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MESSAGE FROM

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Nanomedicine: The Medicine of Future

Human beings are always aware of their own protection by different physical and chemical means. They have come up to the top of the evolutionary tree after a lot of applications learnt from many experimentations in nature or in the laboratory. Humans initially used plant parts as medicines to recover from various diseases which now has transformed into many forms of medicine starting from natural products to a variety of semisynthetic, synthetic and bioengineering products. Among them nano medicine is certainly taking its growth and shaping well in twenty first century. Therefore, the fate of future of medicine certainly depends on the progress of nano medicine.

Nanomedicine, was made possible by the application of various tools of nanotechnology for medical purpose. Although currently it is in various state of experimentations in several laboratories all over the globe certainly it is expected to have a revolutionary the impact on health care system and is expected to be well accepted by the physicians and patients. The National Institute of Health of United states of America started the national nanotech Initiative in the year 2000. From then onwards the use of nano materials in health sector has been improved significantly and implemented in drug development. Food and Drug Administration of USA does not recognise nanomedicine as a different entity and apply the same regulation as per other small molecule. Since the year 2000 development of nanomedicine is strongly supported by public investment, and is progressing rapidly. In India too nanoresearch in drug development has been increasing stupendously in different branches of medicine.

Majority of biomedical scientists think that nanomedicine has all the answers for our problems which are responsible for the failure of many molecules due to their insufficient desired efficacy, bioavailability and toxicity. They see a big future in nanomedicine as it has all potentials to provide several desired benefits including improved efficacy and safety, bioavailability, targeting ability and move towards achieving a personalised form of medicine to achieve maximum desired success in each and every patient, treated. The chances of attrition of drug molecules will also be less. The most exciting concept in this area which is in development is theranostics, which can work for both diagnosis and as therapeutic at the disease target. Scientists have achieved tremendous progress in this area of research.

While FDA considers all types of new molecular entities are same and treat them under same regulation, India has made guidelines on Best Practices for Safe Handling of Nanomaterials in Research Laboratories and Industries and Guidelines for Evaluation Of Nanopharmaceuticals with a aim to serve the people with quality enabled products especially through nano interventions. Howevere, till now nanodrugs developed in India have not yet reached the market in India.

Although a , lot of concern have been raised regarding its safety, nanomedicines have displayed commendable potential in enhancing therapeutic efficacy and reducing side effects, and are considered safe to use. Given the same mass per volume, the dose in terms of particle numbers increases in nanopharmaceuticals as particle size decreases and benefits are driven by the patients. Despite all expected positive and potential benefits of nanopreparations data on pharmacodynamics, pharmacokinetics and toxicity are rare and meagre as per the literature published from India which may be due to absence of critical mass of scientists working in the area of nanomedicine and demand deeper introspection to increase the interaction and valuable communications and collaborations.

It is praise worthy that nanomedicine products have entered the global market with an appreciable global market share of 293 billion dollars which is growing at around 14% compound annual growth rate and expected to be more than 393 billion by 2030. By that time if India is able to put few really good nano derived medicines for tuberculosis, parasitic diseases and cancers that will be a great achievement for this subcontinent. Our scientsts must focus on easily achievable low hanging fruits like dendrimers, liposomes and nanocrystals. I am sure DBT-TDNBC-DEAKIN –Research network will help in creating a suitable ecosystem for innovation towards achieving excellence in this country.

MESSAGE FROM DR ALOK KUMAR PANDEY,

PRINCIPAL SCIENTIST
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1. Nanotechnology

Nanotechnology is helping to considerably improve, even revolutionize, many technology and industry sectors: information technology, security, medicine, transportation, energy, food safety, and environmental science, among many others. Using nanotechnology, materials can effectively be made stronger, lighter, more durable, more reactive, more sieve-like, or better electrical conductors, and many other traits. The applications for engineered nanomaterials and nanotechnology are developing exponentially, along with the awareness in government, industry and public groups of nanosafety issues.

