonal crystalline microstructure makes martensitic steel hard. But it is less ductile and sensitive to heat-treating variables. The heat and strain generated during abrasion reduces hardness of surface significantly. Moreover, martensite steel suffers fragmentation of the wear track because of low plastic deformation at the wear surface, resulting in less adhesion of the damaged area.



Source: Wikimedia Commons

Last fortnight, Minal Shah and Subhankar Das Bakshi, from the National

Metallurgical Laboratory, Jharkhand reported overcoming the problem. They developed a bainitic steel – steel with plate-like microstructure – with superior abrasive wear resistance, high strength, good ductility and low cost.

They experimented with three ferrous alloys of similar hardness but with different microstructures – carbide-free bainite, austenite, martensite – and a mixture of martensite and bainite. The scientists prepared sample bars with these three types of ferrous alloys by melting, forging and heat treatment. They conducted microstructural analyses for confirming the fine structural details of the sample bars.

For abrasion test, they used a standard dry-sand rubber wheel, repeating the test on five samples of each type, to confirm and validate the results. The team made abrasions on the sample bars by manual grinding and shear punching.

They conducted X-ray diffraction analysis before abrasion to find the phases present in the steel. Then, after abrasion, they conducted a three-body abrasion test to calculate the specific wear rates.

The scientists found the specific wear rate of martensite to be approximately two times higher than that of the other two. They report that steel with a mixture of bainite and martensite shows better wear resistance than martensite. Carbide-free bainite has significant plastic deformation at the active surface, and is, thus, most wear resistant, say the scientists.

The plate-like structure of bainite steel undergoes plastic deformation when stressed. But the plates had good adhesion. So, unlike with martensite steel, the harder layer on the active surface improved the abrasion resistance of bainite steel.

Earth moving equipment undergo abrasive wear. This not only reduces the service life but also affects the safety and reliability of the equipment. The costs incurred due to such abrasive wear are high. This research collaboration between CSIR and Tata Steel may soon lead to the replacement of the existing martensitic steel

buckets, with more abrasion-resistant carbide-free bainitic steel buckets.

Wear, **402**: 207–215

Simulating Functional Molecules *Improving solar cells*

Metal-free organic dyes are efficient solar cell sensitizers. They improve sunlight absorption, making solar cells perform better. Prior knowledge of the properties of such sensitizers facilitates pragmatic design strategies for sensitizers. Now, the accumulated structure–property correlations of many sensitizers can be used to drive ‘theory precedes practice’.

In a recent conceptual paper, Mohankumar, Senthil Pandian and P. Ramasamy from the SSN College of Engineering, Chennai derive the light harvesting efficiencies of newly designed sensitizers using computations.

The researchers investigated the donor configuration and computed the properties relevant to sensitizers. The simulation brought out an interesting result: doubling the donors helps decrease the energy gap.

The predicted efficiencies are high. ‘Our results are useful to tailor new sensitizers’, says P. Ramasamy who led the research team.

‘It is now possible to design dye molecules to improve the performance of solar cells.’

About a century ago, Paul Dirac had observed that it is not our knowledge that limits us, but the complexity of the equations. But, now, armed with computing power, researchers are overcoming the limitation. India needs to invest more on high performance computing and take advantage of emerging scientific tools.

Mater. Lett., **219**: 216–219

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