Science Last Fortnight

Antibiotic Resistance
Amplified by urban waste

India is the largest consumer of antibiotics. Antibiotic-resistant strains evolve due to this large scale consumption and the discharge as waste, especially from urban hospitals. The release of such untreated waste into rivers, lakes and seas increases the chances of the transfer of antibiotic resistance genes to other organisms. Consumption or contact with the contaminated water leads to diseases which are not easily treated with existing antibiotics.

Last fortnight, researchers from the Savitribai Phule University, Pune in collaboration with the University of Gothenburg, Sweden reported the impact of untreated sewage discharge, into the Mutha River, on the distribution of antibiotic-resistant strains.

The Mutha is one of the most polluted rivers in Pune. Though Pune has several sewage-treatment plants, 64% of untreated urban waste contaminates the river. The team collected samples from different points of the Mutha and performed a metagenomics analysis. They found that antibiotic-resistant genes are 30 times more in bacteria from river water contaminated with urban waste. These bacteria showed resistance to multiple antibiotics such as tetracyclines, beta-lactams, amphenicols, aminoglycosides, carbapenems, and tigecyclines.

The World Health Organization predicts that 10 million deaths per year may occur in 2050 due to antibiotic resistance. There is an urgent need for efficient treatment of hospital and urban waste – major sources for antibiotic-resistant strains.

Water Res., **124**: 388–397

Metformin Loaded Hydrogels
Regulating glucose levels

Hydrogels are three-dimensional matrices of polymers that can hold large amounts of water. They can be made from naturally occurring polysaccharides such as cellulose and chitosan. Hydrogel technology has wide biomedical applications including contact lens manufacture, wound dressing and as diaper adsorbents. Hydrogels are also being explored as drug delivery vehicles.

Now researchers from the Jabalpur Model Science College and the Kymore Science College, have come up with cellulose pulp hydrogel-based drug delivery. They synthesized a ternary polymeric hydrogel system, comprising of cellulose, polyethylene glycol and sodium acrylate and tested drug delivery using an anti-diabetic drug, metformin hydrochloride.

The researchers prepared the hydrogel complex by incubating the hydrogel with metformin hydrochloride solution. They studied swelling capacity and drug release behaviour using buffers similar to gastric and intestinal fluids. They also addressed the biocompatibility of metformin hydrochloride hydrogel and drug release patterns, from acidic to neutral pH, thus simulating the transitions in the environment of the gut.

The glucose profiles of anti-diabetic rat models, treated with metformin hydrochloride loaded hydrogels, showed significant and results comparable to controls. The hydrogel released metformin slowly and could be administered every third day instead of daily doses of regular tablets.

The scientists also examined islets cells from pancreas under a scanning electron microscope. The metformin hydrogel treated group showed better recovery of islets cells from necrosis and inflammation than that found in the control group.

Thus, researchers highlight the advantages of hydrogel-based metformin hydrochloride over classical oral formulations and throw light on the possibility of hydrogel-based delivery with controlled and sustained release. This method of low frequency drug administration controls glucose levels and aids to taper down metformin hydrochloride daily dosage considerably.

India happens to be the diabetes capital of the world with highest incidence of type 2 diabetes. Among the oral medications for type 2 diabetes mellitus, metformin hydrochloride, a non-sulphonylurea, is an effective antidiabetic prescribed as immediate and extended release tablets.

J. Macromol. Sci., Part A, **54**: 186–193

White Grub – No Pesticide Needed
Nematodes as biocontrol

The areca white grub, *Leucopholis lepidophora*, is a serious pest of arecanut, sugarcane and groundnut. It spends most of its life as a grub in soil and feeds on roots. Unfortunately, the pesticides used to control this pest harm the environment.

Image: School of Ecology and Conservation via Wikimedia Commons

Jagadeesh Patil and team from the National Bureau of Agricultural Insect Resources, Bengaluru tried a new approach to tackle the problem. They experimented with the capabilities of nematodes for managing this pest. Nematodes of the family Steinernema and Heterorhabditis are known to kill soil-dwelling insects. They enter the insect body through natural openings, feed, multiply and eventually kill it.

The scientists focused on two indigenous species – *S. abbasi* and *H. indica*. They reared the nematodes on greater wax moth larvae and tested the efficacy of these nematodes in laboratory and field conditions. For laboratory assay, the team used grubs at second and third instar stages. They inoculated the grubs with infective juvenile nematodes at different rates and assessed mortality after 14 days. They found that *H. indica* was more effective than *S. abbasi* in both instar stages.