2. Nanotechnology to Nanotoxicology

The main focus of current nanomaterial toxicity research is engineered nanoparticles, such as metals, metal-oxides, single-walled and multiwalled-carbon nanotubes, C-60, polymeric nanoparticles used as drug carriers, and quantum dots. The increase in relative surface area that occurs as particle size decreases down to the nano scale gives rise to novel and enhanced material properties, but it also renders them more biologically reactive. The release of nanoparticles into the environment can occur through many processes, such as spilling and washing consumer products incorporating nanoparticles; during synthesis and production; as an accidental release during transport or use; from industries that exploit nanotechnology, for example wastewater treatment and drug delivery. Reducing particles to nanosize can also give them access to distal regions of biological systems that are normally inaccessible to larger particles. Environmental contamination and ecosystem disturbance represent yet another concern. These apprehensions demand the parallel toxicity assessment of nanoparticles alongside their production and application. Manufactured nanomaterials are likely to enter in the environment for several reasons. Some are and others will be produced by the ton, and some of any material produced in such mass quantities is likely to reach the environment from manufacturing effluent or from spillage during shipping and handling. They are being used in personal-care products such as cosmetics and sunscreens and can therefore enter the environment on a continual basis from washing off of consumer products. They are being used in electronics, tires, fuel cells, and many other products, and it is unknown whether some of these materials may leak out or be worn off over the period of use. They are also being used in disposable materials such as filters and electronics and may therefore reach the environment through landfills and other mediums of disposal. Scientists have also found ways of using nanomaterials in remediation. Although many of these are still in testing stages, dozens of sites have already been injected with various nanomaterials, including nano-iron. Testing to determine the safety of these NPs used for remediation to environmentally relevant species has not yet been done. Although most people are concerned with the effects on large wildlife, the basis of many food chains depends on soil flora and fauna, which could be dramatically affected by such NP injections. In addition, nanosized materials may not migrate through soils at rapid enough rates to be valuable in remediation. Future laboratory and field trials will help clarify time line between remediation and contamination.

3. *In vitro* and *In vivo* Models

Toxicity studies are normally conducted either in vitro (in cells) or in vivo (in animals), except in the case of ecotoxicity of nanoparticles. In many cases in vitro studies are conducted first to understand the mechanism of cytotoxicity before any in vivo experiment is designed. Different experimental and theoretical tools have been developed and implemented as cost-effective approaches for efficient nanotoxicity testing an area, where experimental and nanotoxicological data are still very sparse. As a result, various computational techniques, including molecular docking, molecular dynamics simulations, quantitative structure-activity/property relationship, have paved the way for investigating NP-cell interactions, predicting BBB permeation rates, and evaluating the potentially harmful effects of NPs on cells. Different in vitro models for neurotoxicity, genotoxicity, immunotoxicity, nephrotoxicity, hepatotoxicity, phototoxicity and dermal toxicity are available at CSIR-IITR for toxicity/ safety evaluation of nanoparticles and products.

