

PROCEEDINGS

IGC summit opens up new vistas in industrial green chemistry and technologies

The Industrial Green Chemistry Workshop (IGCW-2009) held from 4-5 December, 2009, in Mumbai, was a milestone event that aimed to create awareness and provide the momentum for green chemistry and engineering technologies. The event highlighted global trends in sustainability, besides exploring opportunities for leveraging industrial green chemistry models for business differentiation and competitiveness.



Dr. T. Ramasami lighting the lamp to inaugurate the conference

The event was organized by Green ChemisTree Foundation, in association with Newreka GreenSynth Technologies P. Ltd, a technology-driven company involved in developing 'green' technologies for the chemical and related industries, in association with the Green Chemistry Network Centre (CNC) (the India Chapter of the American Chemical Society's, Green Chemistry Institute) and *Chemical Industry Digest*, a leading publication for the chemical industry.

IGCW-2009 was principally scheduled on the basis of an innovative '9-eye (I) approach' with each 'eye' expanding the vision of participants to emerging views of industrial green chemistry paradigms and its implementation, in order to create tangible and intangible benefits for stakeholders.

Quest for sustainability

Mr. Nitesh Mehta, Managing Director, Newreka GreenSynth Technologies P. Ltd. (Mumbai), delivered the

welcome address and laid the foundation for conference. He emphasized the need for exploring all options to enable industry to shift to more sustainable manufacturing and also dwelt on the benefits brought about by a competitive thrust that green chemistry could deliver to industry.

Mr. Mehta pointed to the unacceptably high waste generated by the drugs, pharmaceuticals and other fine chemical industries, for which today solutions are very well possible through green chemistry, including with better economics and profitability. "One of the objectives of this event is to debunk the myth that green chemistry will add to costs; on the contrary several case studies in the event will prove just the contrary."

'Revisit all processes'

Dr. T. Ramasami, Secretary, Department of Science and Technology (DST), Government of India, inaugurated the three-day event and empha-

sized the Government's support to implementing industrial green chemistry and various barriers to its implementation.

Applauding the initiative of the organizers in putting together the event, Dr. Ramasami, pointed out that while green chemistry events with a predominantly academic insight have been held world over, this is the first time an industrial event on green chemistry has been held. He exhorted

captains of industry to come up with specific action plans, suited to chemical industry segments, including research initiatives for zero emissions, which the government will fully support.

Emphasizing the importance of making green processes relevant to industry, Dr. Ramasami said what is acceptable in the micro scale in the laboratory may become unacceptable at an industrial scale, as the volume of waste also goes up. "It is important to revisit all existing processes," he advised, "to assess whether the processes are clean, whether waste is avoided or minimized and whether the economics of the process could be improved." "A 'don't try to fix what is working' attitude of complacency, is no longer sustainable," he added.

The DST Secretary urged industry to go in for the "best cost solutions" and "not the least cost solutions." He gave examples of how the Central Leather Research Institute (CLRI), which he

once headed, developed 'green' chromium-based processes that helped tanneries continue to function in the wake of Supreme Court orders to close down due to severe pollution caused by them.

Dr. Ramasami said for green chemistry to turn into a movement it should go beyond supply side initiatives, with the demand side (user industries, consumers and the general public) also clamouring and demanding green chemistry.

He felicitated Prof. Paul Anastas and Prof. John Warner, pioneering scientists in the field of chemistry, for completion of 12 years of their well known, '12 Principles' of green chemistry and engineering.

He later released a background paper, 'Industrial Green Chemistry and Technology: Mapping Transformations' prepared by KnowGenix, a Mumbai-based consultancy. This document covers the 25 year journey of



Launch of IGCW 2009 Background Position Paper prepared by KnowGenix (from L to R): Prof Anastas, Dr.T. Ramasami, Dr. John Warner, Dr. Bob Peoples and Dr. R. Rajagopal

industrial green chemistry and technology in the Indian and global context.

'No Bhopal again'

In his keynote presentation on 'Green Chemistry: From here to sustainability,' Prof. Paul Anastas, Scientific Advisor, US Environment Protection Agency (US-EPA) and Director, Centre for Green Chemistry and Green Engineering, Yale University (USA), explained the genesis of the green chemistry movement and elaborated on the need for transformation.

