Industrial Green Chemistry World (IGCW-2011) Symposium and Exhibition- Report

Latest trends in green chemistry and technology highlighted in Mumbai meet

Industrial Green Chemistry World (IGCW 2011), the largest and most comprehensive event showcasing contemporary developments in industrial green chemistry, was held in Mumbai, between 4-6 December 2011. The three-day event encompassed a host of activities, including a symposium, exhibition, technical seminars and an awards ceremony. Satellite programs for students and teachers were also organized. Mr. Nitesh Mehta, Convener, IGCW 2011, and Founder Director, Newreka Green Synth Technologies P. Ltd., described the event as a path-breaking initiative, following the inaugural event in 2009. He termed the long journey leading to the event as a participatory one, involving several stakeholders in industrial green chemistry.

Expanded and broader coverage

IGCW 2011, since its launch, has been vastly expanded in coverage, and includes participation from 350 companies and 25 global experts; and 50 exhibitors from nine countries. Over 42 entries were received for the awards, as compared to 17 in 2009, and of these the knowledge community accounted for the largest number. Exhibits included unique concepts like switchable solvents, intelligent fluids, micro-reactors, recyclable enzyme catalysts, etc. The technical seminars, which were held concurrently with the main symposium, covered topics such as green chemical processes, solvents, catalysts, matrices & measurements, and engineering.

CASE STUDIES shared at the Symposium

Novel approaches to developing cleaner processes The opening technical session of the conference saw presentations on cleaner processes adopted by the pharmaceuticals and the speciality & fine chemicals industries. **The Pfizer experience** Dr. Peter Dunn, Pfizer Green Chemistry Lead, discussed the company's approach to green chemistry with a case study of Pregabalin, an ingredient for *Lyrica,* a neuropathy drug, launched in 2005. He highlighted three different processes for the drug and the systematic method for determining the best process to adopt on an industrial scale. In the classical process, he pointed out the E-factor – the amount of waste generated per unit of the desired product – was as high as 86, it was difficult to recycle the wrong enantiomer and energy usage was high. In the second process, using biocatalysis with low protein loading and by conducting all reactions in water, the waste reduction was significant, but the undesired enantiomer was still produced and had to be incinerated. In the third process, the undesired enantiomer was recycled to a value-added product, and the E-factor was reduced to just 11. The choice of process finally adopted for large scale production – the third process – was as a result of a detailed lifecycle analysis (LCA) that was carried out, with a 'cradle to gate' approach. "The third route has higher energy consumption than the second route without recycle. But the gap between the two closes if you consider the energy consumption of the intermediate suppliers." The sophisticated LCA analysis showed that the third process is most benign and has a lower carbon footprint and its adoption will save emissions of 3-mt of carbon dioxide over the life of the product from 2007 and 2020. "This is the equivalent of taking 1-mn cars off the road."

Eco-designed C-Glycoside

Dr. Laurent Gilbert, Advanced Research, International Development Director, L'Oréal Research and Innovation, spoke on the development of the first eco-designed C-Glycoside using bio-mimicry. "Our strategy was to design C-Glycosides 'hooks' to induce the biosynthesis of glycosaminoglycans and proteoglycans. In this regard, we voluntarily used eco-design strategies for these 'hooks' based on green chemistry principles." The synthesis of the first beta-Cglucosides was based on renewable raw materials, such as monosaccharides and disaccharides, with water as a reaction media and carried out in a single step. The production process was finetuned to take into account: Production footprint – water consumption, raw materials locality index; Environmental footprint – reuse of aqueous effluents, soiled organic solvents, packaging articles; and Design footprint – efficacy of the route of synthesis, E-factor, renewable origin raw materials and potential environmental impact of raw materials.

Green chemistry: one part of sustainability initiatives Dr. M.G. Palekar, President, Pharmaceuticals and Intermediates Division, Atul Ltd., stressed that sustainable development is a sum total of green chemistry, process intensification, new technologies and water conservation. "Organic chemistry can give conversion as per stoichiometric principles, but the competitive edge is gained by mastering downstream processing," he observed. Dr. Palekar discussed several successes at Atul in deploying technologies such as: Cavitation – for chemical reaction, wastewater & cooling water treatment, crystallization & milling; Chromatographic separation – for **Sustainable development methodology Front end (Maximise atom efficiency) Back end (Prevent/reduce pollution & waste)** Selectivity & yield improvement Recovery of raw materials, by-products & solvents Use of heterogeneous- & biocatalysts Waste treatment Process intensification New technology for recovery/waste treatment New technology for reaction & downstream processing purification of intermediates & APIs; recovery of solvents and metals from waste; and Improved reactor design – for better mixing and continuous production. Thanks to these and many other efforts, he pointed out that Atul, as a whole, in 2010-11 achieved: Reduction in gaseous emissions of chlorine, ammonia, hydrochloric acid and acid mist; 10% reduction in liquid effluent, despite 16% increase in production; and 37% reduction in solid wastes generated. **Key role of catalysis** Dr. Raksh Vir Jasra, Reliance Technology Group – Vadodara, highlightedthe role of catalysis in the 'green' manufacture of fine chemicals. He provided examples of catalytic oxidation of styrene to styrene oxide using hydrogen peroxide, aldol condensation, double bond isomerisation, acylation of aromatics and Nopol synthesis. He also discussed the role of cobalt exchanged zeolites as catalysts, solvent- free synthesis of jasminaldehyde using hydrotalcite etc.