4. *In vitro* and *In vivo* Toxicity

The study of the potential toxicity of the metal oxide nanoparticles has gained increasing attention. Silver NPs, which are ranked among the most intensively studied nanomaterials, are used in various commercial products as a disinfection agent due to their extraordinary antimicrobial properties. The cytotoxicity of biogenic SnO_2 nanoparticles was evaluated against a hepatocellular carcinoma cell line ($HepG_2$). SnO_2 nanoparticles inhibited the cell proliferation in a dose- and time-dependent manner. Titanium dioxide nanoparticles (TiO_2) are one of the most widely used nanostructures in various areas. It has been demonstrated that 90 days of increased doses (2.5 to 10 mg/kg body weight) of intragastrically administered TiO_2 nanoparticles resulted in spleen damage and immune dysfunction in mice. The authors also reported alterations in the expression of genes related to stress responses, cell proliferation, apoptosis, metabolic processes, and oxidative stress. The toxicity of commercially available SiO_2 nanoparticles (10 and 300 nm) was investigated in the RAW 264.7 mouse macrophage cell line. The authors observed that 10 nm SiO_2 nanoparticles affected cell proliferation, morphology and cell cycle. Cells treated with smaller SiO_2 nanoparticles greatly reduced phagocytosis, as monitored by the RAW 264.7 cells' uptake of E. coli. The bioaccumulation of small SiO_2 nanoparticles within macrophages may suppress bacterial uptake and impair antibacterial activity. An in vivo study evaluated the toxic effects of suspensions of commercial silica nanoparticles in mice administered via oral gavage. The authors reported significant changes in cholesterol, urea, total protein, LDL, HDL, aspartate aminotransferase activity and alkaline phosphatase activity. CuO nanoparticles induced autophagy in a human breast cancer cell line (MCF7) in a time- and dose-dependent manner. An interesting finding showed that the AgNPs accumulated in the immune system organs of Sprague-Dawley rats, and mild irritation was observed in the thymus and spleen of animals treated with AgNPs, but not with Ag+. The liver and kidneys could be the most affected organs by an acute i.v. dose of AgNP, and significantly increased chromosome breakage and polyploidy cell rates also implied the potential genotoxicity of AgNPs. One study compared the in vivo acute lung inflammogenicity and in vitro cytotoxicity of CuO, SiO_2, ZnO, and Co_3O_4 nanoparticles. CuO and ZnO were the most toxic nanoparticles in both in vitro and in vivo assays. CuO, followed by ZnO, is reported to be the most toxic nanoparticle whereas TiO_2 is the least toxic nanoparticles.

5. Ecotoxicity

The investigation into the effects on the aquatic environment from nanomaterial exposure is of high interest, particularly since the water cycle ultimately receives runoff and wastewater from domestic and industrial sources. In addition, there has also been increased development of water remediation techniques based on the use of nanomaterials for wastewater treatment (e.g. zero-valent iron NPs). Drosophila melanogaster has been exploited in testing the toxicity of several nanomaterials such as carbon nanotubes, cerium oxide NPs, or silver NPs. The silver NPs kill prokaryotic bacterial organisms more efficiently than higher eukaryotic organisms. Drosophila organisms exposed to low concentrations of silver successively adapted to this long-term toxic treatment of silver NPs and their fecundity returned back to the normal level due to their adaptation. The Ag+ ions in commercial nanometer sized silver could accumulate in aquatic environments and seriously damage the development of zebrafish embryos. The toxicity of NPs of ZnO, CuO and TiO_2 for Vibrio fischeri and crustaceans Daphnia magna and Thamnocephalus platyurus was evaluated with a special emphasis on metal oxide formulations (nano or bulk). The obtained results demonstrated that the silver NPs do not exhibit any toxicity action against the tested unicellular eukaryotic organism below the concentration of 25 mg/L whereas ionic silver retains its toxicity even at a concentration of 0.4 mg/L. Studies at CSIR-IITR showed that growth, reproduction and behavior of C. elegans were adversely affected by ZnO NPs different sizes (35 nm, 50nm and 100 nm) in a size dependent manner. Metal oxide particles do not necessarily have to enter the cells to cause the toxicity. Much more important seems to be the intimate contact between the cell (bacterial cell wall or crustacean gut environment) and particle. This may cause changes in microenvironment in the vicinity of organism-particle contact area and either increase the solubilization of metals or generate extracellular ROS that may damage cell membranes.

6. Contribution of CSIR-IITR in Nanotoxicology

CSIR-Indian Institute of Toxicology Research (CSIR-IITR) has been working in the area of Nanotoxicology from the past decade and has been able to develop expertise with a critical mass of its scientific power contributing in this emerging area of toxicology. This institute took lead in the synthesis and characterization of engineered nanomaterials, development of methodology/ assays/ techniques for toxicity assessment, guidelines for nanosafety, alternate models, and mechanism of action and interaction of nanomaterials with biological systems.

