

Science Last Fortnight

Brand New Baryons

Predicting the quantum numbers

Earlier this year, the Large Hadron Collider beauty experiment at CERN detected five new subatomic particles, Omega-c zero baryons¹. These particles are the excited states of the Omega-c zero baryon, a heavier sibling of protons and neutrons. Nilmani Mathur, of the Tata Institute of Fundamental Research, Mumbai, and M. Padmanath, his former Ph.D. student, had predicted the pattern of the masses of these particles three years before their experimental discovery².

Once the masses of particles are determined, physicists want to find their quantum numbers. These quantum numbers can elucidate the internal structures of the particles which, in turn, can provide important information about the fundamental strong force of nature. Last fortnight, Mathur and Padmanath reported a calculation providing the quantum numbers of these new particles³.

This involved mapping the energy spectra and the quantum numbers of these particles using Quantum Chromodynamics, the theory of the fundamental strong force. So far, there is no analytical solution for using this theory to obtain the properties of these particles – it is a challenge related to a Millennium Problem of the Clay Institute. So, physicists use a four-dimensional system of lattices or grids – a method suggested by lattice gauge theory – to solve the highly complicated equations of this theory.

To obtain accurate results, the distance between grid points needs to be small, a fraction of a femtometer – one 1000,000,000,000,000th of a meter! Solving the equations of Quantum Chromodynamics on such small grids requires powerful supercomputers. Mathur and team used the facilities of the Indian Lattice Gauge Theory Initiative, which hosts one of the fastest supercomputers in the country. They could, thus, succeed in extracting the energy levels as well as predicting the quantum numbers of the newly discovered particles.

These baryons are made up of even smaller particles, quarks, which are believed to be fundamental particles. The force acting between the quarks, known as strong force, is the glue that holds all baryons. Certainly, the force is strong with this one.

¹*Phys. Rev. Lett.*, **118**: 182001

²Padmanath, M., Thesis, TIFR, 2014

³*Phys. Rev. Lett.*, **119**: 042001

Pollution and Rationing Traffic

Results from an experiment in Delhi

Delhi is one of the world's most polluted cities. Minute pollutants in the air, smaller than 2.5 microns, are a major concern. These particles are small enough to bypass the respiratory system's defences and can cause havoc in the body.

In January 2016, Delhi regulated traffic by formulating an 'odd-even' policy for 15 days. During this period, odd and even numbered private cars were restricted to odd and even days. Did this 15-day experiment have any significant impact on the pollution caused by micron sized particles?

A team of scientists from IIT Kanpur, IIT Delhi, NPL New Delhi, TERI, Delhi and IITM Pune examined the impact of this policy intervention on ambient particulate matter smaller than 2.5 μm through a combination of *in-situ*, satellite and model data. They analysed meteorological variables such as wind speed, wind direction and stability parameters. The team fed multi-sectoral emission inventories into an air quality model along with meteorological inputs to assess air quality in two scenarios: with odd-even rule and without odd-even rule. The researchers ascertained the difference in air quality in the two scenarios using a weather research forecasting model. Though traffic restriction reduced the presence of particles smaller than 2.5 μm by 4–6%, this is within the uncertainty range of satellite-based estimates.

The failure of the policy to have any significant impact on the micron sized particles is attributed to the meteorological conditions during that period. Besides vehicular emissions, there are other major contributors to the total

amount of particles: biomass burning, municipal solid waste burning, suspended soil and road dust. Moreover, there was no control over sources of particles outside the periphery of the city. The researchers say that merely restricting traffic volume in Delhi, without considering the meteorological conditions of the NCR, cannot control the 2.5 μm concentration over Delhi.

The Delhi Government missed the opportunity to conduct a unique experiment involving social, environmental and other scientists to study the issue in a holistic manner involving all parameters associated with traffic rationing: traffic congestion, air pollution, other related inconveniences and public perceptions. A more comprehensive multidisciplinary, inter-sectoral and inter-state action plan is required, if Delhi wants to stop being among the top polluted cities of the world.