Dr. Raksh Vir Jasra

EVALUATING PERFORMANCE **'New paradigms needed to measuring greenness'** hydroxide, along with significant solvent reduction. **Catalytic options** He went on to discuss new developments in organocatalysis, biocatalysis, homogenous and heterogenous catalysis, and the rationale for choosing solvents. "If you have to oxidize do it in water and catalytic oxidations are the best." He also discussed the use of air as an oxidant and development of a green carboxystarch from starch, which is a biodegradable super-absorbent polymer (SAP), that can potentially replace poorly-biodegradable polyacrylates, which are widely used today. On biocatalysis, Dr. Sheldon opined that while enzymes are biodegradable, and without water." "Water should be counted only if treatment of the water is needed," he added.

Novel green metrics Dr. Sheldon also pointed out that over the last two decades there have been various metrics introduced for measuring the greenness of a process. The solution, according to him, lies in atom economy and catalytic processes in alternate media such as water, supercritical fluids, ionic fluids etc. "However, the best solvent is no solvent." Dr. Sheldon cited the case study of a new Sertralin process of Pfizer where most of the steps are done in a green solvent like ethanol. The process led to elimination of 440-tonnes of titanium dioxide, 150-tonnes of 35% hydrochloric acid and 10-tonnes of 50% sodium Dr. Roger Sheldon, TU Delft University, CLEA Technologies, Netherlands, noted that organic chemists use excess of everything and produce more wastes. "To measure is to know. We need to define greenness better. A new paradigm is needed with emphasis shifting from efficiency, to one of avoiding wastes."In the last 30 years, he added, his'E factor' has been widely used in the chemical industry and especially pharmaceutical industry. The concept has also evolved and many companies think water should be included in calculation of the E-factor. "I decided not to include process water, due to complexities, but now a lot of companies think water should be included and so I calculate E factor with allow avoidance of metals, and have high regio-specificity, they have limitations such as low operational stability and shelf-life; cumbersome recovery and reuse; product contamination issues, and the problem of protein allergy. "Enzyme immobilization is the answer to all the problems," he noted and described a technique for Cross Linked Enzyme Aggregates (CLEA), which is inexpensive, simple and scalable. He pointed to the conversion of trinitrotoluene to phloroglucinol – a seemingly efficient process with 90% yield. "But is it selective, as 40-kg of by-product is formed per kg of phloroglucinol? The process had an E Factor of 40% and atom utilization of 5%."

Opportunities in the food chain

Professor James Clark, Green Chemistry Centre of Excellence, University of York, UK, struck a note of caution when he pointed to an "elemental unsustainability" and the more important issue of "the ownership of what is left." The food chain, he added, offered potential for making a number of value-added chemicals, such as waxes and switchable adhesives for carpet tiles. "Orange peels are being used to make bio-chemicals, bio-materials etc." He also elaborated on the wide potential for Starcarbons, a new class of carbonaceous materials and stressed that microwave activation of biomass holds much promise as an alternative method of decomposing biomass.

Taking ideas to the marketplace Dr. Philip Jessop, Technical Director, Green Centre Canada, dwelt on the commercialization challenges of green technologies and the university-industry mismatch. "While universities provide bench scale, speculative, unproven processes, with incomplete material characterization and grams of samples, the industry wants demonstrated scale-up, optimization, field-tested proof-of-utility and kilograms of sample."

'Innovation begins with science fiction'

Dr. John C. Warner, President and Chief Technology Officer, Warner Babcock Institute for Green Chemistry, LLC highlighted that all innovation begins with science fiction. "Innovation happens not within the field of focus, but in the periphery. Encyclopedic knowledge inhibits innovation in the absence of intuitive knowledge." He maintained that the ability to innovate is simultaneously proportional to wisdom and the tolerance of intellectual risk and that innovation is orthogonal to complexity.