To assess the safety/ toxicity of nanomaterials, some of the most critical issues that need to be addressed include: i) effect of shape and size; ii) dosimetry; iii) route of delivery and tracking; iv) development and validation of test models; v)in vitro vs. in vivo extrapolation; vi) ecotoxicity; vii) computational nanotoxicity and viii) life cycle analysis. Some of the key achievements of CSIR-IITR includes:

- IITR has established and validated 16 in vitro models, 7 in vivo models that are GLP compliant for genotoxicity studies and 6 models for ecotoxicity studies.
- More than 200 publications are there in peer reviewed high impact factor journals.
- CSIR-IITR as a Member, ISO/ TC229 (nanotechnologies) was instrumental in getting ISO standards approved and adopted by BIS, Government of India.
- Standards for methods in nanomaterial toxicology has been formulated for submission to BIS for ISO approval (Ecotoxicity methods).
- Toxicity/safety evaluation of various nanomaterials has been done at CSIR IITR.
- Different assays/methods are available at CSIR-IITR for toxicity/ safety evaluation of various nanomaterials.
- CSIR-IITR has also played major role in bringing up the National and International guidelines for nanomaterials used in different sectors.

7. Future Strategies

CSIR-IITR is striving hard from past few years in terms of the following key areas of Nanotoxicology that can`t be overlooked. They can be summarized as follows:

- Validated test models, methods for toxicity and safety assessment to evolve a decision tree for protection of human health and the environment.
- Strategic plan to minimize risk in workers of nano manufacturing industries.
- Establishment of world class competence in the area of risk assessment and hazard identification of nanomaterials, useful for Universities, IITs, Pharmacy sector, Industries, etc.
- Guidelines for safe handling of nano-materials in laboratory and occupational settings.
- Civil society to be better informed in the country about nanotechnology.

On exposure nanoparticles may be accumulated in different organs upon systemic circulation and will end up as waste; further their subsequent degradation may liberate particles into the environment where they may remain or circulate in food web. Therefore, keeping in view of the pros and cons of nanomaterials, a detail strategic plan should be chalked out to deal with the possible future outcomes. The role of these studies is very important in terms of setting regulations by authorities.

MESSAGE FROM

MS NEHA KHANDELWAL,

Team member for research collaboration in Nano-science TERI Deakin NanoBiotechnology Centre (TDNBC), Gurugram, Haryana, India

Significance of Research Collaboration and Networks

"Instead of better glasses, your network gives you better eyes."
-- Ronald Burt

International collaboration is growing exponentially, and researchers from different institutions and countries increasingly work together as consortia focused on specific research questions. Such consortia are especially valuable for the DTD-RNA research network because they offer interdisciplinary expertise and allow us to join hands in different settings. Establishing research networks and collaborations to conduct webinars/ seminars/ workshops/

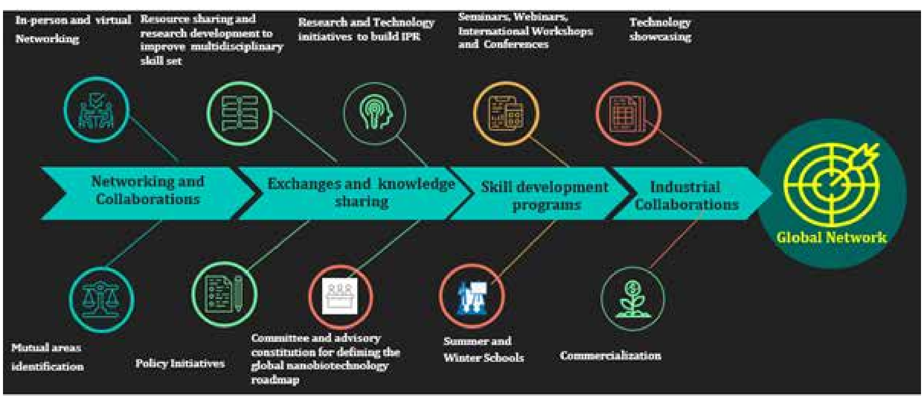
conferences/training for various research groups, industries, and other voluntary participants' groups provides the necessary flexibility to adapt to a broad spectrum of arising challenges. It enables shared learning, new research opportunities, new research projects, joint applications for funds, and technology transfer. The collaborations increase research manuscripts' citations, especially if an international team of authors is involved. Building research networks is particularly important for TERI Deakin NanoBiotechnology Centre (TDNBC), India and globally, which have fragmented scientific communities, small research groups, and low financing.