He stressed the urgency of embracing green chemistry and pointed out that all along the drivers towards sustainable manufacturing was due to regulatory pressures. Such a growth, he noted, is characterized by unsustainability and had to change. By following the twelve principles of green chemistry that he and Dr. John Warner had enunciated, incidents like Bhopal need never take place, he contended.

According to Prof. Anastas, through innovative chemistry and chemical engineering, chemical manufacturing can be greener and safer and, at the same time, advance competitiveness. He displayed through several examples how the industry could learn and mimic nature and also dwelt on issues related to use of alternative energy, reutilization of greenhouse gases, including carbon dioxide, as feedstock, and resource depletion.

DAY ONE

Ignition, Inspiration and Initiation

The first day of the event was focused on three key themes: Ignition, Inspiration and Initiation and sought to recognize and explore the ecological and economical footprint of industrial green chemistry. The sessions were targeted at and attended by over 200 senior management personnel, including Directors, CEOs, consultants, entrepreneurs, strategic advisors etc.



Prof. John Warner delivering his talk

'Incredible business opportunities'

The theme session, Ignition, aimed to ignite awareness of the participants towards green chemistry and engineering based solutions. It was chaired by Dr. Rajender Varma, US-EPA.

Prof. John Warner, President and Chief Technology Officer (CTO), Warner Babcock Institute for Green Che-

mistry, spoke on ‘Green chemistry through collaborative innovation.’

He articulated the incredible business opportunities that can be realised from the design and development of safe materials. He pointed out that green chemistry was catching up very fast now and will become very common within the next ten years. “Those with vision and foresight, who start practicing green chemistry now, will have the first mover advantage.”

Prof. Warner also pointed out that



Dr. Murali Sastry, CSO, Tata Chemicals Innovation Centre, India

in this very competitive world, where driving down costs is essential, even to survive, one had to eschew hazardous

and dangerous materials and difficult chemistries, which are far costlier. “Green chemistry is safer, performs better and reduces costs.”

Dr. Murli Sastry, Chief Scientific Officer, Tata Chemicals Innovation Centre, threw light on the ‘100 years journey of sustainability at Tata Group.’

Inspiration

The theme session, Inspiration, aimed to inspire people through real world case studies of green chemistry and engineering solution, which

Open-ended projects supported by DST

Project	Participants
How to make ionic liquids more effective for promoting organic reactions	NCL, Pune
Non- hazardous bromination with bromide/bromate couple obtained as intermediate of bromine recovery plants: Exploring studies on diverse applications.	CSMCRI & IACS
Development and performance analysis of completely degradable polymer composites	SK Univ., Ananthapur
Enhance biodegradation of polypropylene using biosurfactants	IIT, Chennai
Development of tailor-made green packaging plastics	TERI, Bangalore
Remediation of metal ion contamination in Delhi soils using green approach	DU, Delhi
Developing membrane integrated hybrid reactor system for producing high purity lactic acid from renewable resources	NIT, Durgapur.
Characterization and utilisation of waste plastics for various applications.	TEC, Madurai.
Developing fly ash reinforced polymer matrix composites to be used as green building materials	Calcutta Univ., Kolkata
Synthesis of novel basic green catalysts (zeolite and mesoporous material based), and study of applications	Tezpur Univ, Tezpur
Exploring triarylbiismuth as a new organometallic catalyst for C-C bond forming reaction	IIT, Kanpur
Development of nanocomposite based on natural resources (soya flour and jute fibre)	Tezpur Univ., Tezpur
Develop nanostructured membrane for solvent recovery applications.	NEIST, Jorhat
Synthesize novel metal organic framework compounds with appropriate pore size and explore their uses as catalysts and for selective adsorption of gases	IIT, Kanpur
Synthesis of cobalt and copper based complexes, immobilize them on porous silica support and study catalytic application of the material in organic transformations	Guwahati University, Guwahati
Developing benign process for synthesizing natural and synthetic glycolipids as potential biosurfactants using renewable feedstock	NCL, Pune
Synthesis of novel heterocyclic systems using multi-component reaction protocols	Pondicherry Univ., Pudhucherry
Development of biodegradable plastics	Basanti Devi College, Kolkata