The team then tested the field efficacy of the nematodes against a common chemical insecticide, chlorpyrifos, in two separate arecanut plantations. They did a preliminary reconnaissance check-up for the presence of selected

nematodes, to ensure accuracy. The scientists applied the reared infective juveniles in 5 litres of water per infected palm and, for control, the recommended dosage of chlorpyrifos in similar volume per infected palm. After six weeks of application, *H. indica* caused >90% reduction of grubs and had better efficacy than *S. abbasi* and the insecticide. They also reported that nematodes can persist up to 120 days after application.

The team suggests that combined application of both entomopathogenic nematodes can improve efficacy. This indicates that there is greater potential for entomopathogenic nematodes to be commercially utilized as biocontrol agents.

Crop Protect., **101**: 84–89

Fruit Ripening Indicator

Fruitful research

Ripened fruits, especially soft-skinned ones, are often damaged during transportation, affecting trade. Early detection of ripening stages may reduce the risk for fruit traders and help them transport fruits before they spoil.

Recently, a team of researchers from the CSIR-IGIB, New Delhi and the Deenbandhu Chhotu Ram University of Science and Technology, Haryana, developed an ultrasensitive nanosensor to detect the stages of fruit ripening. This technology is based on the detection of the level of malic acid in fruits, which indicates the timing of fruit ripening.

The team used a screen-printed, carboxylated, multi-walled carbon nanotube electrode that can transfer electrons from sensor to detector. They immobilized malic enzyme covalently onto this electrode. When malic acid from the samples reacts with the enzyme, electrical signals can be detected from the carbon nanotubes. This helps quantifying malic acid content.

Using juice extracts from different stages of tomato, the scientists measured electrical signals from the nanosensor to determine its sensitivity. They found that there is an increase in malic acid as the tomato ripens. However, the amount of malic acid reduced in over-ripened tomatoes. This indicates that malic acid concentrations correspond to fruit ripening stages. Using this technology, tomatoes can now be tested before being transported.

Image: Economic Times

The nanosensor can even detect 0.01 mM of malic acid in samples and needs less than two minutes to complete the process. The nanosensor does not produce signals when compounds other than malic acid bind with the enzyme. So the test is very specific. Fruit farmers, traders and industries will find this technology helpful for large scale, rapid screening of fruit maturity.

Food Anal. Methods, **10**: 3680–3686

Role of Soil Macrofauna

Modifications by leaf litter

Soil biodiversity is an important aspect of ecology. It contributes to the sustainability of agriculture. Little is known, however, about the relationship between soil macrofauna and soil fertility management in the agricultural fields of the Himalayas.

Soil fertility restoration in the region is usually done with farmyard manure. The most common practice is the use of pine and oak litter along with dung. Is there a difference in soil macroflora diversity, depending on the leaf litter used? Researchers from the G.B. Pant National Institute of Himalayan Environment and Sustainable Development, Uttarakhand examined the influence of soil macrofauna communities on litter decomposition, nutrient release and soil quality.

They chose two sites, both more than one kilometre above sea level – one where pine litter is used and the other where oak litter is used, for preparing manure. They also maintained defaunated soil in both sites. They found greater decomposition in control plots than in defaunated soil, demonstrating the role of macrofauna in decomposition. They made observations and measurements for about two years.

They found maximum density of macrofauna in the first 10 centimetres. As the soil depth increased, the fauna density reduced till 30 centimetres. The team identified 10 soil macrofauna groups, common to both sites, over an annual crop cycle of wheat and rice, in both sites. Interestingly, they found that, whereas centipedes were abundant between 10 and 20 centimetres of soil in the site using pine litter, they were totally absent in the site with oak litter. And Acarina, a group that contains ticks and mites, found in the oak litter site, was absent in the site with pine litter farm yard manure.

The researchers observed greater abundance of macrofauna in the site that used oak litter. As well as greater decomposition in oak litter farm yard manure.

The team observed that the rate of litter decomposition increased across the decomposition cycle. And that soil fertility improved in both sites, over the two-year period of the study. The scientists also found that there was greater increase in nitrogen content in the site with oak litter farmyard manure than in the other site.

The researchers analysed soil moisture correlation with soil macrofauna density. Interestingly, they found that the peak abundance of soil fauna occurred in February in the plots with oak litter, whereas in the site with pine litter, it happened in September.

In mountain agroecosystems, macrofauna varies with soil depth and the quality of organic matter. Thus, to restore the decomposition function of nutrient-poor soils, the colonization and diversity of soil macrofauna has to be promoted. The team recommends the use of oak, rather than pine, litter as organic matter input.

Given the growing interest in microbial communities in soils, the next step is to understand the network among microflora, macrofauna and plants.