Environ. Sci. Policy, **74**: 8–13

One Stone, Two Kills

New route to malaria prevention

Mosquitoes have developed resistance to many common insecticides. In the absence of efficient methods to check the vector population, there has been a rise in malaria transmission.

Managing mosquito population holds the key to disease control. Current larval control of mosquitoes hinges on the use of organophosphates and other insect growth regulators that are harmful to the environment. Scientists from the Bharathiar University, Tamil Nadu and the Calcutta University, West Bengal combined forces with researchers in Italy, Taiwan and Saudi Arabia and now report overcoming the problem.

The researchers opted to make use of silver nanoparticles which have a strong insecticidal action. These nanoparticles were further potentiated using chitosan – a polysaccharide which is known for its antibacterial and insecticidal potential.

The researchers extracted chitosan from crab shells by a multi-step process – the shells were ground, boiled and treated with chemicals to demineralize

them. The chitin thus extracted was deacetylated to yield chitosan and used in the synthesis of silver nanoparticles.

Chitosan conjugated silver nanoparticles were then tested for their larvicidal and pupicidal action on *Anopheles sudaicus* – a mosquito species found in coastal areas. When added to a tank containing larvae, the chitosan capped nanoparticles proved to be seven times as potent as chitosan in killing mosquito larva. These were also effective in reducing mosquito larvae in water reservoirs. The addition of nanoparticles could also improve the predation efficiency of goldfish for mosquito larva. This is of significance because goldfish is a natural predator of insect larva.

The scientists believe that these effects arise due to the small size of the silver nanoparticles that allows them to enter cells and interfere with physiology. By the same principle, they also inhibit many bacterial pathogens that cause waterborne diseases. These nanoparticles could, therefore, be used to tackle two issues at once: control mosquito larval population while improving water quality.

Hydrobiologia, 797: 335–350

Grin and Bear it?

Effect of stress and depression

The prenatal period is significant for brain development in the new born. However, during pregnancy, women tend to be vulnerable to stress and depression. Many studies reveal that psychological distress during pregnancy affects the neurodevelopment of offspring, and, thus, impacts the behaviour and physiology of the new-born. But the mechanism of this effect is not well understood.

Recently, A. C. Mondal and team from the Jawaharlal Nehru University, New Delhi, reported the impact of prenatal stress on neuronal development in neonates. They used animal models for experiments with different stressors. The researchers found that pregnancy-related stress and depression alter the function of the hypothalamic–pituitary–adrenal axis and autonomic nervous system. As a result, the glucocorticoid-cortisol level is increased which leads to the degeneration of foetal

hippocampal neurons – a major component of the brain, responsible for memories that enable navigation.

An elevated level of norepinephrine causes narrowing of the blood vessels of the placenta. This limits uterine blood flow. Oxygen and nutrient supply to the foetus is impaired which leads to low birth weight. The researchers noted that decreased levels of dopamine and serotonin alter signalling pathways, increase anxiety and depressive behaviour such as social dysfunction, inability to feel pleasure, cognitive impairment and decrease motor development. The team concluded that there was a significant association between maternal stress and neurodevelopment in the foetus and birth outcomes.

Prospective mothers might need to smile for two, just as they now eat for the foetus.

Int. J. Dev. Neurosci., 60: 1–7

Cognitive Deficit?