Industry-academia collaborations supported by DST

Project	Participants
Production of calcium magnesium phosphate fertilizer from low-grade phosphate ore and bulk circuit tailings of Jhamarkotra Plant, Rajasthan	MLSU & RSMML
Improved processes based on membranes for the recovery of acid and organic compounds.	CSMCRI & Atul
Production of biosurfactants from genetically engineered <i>Pseudomonas aeruginosa</i> .	AU & Galaxy Surfactants
Development of environment-friendly saccharification process for enhanced ethanol yield from rice straw.	TERI and Praj Industries
Study on the characterization and utilization of waste plastics.	TEC & VTM
Developing eco-composites using polylactic acid, starch and reinforced with modified clay nanoparticles.	CIPET & Harita

have become profit centers today. The session, chaired by Prof. Anastas, focused on successful case studies of industrial green chemistry implementation at commercial level.

Dr. Joseph Armstrong, Merck & Co Inc. spoke on 'Innovation as driver of Green chemistry advances in the pharmaceutical industry,' while Dr. Rakeshwar Bandichhor, Dr. Reddy's Laboratories elaborated the experiences of his organization in his talk, 'Pharmaceutical Industry as an epicenter of green chemistry: A perspective.'

Money to be saved

The session on Initiation, was focused on initiating green chemistry and engineering based solutions and use them as environmentally friendly alternative to conventional technologies. The session was chaired by Dr. John Warner.

Dr. Robert Peoples, Director, ACS-GCI, spoke on 'Green chemistry means business' and how implementing initiatives based on green chemistry and engineering can be profitable for an organization. According to him, green chemistry is a business and investment opportunity for our future and can be a competitive advantage. "There is money to be saved and made applying green chemistry and engineering principles," he said.

He termed the current models of the industry as not sustainable, especially when viewed in the eyes of nature. "We must do things differently in the future."

Citing examples of successful green chemistry approaches, Dr. Peoples referred to the multi-step synthesis of the drug Pregabalin, which through the traditional route results in 86-kg of waste per kg of product, besides being a significant consumer of energy. In contrast in the bio-catalytic 'green' route to synthesis, all four reactions are performed in water, resulting in solvent savings, and the amount of waste generated is reduced to 12-kg per kg of product. In addition, there is a dramatic reduction in raw material use and costs, besides a more than 80% reduction in energy consumption.

Thanks to this approach, Pfizer, the drug's manufacturer expects the new synthesis to eliminate (between 2007 & 2020):

- 85,000-tons of solvent, a 88% reduction;
- 4,800-tons of mandelic acid, a 100% reduction;
- 1.890-tons of Raney nickel catalyst, a 85% reduction; and
- 10,000-tons of starting material, a 39% reduction.

Dr. Peoples was also pragmatic in admitting that not all 12 principles of

green chemistry would be applicable in every situation. "Incremental improvements are good; step changes and breakthroughs are better," he commented. "Start the journey; don't let perfect get in the way of good enough."

Taking green chemistry to the next level

In his theme talk 'Green chemistry and technology platforms: design and development strategy' Dr. R. Rajgopal, CCO, KnowGenix, discussed the need for taking green chemistry and technology to the next level by leveraging the potential of new technologies and past experiences.

Government funding

Dr. R. Brakaspathy, Scientist, Department of Science and Technology discussed the various initiatives undertaken by DST to felicitate industry-academia collaborations and also initiatives taken to create awareness and to promote green chemistry and engineering.

He pointed out the DDT Green Chemistry technology funding initiative was started in Jan 2004 to support all aspects of green chemistry including research (open-ended, industry collaborative), teaching and training. So far the scheme has funded about Rs. 507-lakh, with a Rs. 43-lakh contribution coming from industry.

RECOGNITION

PI Industries, IICT-Hyderabad and Catapharma amongst winners of awards

The IGC awards for outstanding research and initiatives in green chemistry and engineering was a pioneering initiative of the organisers of the event. The aim of the awards was to promote the pollution prevention models adopted by the winners and to recognize outstanding contributions in green chemistry in the Indian industries.