Appl. Soil Ecol., **120**: 20–29

Increasing Aquaculture Yield

Tackling infections

Disease outbreak is a major threat to aquaculture. Pathogens can spread faster in an aquatic environment than on land. Infectious diseases are the biggest killers of farmed fish. An outbreak can wipe out the entire stock. Antibiotics are conventionally used to control infections. However, they are not effective, as most pathogens form biofilms – thin layers of mucilage – to protect themselves. Also, resistant strains are emerging in aquaculture farms due to the indiscriminate use of antibiotics. Residual antibiotics, in cultured organisms, also pose a potential health risk.

To address this problem, Faseela Hamza and associates, from the Savitribai Phule University, Pune prepared modified probiotics using marine yeast, *Yarrowia lipolytica*. This yeast species is an excellent nutrient supplement in fish farms. Previous studies have shown that it has immunostimulant properties and improves the health of cultured fish.

Image: Hans Hillewaert, Wikimedia Commons

They cultured the yeast under different laboratory conditions with sodium selenite. The organism is known to bioaccumulate selenium, an essential trace element for human and animal health. It is an integral part of an enzyme that protects the organism from oxidative damage. Interestingly, they found that the organism accumulates high amounts of selenium as nanoparticles in a cell associated manner. The nanoparticle form of selenium has shown high effectiveness in medical uses.

After obtaining yeast biomass loaded with selenium nanoparticles, the researchers fed it to brine shrimp, *Artemia salina*, a model aquaculture organism. The results were promising: compared to normal feed, the selenium enriched yeast increased survival rates of brine shrimps and offered better protection against bacterial infections. What's more, the treatment increased the growth of brine shrimp!

The results of this study indicate the possibility of using this specialized probiotic in aquaculture farms for increasing yield and curbing infectious diseases without causing harm to the environment and human health.

Enzyme Microbial. Technol., **106**: 48–54

Arsenic Accumulation by Vetiver

Arsenic is an abundant element in the environment. Weathering of rocks, microbial and human activities accumulate arsenic in specific locations. Industries, arsenic-based pesticides, semiconductors and lead-acid batteries are major sources of arsenic in the environment. Arsenic toxicity is a global issue due to its increasing contamination of water, soils and crops.

There are many conventional methods to remove arsenic including the use of adsorbents, as well as chemical, photochemical and photocatalytic oxidations. The costs of these technologies, however, are not suitable for large ecosystems.

Recently, scientists from the Bhabha Atomic Research Centre reported bioremediation of arsenic using vetiver plants. Vetiver has a well-developed root system, which is used for soil/water conservation and wastewater treatment. It also removes heavy metals like manganese, iron, zinc and copper from industrial wastewater and contaminated soil. However, information about the plant's capacity to remove arsenic is limited.

The scientists exposed vetiver plants from their experimental field station to different concentrations of arsenic in controlled conditions. They used a hydroponic system – without soil – to reduce the chances of interference by soil microorganisms. And they analysed the arsenic absorption rate using several analytical methods.

The results of the study indicate that vetiver plants can remove 11% of arsenic in one week and 28% in two weeks from a 10 μM arsenic solution. The capacity of the plants increases with increase in arsenic concentration and duration.

Vetiver is thus a potential accumulator of arsenic. Since it can be used for the removal of other heavy metals as well, it can help restore mine spoil-dumps, fly ash dump sites and inland re-vegetation/reclamation projects.

Biological methods to remove arsenic are economically viable and environment friendly. However, the time taken for bioremediation is a drawback. Meanwhile, arsenic contaminated drinking water affects the lives of 150 million people across the world.

Ecotoxicol. Environ. Safety, **145**: 50–56

Make Room for the Shroom

For heavy metal pollution

Despite the recent rise in alternative energy sources, India still depends on coal as its major source of energy. Inevitably, this has led to an environmental crisis due to mining, washing and processing of coal. Effluents enriched with fine coal particles, impurities and toxic metals such as arsenic, lead, cadmium, chromium, iron, manganese, cobalt, copper, aluminium and nickel have become a serious cause for water quality deterioration. Although many methods have been developed for the removal of heavy metals from coal washery effluents, the development of a fast, economical and environmentally suitable method is imperative. To this end, mycoremediation, the use of mushrooms or macrofungi for the removal of heavy metal waste, is being considered as an effective alternative.

M. P. Singh and team, at the Centre of Biotechnology, University of Allahabad used oyster mushrooms, *Pleurotus ostreatus*, for the decontamination of coal washery effluents. They assessed heavy metal concentrations as well as physicochemical parameters such as dissolved oxygen and CO_2 levels in the effluents collected from one of the coal washery plants of BCCL, Dhanbad. They then treated both raw as well as diluted effluents with the

fungus and measured changes in their heavy metal concentrations. They also investigated how these mushrooms detoxify the accumulated metals and the subsequent changes in the physiology of the mushrooms by analysing stress marker parameters such as the levels of metallothionein proteins and antioxidant enzyme levels.