Recognizing the value of research networking, TDNBC established this network in 2019 and started building a relationship with research Institutes and Industries by establishing DTD-RNA (DBT-TDNBC-Deakin – Research Network Across continents for learning and innovation) network program. During the program's first three years, TDNBC established partnerships with research institutions in India, the United States, Spain, Netherland, Malaysia, Austria, Portugal and Europe. TDNBC provided training on different aspects of nano-biotechnology.

The network promotes creative thinking and helps its members provide a platform for showcasing their work and interacting with numerous industries and researchers also does skill development programs for knowledge sharing. Besides that, among its highest priorities is the involvement of PhD students in the TDNBC research programs.

TDNBC has also collaborated with different network consortia globally, which is considered a scientific periphery; there must be an even stronger impetus to increase their participation in international research consortia. Sustained engagement in training programs and joint applications to research funding can stimulate research network development, a platform that offers such research networking opportunities, and the benefits of participation in such a consortium can result in the long term. Even today its positive impact is already visible, judging by the number of joint publications, white papers, and research proposals developed.

As part of the ongoing process of the DTD-RNA network, it contributes to the establishment and increases competitiveness, enhancing international collaboration. Using the network as a model should be the goal of every researcher and research institution because such a partnership enables capacity building and offers multiple opportunities to surpass limitations that arise within a single institution due to scarce resources.



SUMMER SCHOOL ON “ADVANCED TECHNIQUES ON MICROBIOLOGICAL BIOTECHNOLOGY”

A summer school on “Advanced techniques on Microbiological Biotechnology” organized by TERI-Deakin Nanobiotechnology Centre (TD-NBC) along with International Iberian Nanotechnology Laboratory (INL), Braga, Portugal through DBT -TDNBC - DEAKIN – Research Network Across continents for learning and innovation (DTD-RNA) network. The one day program with 9 M.Sc. Biotechnology student was chaired by Dr. Pushplata Singh, Director, TERI-Deakin Nanobiotechnology Centre (TDNBC), Gurugram, India & Dr. Shruti Shukla, Fellow, TDNBC. The program has been successfully organized by Dr. Shovon Mandal, Fellow, TDNBC, Dr. Amritpreet Kaur Minhas, Associate Fellow, TDNBC and Dr. Leena Johny, Associate Fellow, TDNBC on 11th May, 2022.

The training program included two different sessions, Session I focussed on ‘**Demonstration on morphological and molecular characterization techniques of Arbuscular Mycorrhizal fungi**’ where the participants were briefed about the different mycorrhizal structures formed during the symbiotic association along with demonstration of the staining techniques used to define the mycorrhizal spore characteristics using microscopic analysis. This was followed with molecular characterization where extraction of genomic DNA from mycorrhizal spore was demonstrated and explanation regarding different instrumentation utilized to analyse the extracted genomic DNA was shared with the participants. Session II was based upon ‘**Demonstration on Algae culturing techniques and biochemical Characterisation**’ where the discussion was focused on basis of selection of algal habitat for different applications (agriculture, carotenoids and biofuels). Experts shared their recent accomplishments with participants to enhance the society’s understanding of the existing state of the art on algal biology and other resources to identify challenges.