De-stressing to overcome

Stress is a part of our daily life. However, it does not always have a negative impact. Positive stress at work or in academics may lead to a promotion or to success in an examination. On the other hand, negative stress is linked to the development of depression, schizophrenia and Alzheimer's. Scientists from the National Institute of Mental Health and Neurosciences, Bengaluru recently demonstrated the impact of stress on memory, learning and anxiety-like behaviour

V. Bhagya and colleagues studied the effect of chronic stress on the hippocampus – the region of the brain responsible for learning, anxiety and memory formation. They took four groups of Wistar rats. The first was exposed to normal laboratory conditions. The second to stress for 6 hours a day. A third group was exposed to stress followed by time in an enriched environment, and the last group was only exposed to an enriched environment. The team found a reduction in normal learning, increase in anxiety like behaviour and deficit working memory in the rats exposed to stress. Those who were exposed to stress followed by time in a relaxed and happy environment, however, showed a high

degree of improvement in all these functions.

Based on the study, the scientists conclude that exposure to a relaxed environment, after prolonged exposure to stress, restores and improves hippocampal function. This, in turn, will lead to reduced risk of hippocampus associated diseases such as Alzheimer's, schizophrenia and depression.

So, time in a garden might not only de-stress you but also improve your cognitive functions.

J. Neurosci. Res., 95(8): 1602–1610

Bioartificial Pancreas

Permanent cure for diabetes?

Type 1 and Type 2 diabetes are chronic diseases affecting more than 422 million worldwide. In Type 1 diabetes, insulin production is deficient. While this can be controlled by insulin tablets and injections, transplanting the pancreas as a whole is a permanent cure. However, this is but a dream so far, and may be limited by availability. Moreover, transplantation triggers the immune system, eventually destroying the transplanted organ. Last fortnight, researchers from the Indian Institute of Technology, Bombay, reported that they have developed a bioartificial pancreas and collaborated with the Krishna Institute of Medical Sciences, Malkapur, to test it in mice. The researchers developed a biocompatible semipermeable hollow fiber membrane with a polysulphone composite. They then used this material for the encapsulation of umbilical cord derived stem cells differentiated into islet cells. This was then implanted into mice with diabetes. The bioencapsulated pancreatic islet cells mimic the fully functional organ in mice. The mice showed reversal of diabetes. The bioartificial pancreas is readily implantable and has not shown graft rejection. Moreover, it exhibited low absorption and high permeability of insulin.

Though diabetes was described more than 3500 years ago, we still lack a permanent cure. This is where the bioartificial pancreas shows promise, by reversing diabetes in mice. In the near future, such a bioartificial pancreas might save innumerable lives.

Mater. Sci. Eng. C, 77: 857–866

Easy Detection of Viruses*Technology to help animals*

Epizootic Haemorrhagic Disease Virus causes severe breakdown of blood cells leading to death. In deer populations this can reach epidemic proportions. Domesticated cattle too, often get infected by the virus, though with less severity. There are eight serotypes of the virus reported from various parts of the world. Accurate and easy detection of the virus is still a challenge for veterinary researchers.

S. Maan and researchers from the Department of Veterinary Science, LLR University, Haryana in collaboration with scientists from the UK and South Africa, have now developed quantitative real-time polymerase chain reaction assays for the detection of all serotypes of Epizootic Haemorrhagic Disease Virus in domestic and wild animals.

The genomic RNA of this virus has ten segments encoding different proteins. Segment-9 which encodes the viral helicase protein-6 is highly conserved. Scientists designed a pan reactive assay to detect this segment of viral RNA. They evaluated the diagnostic specificity of this assay using a wide range of the virus isolates. Uniformly negative results with other related virus groups and uninfected samples assured the specificity of this assay.

The typing assays were designed targeting Segment-2, the most variable and type-specific region of the virus genome encoding outer capsid protein. All eight of the Segment-2 based serotype-specific assays were good in terms of sensitivity and specificity. The pan-reactive Segment-9 and type-specific Segment-2 assays can detect as few as two copies of viral RNA per microlitre per reaction, indicating that these assays would be able to detect the presence of the virus in a diagnostic blood sample, even if the animal has extremely low levels of infection.

These assays are currently being used in England to help implement appropriate surveillance and control measures against this virus. Similar technology can be used in India also for detecting and protecting cattle against various virus-borne diseases.