The awards provided national recognition to outstanding chemical technologies that incorporated the princi-

ples of green chemistry into chemical design, manufacture and use, and that have been or can be utilized by industry in achieving their pollution prevention goals.

The IGC award was an unique opportunity for a student or professor, research groups, institutes, government laboratories, universities, large scale industries, MNC's, start-up companies and small to medium scale industries, to showcase their developments in the

area of green chemistry and engineering. The awards were presented in four categories:

Academicians

Seven entries were received in this category from IICT Hyderabad, CLRI Chennai, IIT-Kharagpur, Amritsar University and Goa University.

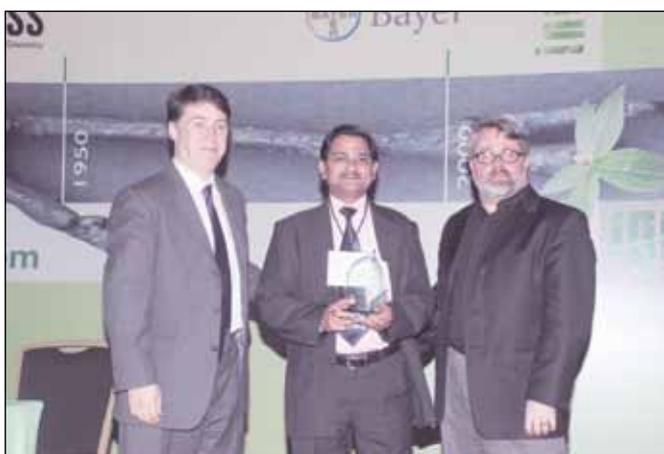
The winner was IICT, Hyderabad, for their work on technology for enzymatic degumming of rice bran oil.



Dr. Abid Ali, VP, R&D, PI Industries, receiving the Green Chemistry award for large and MNC category



Dr. Shrikant Kabra, Managing Director, Catapharma India, receiving the Green Chemistry award for SME category



Dr. R.B.N. Prasad, Scientist, IICT, receiving Green Chemistry award for academia category



Mr. Lalit Darunte, Project Coordinator, Biosynth, receiving Green Chemistry award for student category

Student

Four entries were received in this category from IIT-Bombay, ICT-Mumbai, Anna University and University of Rajasthan.

The winner was the Biosynth Group from IIT-B for their work on biodiesel synthesis from waste vegetable oil.

Start-up and small to medium companies

Six entries were received in this category from Deven Supercritical Ltd., Geist Research P. Ltd., Catapharma P. Ltd. and Clean Sciences P. Ltd.

The winner was Catapharma P. Ltd. for their work on catalytic hydrogenation.

MNC and large scale industries

Nine entries were received in this category from Atul Ltd., Dr. Reddy's Laboratories Ltd., Jubilant Organosys Ltd., PI Industries and Lanxess Ltd.

The winner was PI Industries for their technological innovations in the manufacturing process for the pesticide, phorate technical.

DAY TWO

Identification, Invention and Innovation

The second day of the conference was divided into three themes – Identification, Invention and Innovation – in continuation of the '9I approach.' The sessions were attended by almost 230 delegates most of whom were primarily focused on strategizing R&D activities for greener and environmentally-benign synthesis and included Technical Directors, R&D Managers, Chief Scientists, CTOs etc.

In his keynote address on 'Green Chemistry and Formulation Science,' Dr. Warner deliberated on the regulatory requirements, process modification and use of green chemistry for cost as well environmental benefits.

Identification

The theme session, Identification, was primarily to sensitize people to identifying gaps in their existing processes and steps to overcome them by using green chemistry tools. The session was chaired by Dr. Warner.

Speaking on 'Towards a molecular design strategy for green chemistry,' Prof. Anastas emphasized designing of molecules to eliminate hazards at a molecular level.

Dr. John Peterson Myers, CEO, Environmental Health Science, spoke on 'A revolution in the environmen-

tal health sciences: New challenges to safety of common chemicals in commerce.' He brought out the environmental hazards of existing common chemicals to human health and the environment and stressed the preventive measure that need to be worked upon.