The session II was followed by the visit to outdoor microalgal pilot scale production facility where the experts showed the possible solutions to overcome the challenges and knowledge gaps in the downstream processing of microalgae at pilot scale with a central focus on maintaining the quality of the products and biomass.

Overall, it was a dedicated forum to discuss ‘How microalgae can be a great advantage for industrial applications?’ and ‘How can they be promoted and exploited in a better manner?’ Hence, experts demonstrate the approaches for effective cultivation strategies with main emphasis being on the downstream processing via offline platform.

There was an overwhelming response from the students who participated actively in the program and have gained valuable learnings that would help them in achieving their research goals.

SUMMER SCHOOL ON "NANO-BASED SOLUTIONS FOR AGRICULTURE AND ENVIRONMENT"

A summer school on "Nano-based Solutions for Agriculture and Environment" was organized by TERI-Deakin Nanobiotechnology Centre (TD-NBC) along with International Iberian Nanotechnology Laboratory (INL), Braga, Portugal through DBT –TDNBC – DEAKIN – Research Network Across continents for learning and innovation (DTD-RNA) network. The one-day programme with 9 MSc Biotechnology students was chaired by Dr Pushplata Singh, Director, TERI-Deakin Nanobiotechnology Centre (TDNBC), Gurugram, India. The programme has been successfully organized by Dr Ruchi Agrawal, Associate Fellow, TDNBC and Dr Suneeti Singh, Research Scientist, TDNBC on May 17, 2022.

The summer school included two major sessions. Session I focussed on an overview of nanotechnology and its applications in different field. Subject expert of nanomaterials, Dr. Suneeti Singh gave a detailed lecture on "Introduction to Nanotechnology and Its Application for Environmental Health and Safety", where the participants were briefed about the various nanomaterials and mechanisms for their synthesis along with a brief on the impact of nanotechnology in agriculture. The session continued with laboratory visit and demonstration on nanomaterials synthesis and their characterization via different techniques such as DLS, Zeta potential, FTIR, and UV spectroscopy and toxicity evaluation of nanomaterials.

In Session II Dr Ruchi Agrawal talked about the 'Bio-based Nano materials and Nano polymers' and introduced the young minds with various methods for the synthesis of nanomaterials and various tools for their characterization which was followed by the Demonstration of the 'Process for the extraction of polymers from Agro-residues via Hydrothermal Fractionation of Biomass'. The sessions were followed by an hour long brainstorming Q&A and an Interactive session.

Overall, it was a dedicated forum to discuss the 'Alternate Solutions for Nanotechnology' which are cost-efficient and eco-friendly and 'How can they be promoted and exploited in a better manner?' There was an overwhelming response from the students who participated actively in the programme and they have gained valuable learning that would help them in achieving their research goals.

E-SUMMER SCHOOL PROGRAM ON “NANOSAFETY CHALLENGES: RETHINKING NANOSAFETY”

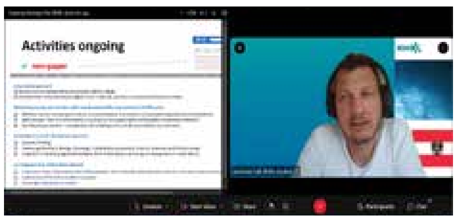
Globally, as multiple nanoproducts are reaching the application and commercial stages, it becomes vital to understand any potential risks associated with their synthesis and application. However, due to unique physicochemical properties these nanoparticles also tend to have complex interactions in environment and interfere with the assays, detection and estimation systems. Factors like these pose great challenge in their overall safety assessments.

The **Teri-Deakin NanoBiotechnology Centre (TDNBC), Gurugram, India**, in association with the Department of Biotechnology, Government of India under “DBT-TDNBC-Deakin-Research Network (DTD-RNA)” for learning and innovation across the continents, organized E-Summer School program on “Nanosafety Challenges: Rethinking Nanosafety” on 18th May 2022.