Transbound. Emerg. Dis., **64**: 1120–1132

Shaping Sensitive Sensors*Effect of nanoparticle morphology*

Imprinted polymers are designed to detect specific compounds and to act as sensors. When conjugated with nanoparticles they often exhibit improved performance. However, no study has, so far, examined the effect of embedding different shapes of nanoparticles in the polymer matrix. Recently, scientists from the Indian Institute of Technology, Dhanbad collaborated with scientists at the Indian Institute of Science, Bengaluru to study this effect.

The team constructed four different shapes of silver nanoparticles – spherical, rod-like, hexagonal and flower shaped – using starch solution as a reducing agent. These were then characterized by spectroscopy and used for the construction of an imprinted polymer specific for phenformin. Phenformin is a class of antidiabetic drug which has been discontinued due to associated toxicity.

The scientists explored both the electrochemical and the optical sensing ability of phenformin sensors constructed with different shapes of silver nanoparticles. Results reveal that the polymers created with flower-shaped nanoparticles have the widest range for optical detection. They were also superior to other polymers in terms of electrochemical detection. This is attributed to the multi-facets and planes that a flower shape offers in comparison to a simple sphere.

The flower shape allows a larger surface to volume ratio and offers more sites for capturing the analyte thus boosting the efficiency of the imprinted polymer. The performance was also tested in the presence of body fluids like blood and urine where the biological samples were spiked with the target analyte. Results show that these polymers can function without interference from other biological agents and can be used for drug detection in clinical samples.

Because different shapes of nanoparticles can be created with eco-friendly approaches, such inexpensive methods could be used to construct a new breed of potent sensors for analyte detection.

Chem. Eng. J., **321**: 195–206

Bioaccumulation in *Arius arius**Indicator of pollution*

Seafood is the staple diet in Goa. Recent research discovered high amounts of metals and petroleum products in *Arius arius*, an edible catfish found in the Mandovi and the Zuari rivers. This is an indication of the extent of water pollution. It is also a red flag: consuming fish from these rivers could induce tumours and affect growth and reproduction.

Last fortnight, scientists from the Goa University reported a study on such bioaccumulation in fish. They collected fish samples from Palolem – a small beach – and Vasco – an industrial hub. The team recorded physico-chemical parameters of the water such as temperature, pH, and salinity. They analysed the fish for genotoxicity using a micronucleus test and comet assay. The researchers found a positive correlation between DNA damage and micronuclei in all samples. The team suggests that the presence of metals and petroleum hydrocarbons in the tissues of the fish cause DNA damage. The samples from Vasco showed higher genotoxicity than those from Palolem. This could be due to greater industrial and mining activities in the area.

Industrial and mining effluents endanger the flora and fauna of rivers. Consuming fish from such rivers is dangerous. Such news threatens the livelihoods of the local fisher community. The scientists call for action from the Government to quell this cascading effect.

Ecotoxicol. Environ. Safety, **142**: 22–28

Biodegradable plastics*Cellulose fibres for reinforcement*

Plastics are non-degradable and their rampant use is detrimental to the environment. As an alternative to conventional plastics, scientists all over the world are exploring biodegradable plastics produced from starch. One problem with such plastics is their poor barrier properties and their hygroscopic nature. Now, Sabu Thomas and colleagues from the Mahatma Gandhi University, Kerala, in collaboration with researchers from the Sri Sankara College, Kerala and the National

Institute of Chemistry, Slovenia have found a solution.

The scientists decided to embed cellulose nanofibres in the starch matrix to enhance its mechanical properties. They sourced these nanofibres from pineapple leaves which are extremely rich in cellulose and discarded as agricultural waste. The researchers washed, chopped and treated the pineapple leaves with chemicals to isolate the cellulose nanofibres. Next, they added a suspension of the cellulose nanofibres to potato starch and glycerol solution which was mixed vigorously for 90 minutes. Finally, they poured this solution into petri plates to cast biodegradable plastic films.