Dr. K.V. Raghavan, former Director, CLRI, discussed developments in catalysis in his talk 'Novel catalytic systems for green chemical process intensification.'

Invention

The theme session, Invention, chaired by Dr. Rakeshwar Bandichhor, aimed at encouraging participants to strategize their inventions in alignment with the principles of green chemistry and engineering.

Mr. Mark Dorfman, Biomimicry Guild, in his talk, 'Biomimetic green chemistry solutions: Achievements and outlook' provided a detailed perspective and understanding on Nature's chemistry and how we can mimic it to design environmentally benign synthesis.

Dr. N. Sekar, Department of Dye-stuffs, ICT (Mumbai), in his talk, 'Safe product design: Perspectives from dyestuffs and intermediate industries,' discussed how environmentally haz-

ardous industries like dyes and pigments can also become environmentally-friendly by safer synthesis and product designs.

Referring to benzidine-based dyes which have been found to be carcinogenic, Dr. Sekar advocated a multi-pronged approach to tackling the problem by evaluating the use of substitute dyes. According to him, the cause of carcinogenicity includes the basicity of the amino group, the lipophilicity and the presence of the biphenyl linkage in the benzidine moiety. Introduction of suitable substituents and chemical groups could dramatically change the safety profile of the molecule, he added, advocating the use of aminophenyl amino quinoline as a safer alternative to benzidine.

Dr. Rajender Varma, US-EPA, in his speech 'Greener pathways to organics and nanomaterials: Sustainable applications of nanocatalysts,' brought forth the emerging and cutting edge area of nanotechnology and its role in implementing green chemistry.

Innovation

The theme session, Innovation, chaired by Dr. Myers, focused on new technologies emerging from the tool box of green chemistry and engineering.

Dr. B. Gopalan, Chief Scientific Officer, Orchid Chemicals and Pharmaceuticals Ltd., in his talk, 'Water – The greener solvent for organic chemists' discussed the potential for water-based reactions.

According to him, water has been precluded from use as a medium in organic synthesis for the following reaction rates: low reaction rate; low yield of the desired product; and possible water reaction, especially for water-sensitive products. However, he added, a number of well-known reasons exist for choosing water as a medium. These include the ability to carry out many bio-catalytic reactions, which permits the consideration of a chemo-enzymatic strategy for chemical transformations. "Water as a solvent is not only inexpensive and environmentally benign, but also shows completely dif-

ferent reactivity to organic solvents. Organic reactions in water are varied and have many applications such as, in the synthesis of biological compounds from carbohydrates and the chemical modification of biomolecules," he added.

Dr. Gopalan also added that organic reactions in water are now as diverse as those that occur in the organic solvents. "The broad and varied application of aqueous organic reactions will provide a strong driving force for the future development of this area," he stressed.

The types of organic reactions in water, according to him, are broad and include pericyclic reactions, reaction of carbanion, carbocation, radicals and carbenes, transition-metal catalyses and oxidations-reductions.

Prof. G.D. Yadav, Director, ICT (Mumbai), spoke on 'Innovation in catalysis as a tool for greener chemical products.' He threw light on designing novel catalysts and increasing their activity to enhance reaction rates. According to him, green chemistry principles can be adopted for a number of industrial processes. These include:

- Converting biphasic reactions into triphasic reactions, which leads to waste minimization and economic benefits; and
- Cascading of reactions, which leads to better catalyst utilization, reduction in separation costs, and enhanced throughput and economics.

Dr. S. Ahmad concluded the day with his talk on 'Green Nanotechnology.'

DAY THREE

Implementation, Industrialisation and Impact

The third day of the conference, focused on the specific requirements of industries for implementing industrial green chemistry. It was attended by around 200 delegates, including production, project and operation managers.

Implementation

Dr. Amy Cannon, Executive Director, Beyond Benign Foundation, in her keynote speech, 'Green chemistry: From the class room to industrial implementation' discussed the importance of creating green chemistry and engineering awareness in young students.

Industrialisation

The theme session, Industrialisation, chaired by Dr. Peoples, aimed to deliver the benefits of implementation of green solutions at the ground level.