The winter school was aimed to spread advanced knowledge about Nanosafety challenges. Young researchers, students, and technocrats participated in this program to learn new insights into the thematic area.

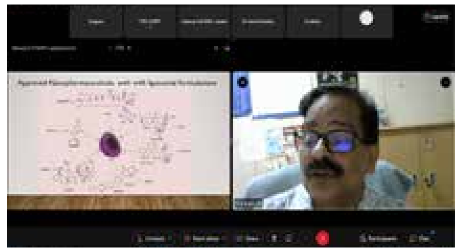
The program began with the welcome address by **Dr Pushplata Singh, Director – Teri Deakin Nanobiotechnology** Centre, Gurugram,

followed by an introductory virtual tour of TERI and TDNBC nano-research achievements and facilities. The program was moderated by Dr Palash Kumar Manna, Senior Scientist, TDNBC, TERI.

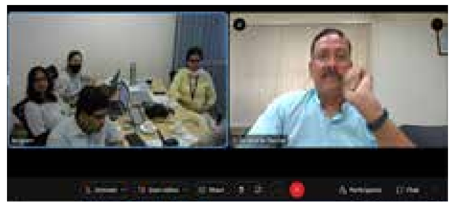


The scientific session started with a keynote talk by **Mr Andreas Falk, Chief Executive Officer Bionanonet Forschungsgesellschaft Mbh (BNN), Austria**, on Nano-Safety Challenges and Way Ahead for Global Collaboration. He briefly explained the challenges and focused on leading the way in global research nanosafety partnerships and tackling scientific and societal challenges in various areas.

Dr Srikanta K Rath, Chief Scientist, Division of Toxicology & Experimental Medicine CSIR-Central Research



Drug Institute, India, delivered a perceptive talk on the Safety of Nano Pharmaceuticals. He explained the basics of the safety challenges involved.



The last lecture was presented by **Dr Alok K Pandey, Senior Scientist, Systems Toxicology & Health Risk Assessment CSIR-Indian Institute of Toxicology Research, India**, who delivered an insightful talk on the Nanomaterial Toxicology: Methods and Challenges. He explained the methods and challenges one may face during the synthesis and characterization of nanomaterials.

After each session, an interactive Q & A session was held. The E-Winter School platform was attended by more than 70 participants across the globe.

WEBINAR ON "ELECTROLYSIS OF WATER: THE WAY FORWARD"

Water electrolysis has come a long way since its discovery around 200 years ago. The world is working remarkably to cope with the energy demand and replace conventional fossil-fuel-based energy with affordable, reliable, and cost-effective green energy sources like hydrogen. The electrolysis of water is one of the go-to techniques for the same. However, the choice of catalyst, electrolyte and operating conditions play a significant role in energy generation and pilot/industrial-scale production. A clean hydrogen economy could be the answer to transitioning out of fossil fuel use. Being the most abundant element on the Earth and making up more than 90% of all known matter, it can be seen as the most feasible renewable resource available.

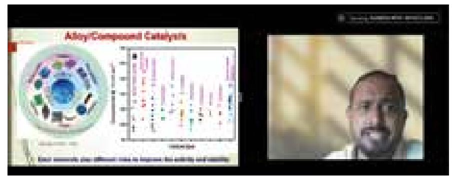
The Teri-Deakin Nanobiotechnology Centre (TDNBC), Gurugram, India, in association with the Department of Biotechnology, Government of India under "DBT-TDNBC-Deakin-Research Network (DTD-RNA)" for learning and innovation across the continents, organized a webinar on "Electrolysis of Water: The Way Forward" on 28th June 2022.

This Webinar was a great platform to recall the history and understand the present and future potential of water electrolysis in green energy generation. We aimed to bring together participants from academia, industry and regulatory bodies and brainstorm about water electrolysis's role as a future energy source.