Studies on the film show that the addition of cellulose nanofibres improves its mechanical strength in a concentration-dependent manner. Because cellulose has a structure similar to starch, it tries to enter the starch matrix and, in doing so, decreases its permeability to water. This is reflected in the enhanced transport properties exhibited by the reinforced polymer composite. This is also in part due to the improved crystallinity of cellulose nanofibres.

With optimised properties, biodegradable plastics could replace synthetic plastics—a move that would benefit the environment. The scientists are confident that a single cost effective step, like reinforcing with cellulose nanofibres, will catalyse their seamless integration into our shopping bags as biodegradable plastics.

Carbohydr. Polym., **169**: 176–188

Waste to Detect Toxicity

Whey shows the way

Selenium, a naturally occurring trace element, has emerged as a major water pollutant. Its bioaccumulation is shown to cause hair loss, loss of sensitivity in extremities and disruption in the circulatory system. Hence, detection of selenium in water is important.

Whey is a major liquid waste obtained from the dairy industries. Carbohydrate constitutes an important fraction of this by-product and may act

as precursor for the synthesis of carbon nanomaterials. Quantum dots are carbon based nanomolecular structures possessing variable optical and electrical properties. Scientists from the Academy of Scientific and Innovative Research, Central Scientific Instruments Organization, Chandigarh, improvised a cost effective environmental friendly strategy to synthesize light emitting carbon quantum dots from whey. They collected dairy waste and heated the whey from the waste for a few minutes resulting in the formation of dark brown residue. This residue was re-suspended in distilled water and filtered to obtain pure quantum dots.

The research team identified the shape and size of the quantum dots using electron microscopy. They noted that the absorbance maxima at 425 nm indicated a fluorescence property. The team observed that, exposed to yellow light, the quantum dots exhibited blue fluorescence. They also performed light scattering studies and confirmed the solubility of the dots in water. They attributed this property to the carboxyl and hydroxyl groups on the surface of the quantum dots.

The researchers functionalized the quantum dots with a nitrogen rich ligand. They monitored the interaction of the quantum dots with different concentrations of selenium using a luminescence based study. And found that increasing the concentration of selenium led to diminished fluorescent emittance. The team also used other ions to check for the selectivity of the test. The scientists discovered that ionic selenium reduced fluorescence by 70%, thus ensuring very high selectivity.

The very whey waste from dairy industries that pollutes our rivers can now be used to detect pollution.

Talanta, **170**: 49–55

Efficient Path Planning

For snake robots

Hyper-redundant robots have more joints than necessary for any single task. They have many rigid links, active joints and wheels to navigate

complex environments. A snake robot, or hyper-redundant serial robot, can be used to search for humans in debris during disasters. There is an algorithm for obstacle avoidance and path planning in non-redundant robots. However, obstacle avoidance in hyper-redundant robots is not clearly understood.

Recently, Ashitava Ghosal and team from the Indian Institute of Science, Bengaluru reported developing an innovative path planning algorithm for hyper-redundant robots. They used an optimization-based approach to handle obstacles. For free movement, this algorithm uses tractrix curve based path planning. And, for obstacle avoidance, a constrained Lagrangian formulation method.

The team explored the numerical results of this algorithm using Matlab 2D and 3D simulations. The simulations showed that tractrix motion follows obstacle free spaces and automatically switches to obstacle avoidance if any object is encountered.

The team then developed a 12-link snake robot prototype to verify the feasibility of implementing this tractrix-based algorithm. The results of this experiment show that the robot's behaviour is very close to that of the simulation. However, in the experiment, wheel slip happened occasionally due to design related problems and other dynamic effects on wheel-ground contact.

The team plans to implement on-board sensing of obstacles in real time situations and reduce wheel slippage.

J. Mech. Robot, **9**(4): 041010

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