The team observed that the fungus removed significant amounts of metals from the effluents. However, they also noticed that diluting the raw effluents prior to fungal treatment resulted in improved metal removal by the fungus.

Image: Charl de Mille-Isles via Wikimedia Commons

The researchers are optimistic that the use of *P. ostreatus* can serve as an economic and environmental friendly method for decontamination by various industries prior to waste removal.

Ecotoxicol. Environ. Safety, **149**: 42–49

Antimicrobial UV-Resistant Cloth

Protection with neem and chitosan

Clothes give us protection from sunlight and act as a primary barrier against many harmful bacteria. Yet, people suffer from skin infections caused by *Staphylococcus aureus* and *Escherichia coli*.

To counter these bacterial infections, scientists from the Rangasamy College of Technology, Tamil Nadu, collaborated with a scientist from Singapore and developed an antibacterial fabric using nano formulations of neem, *Azadirachta indica*. Interestingly, the fabric turned out to be UV resistant as well.

'Neem leaves are claimed to have antifungal, antibacterial and antiviral properties. So we thought of using neem to develop a fabric that can protect us against common bacteria such as *S. aureus* and *E. coli*', says Rajendran Venkatachalam.

The scientists collected neem leaves, washed them in distilled water and dried them in shade. The dried leaves were made into nanopowders. The researchers homogenized the powder with nano chitosan.

After preparing herbal nanoparticles and nanocomposites, they took fine cotton woven fabrics and coated these two materials on the fabric. The padded fabric was dried to get a uniform coating.

'We tested the fabric against two common bacteria, *S. aureus* and *E. coli*, by dipping the nano coated fabric into the bacterial culture. The fabric successfully suppressed the growth of bacteria in its surroundings by its antibacterial property', says Karthik Subramani.

Then the scientists tested fabric qualities such as tensile strength and tearing strength against standards followed by textile industries. 'The coated fabric has properties similar to those of normal fabric' says R. Suriyaprabha.

The team also tested the fabric against UV radiations by exposing it to UV rays, and found that the nanoparticles in the fabric blocked UV radiations, thus providing protection against these harmful rays.

The scientists claim that the antimicrobial and UV protection property of the fabric remained even after repeated washes.

Here is a research report that can be used by textile industries to make UV-resistant cloth with antimicrobial properties. Such fabric might also prevent skin cancers and the wrinkling of skin caused by UV rays.

J. Alloys Compd., **723**: 698–707

Preventing Plastic Pollution

Nanomaterials and sunlight

Most plastics are non-biodegradable. And that presents us with the problem of plastic pollution – accumulation in the environment. Plastic waste management is a problem, worldwide.

Recently, a team of scientists from the CSIR-National Physical Laboratory, New Delhi came up with a method to degrade polypropylene, a non-biodegradable plastic, using solar irradiation. They used TiO_2-reduced graphene oxide nanocomposites to achieve this.

TiO_2 is a well-known photocatalyst and can be used to degrade plastic. The reduced graphene oxide in the nanocomposite helps improve the absorption spectrum of TiO_2 nanocomposites, from the ultraviolet to the visible region. Thus, solar radiation is more efficiently absorbed.

The scientists mixed polypropylene with pure TiO_2 nanoparticles and TiO_2-reduced graphene oxide nanocomposites to conduct a comparative study on the photocatalytic degradation of the plastic. They examined photodegradation on thin film samples of these nanomaterials before and after subjecting them to 130 hours of solar radiation. After solar irradiation, they found that cavities had formed on the film surface, which demonstrated the photodegradation of the polypropylene plastic. This was further confirmed by a chemical compound analysis.

The scientists claim that the photodegradation of polypropylene by TiO_2-reduced graphene oxide nanocomposites is better than that by pure TiO_2 nanoparticles. Tailoring a nanomaterial for the photodegradation of a non-biodegradable plastic is an innovative step. But to tackle plastic pollution in the environment, more steps are required to take the results from lab to field.

Mater. Des., **133**: 10–18

S. Suresh Ramanan, G. Sharath Chandra, P. Gowdhaman, H. M. Mahadeva Swamy, K. S. Nitin, S. Balaji, K. V. Srividhya, Shumaila Afrin, Biraja Kumar Sahu and **Sileesh Mullasseri**

scienceandmediaworkshops@gmail.com