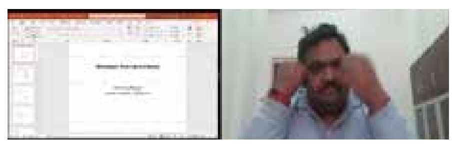
The program began with the welcome address by Dr Palash Kumar Manna, Associate Fellow– Teri Deakin Nanobiotechnology Centre, Gurugram, followed by an introductory virtual tour of TERI and TDNBC nano-research achievements and facilities. The program was moderated by Dr Shruti Shukla, Fellow, TDNBC, TERI.

Electrolyzer technologies have been gaining more attention as they serve as a potential hydrogen production method capable of producing high-purity hydrogen from water and meeting hydrogen demands at various capacities. The scientific session started with a talk by **Prof Subramaniam Chandramouli, Assistant Professor, Indian Institute of Technology Bombay, India**, on **Electrolyser Technology: The Basics**. He briefly explained the water electrolysis technologies for hydrogen production, which are discussed in the context of different electrolysis processes, including the historical development, theoretical thermodynamic, and electrochemical principles.

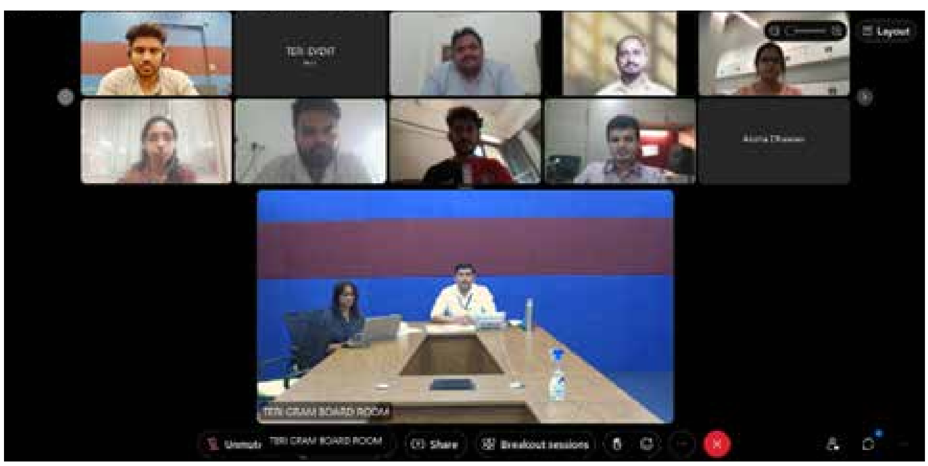
Water electrolysis is a well-established commercial technology; nevertheless, its practical application for the mass production of hydrogen is still limited as it suffers from several significant obstacles. With the advancement in the field of nanotechnology, the problems can now be addressed effectively. **Prof Nainesh Patel, Associate Professor, Christ University India, delivered a perceptive talk on Water Electrolysis: The Role of Nanotechnology**. He explained that the field of nanotechnology is integral for advancing a more green economy with the characterization of novel catalysts, which will ensure the quality of the catalyst is quantifiable and the use of nanomaterials as catalysts.



A revitalization of organic electrosynthesis has incited the research community to adopt electrochemistry as a green and cost-efficient method for activating small molecules to replace highly toxic and expensive redox chemicals. The last lecture was presented by **Prof Chinmoy Ranjan, Assistant Professor, Indian Institute of Science, India, who delivered an insightful talk on Electrolyzers: From Lab to Industry**. He explained the commercialization of wide-scale electrification of organic synthesis. He highlighted the perspective and the advances made in large-scale flow electrosynthesis, its future trajectory while pointing out current methodologies' main challenges and critical improvements.



After each session, an interactive Q & A session was held. The Webinar was attended by more than 45 participants across the globe.



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Upcoming events of DTD-RNA network during July – September 2022

- Webinar on "Drone Technology for Specialised Agrochemicals in Precision Agriculture: Awareness and Adoption in India".
- Webinar on "Effects of multiple nanoparticles from plant and data from field trials".