Dr. Pierre Woehl, Corning Inc, in his talk, 'Efficient processing with advanced flow reactor technology' high-

lighted developments in advanced flow reactor technology and how it helps to enhance process intensification. He



At a session: Mr. Nitesh Mehta, Prof. Paul Anastas and Dr. John Warner

advocated the use of continuous reactors in contrast to batch reactors on the grounds that the former are easier and safer to operate; allow better heat and mixing control; allow predictable scale-up by adding modules; and are more adaptable to chemistry.

He also highlighted the use of micro-reactors to enhance safety and performance, while ensuring lower manufacturing and operating costs. Reactions which have already benefited from these reactors, according to him, included: nitration, oxidation, reduction, coupling, substitutions, rearrangements, amidation, bromination, alkylation, hydrogenation etc.

Dr. Shailendra Kumar Singh, Associate Head R&D., Jubilant Organosys Ltd., in his talk, 'Niacin: Vapour phase catalytic oxidation of beta-picoline' discussed the advantages and benefits of green technology over the conventional technologies.

Dr. G.V. Subbaraju, Senior Vice President, Aptuit Laurus P. Ltd., presented a case study of 'Green technology for esterification of carboxylic acid' and compared the new technology with existing technology.

Implementation

The theme session, Implementation, was primarily to sensitize and make people aware about new concepts and technologies that individuals or organizations have used, in spite of various barriers, to implement green solutions. It was chaired by Prof. Anastas.

Prof. R.K. Sharma, Co-coordinator, GCNC, University of Delhi and Dr Alok Adholeya, Director, Department of Biotechnology, TERI, addressed applications of the microbe-plant chemistry approach to address bio-energy and bio-remediation needs.

He cited the use of microbes and plants in order to recover the chromium present in soil contaminated with waste from the leather tanning industry. This 'bio-mining' of chromium then involved development through extensive research of a metal-specific resin, which would be able to extract the chromium from the processed biomass.

Mr. Nitesh Mehta, Founder Director, Newreka Greensynth Technologies P. Ltd., spoke on 'Entrepreneurship – a model to accelerate implementation of green chemistry.' He presented an overview of Indian chemical industry and academia scenarios and how the bridging the gap through green chemistry based solutions can be advantageous to both industry and academia.

Dr. Kira Matus, Policy Analyst, Yale University, in her talk, 'Understanding innovation for sustainable development: A comparison study of green chemistry in the United States, India and China' brought forth different dimensions of sustainability. She gave a comparative study on US, India and China in green chemistry implementation barriers, policy regulations and technology implementation barriers.

Impact

The final theme session, Impact, focused on policy regulations and implementation barriers for green chemistry and engineering based technologies.

Mr. S.G. Choudhary, CT&SO, Tata Chemicals Ltd., in his talk 'Process integration for greening the footprint: Experience of Tata Chemicals' spoke on how integration of end-to-end processes makes for a greener process with reduced carbon footprint. He defined process integration as a holistic

approach to process design, which considers the interactions between different unit operations from the outset, rather than optimising them separately.

He pointed to the success in driving down the energy consumption in ammonia manufacture – almost to theoretical levels – through skilful process integration.

In his view, a multi-discipline R&D approach is essential to process integration and intensification. "Collaboration between chemical engineering and other discipline such as material science, catalysts, equipment fabrication, instrumentation and electronics is of crucial importance. Process integration outside the fence along the supply chain and collaboration for clustering of chemical processing for process integrations can explore untapped benefits in future."

The final presentation of the event was delivered by Prof. Anand Patwardhan, IIT-Bombay. His talk, 'Policy initiatives to accelerate implementation of green chemistry' emphasized governmental initiatives to accelerate green chemistry based solutions.

PANEL DISCUSSION

The conference concluded with a panel discussion consisting of Prof. Anastas, Dr. Warner, Dr. Varma, Dr. Matus, Mr. Mehta and Prof. Sharma.

The panel focused on bridging the gap between the industrial and academic world with respect to green chemistry and engineering based solutions. It also discussed implementation barriers, policy regulations and other dimensions like human mindset, apart from technology implementation barriers.