Dr. Robert Peoples, Director, ACS Green Chemistry Institute, USA, pointed out that modern analytical chemistry is revealing just how widespread, persistent and bioaccumulative many synthetic materials are. "Coupled with growing awareness of the demands of an expanding population, rising standards of living and the scale of resources and energy required to meet those demands, the developing rules of sustainable design offer a new paradigm for the 21st century," he said. He stressed that detailed information will be a key enabler to addressing these challenges for the design of safer alternatives.

'Factor in endocrine disruption'

Dr. John Peterson Myers, CEO, Environmental Health Sciences (USA), pointed out that chemical hazards must be considered at all stages of molecular design and synthesis. As an example, he discussed the latest developments in endocrine disrupting chemicals (EDCs) and why it is important for green chemists to avoid them during design stages. He urged chemists to develop an understanding of issues such as how contaminants interact with genes in ways not reflected in current health standards and how these interactions can take place at extremely low concentrations. "Exposures in the womb can set in motion processes that play out over a lifetime. Exposures are ubiquitous, and in mixtures they can interact in unexpected ways. The traditional tools we have used to assess risk are blind to these impacts with dependence upon falsified assumptions and reliance upon out-dated tools." Green chemistry, he added, can use this new science to guide innovative development of new materials that are inherently safe. "Design should span a comprehensive range of EDC mechanisms of action. While in *silico* and *in vitro* assays offer less costly starting points, live animal assays are necessary to conclude that a chemical is unlikely to have EDC activity."

Sustainability by design

Dr. David Constable, formerly Director of Operational Sustainability at GlaxoSmithKline, provided a perspective on green chemistry innovation and opportunities in the pharmaceuticals and specialty chemical industries. In his view, some of the many sustainable chemistry risks include: Use of non-sustainable feedstocks; Poor process efficiencies; Lack of data on materials, streams & emissions; Use of high-hazard materials; Use of high risk process chemistries; and Inappropriate engineering or process controls.

DESIGNING FOR SAFETY

'Green chemists must design against hazards from chemicals' Many challenges for wider adoption

Mr. Nitesh Mehta, Founder Director, Newreka Green Synth Technologies P. Ltd., pointed out that the lack of an ecosystem for knowledge-based entrepreneurship, such as seed capital and funding barriers are limiting widespread adoption of green technologies in the country. "Appropriate business models, and inertia to change and scale up barriers are other impediments to overcome," he added.

Dr. Robert Peoples

Dr. R. Rajagopal, COO, Know- Genix, touched upon a host of issues and concerns in his talk on bio-based chemicals. He pointed out that the business of bio-based chemicals begins with the generation of renewables, which are converted through enzymes/microorganisms to platform chemicals and then value-added specialties. He dwelt on the challenges of finding market access amidst complex logistics, evolving policies & regulations, while addressing sustainability challenges. According to him, research in biobased products from a wide range of renewables has been at the forefront of the chemical industry's attempts to seek newer growth opportunities. "Though holding much promise, the transition from a fossil-based economy to a biobased economy will lead to profound shifts in the industry structure, as new technologies in agriculture and bioprocesses usher in new complexities," he observed. According to Dr. Rajagopal, the bio-based chemicals industry faces macro- and micro-level barriers. At a macro-level, the barriers include accessto feedstock, technology, capital and alliance formation, while at the micro level there are issues related to agritechnology, value chain integration and sustainability. "Regulatory barriers impact bio-based materials and alternate fuels in different ways," he added.

Multiple alliances emerging

The potential for bio-based products and the immense challenges in the business, he pointed out, has led to a large number of initiatives and alliances by the chemical and biotechnology players. "Since 2008, we have seen a number of alliance announcements.""As the bio-based chemicals industry moves along the path from development to maturity, several roadblocks need to be resolved. At present, there exists a large gap between the well-established petroleum based industry and the nascent bio-based industry. How fast the industry matures will depend on access to new technologies, capital and alliance partners," he added.

Market potential

In his estimate, the bio-based chemical market is projected to reach a size of about €104-bn by 2012 and to around €264-bn by 2017, with their share of the overall chemical markets, rising from 4% in 2007 to 6% by 2012 and 12% by 2017. "These numbers will be determined by how the technologies mature, success in capital generation, alliance formations and resolution of supply chain complexities," he added.

BIO BASED CHEMICALS

'Transition from a fossil- to bio-based economy will lead to profound shifts in industry structure'

"If we want to build sustainability into the design of products and services, we have to think differently about the 'what' and 'how' of R&D. Increasing demands and decreasing budgets are likely to mean greater reliance on easily accessible company-wide tools that provide early assessments and highlight sustainability issues."He described how Life Cycle Analysis can help to evaluate the true greenness of a process and provide a common set of accepted metrics to measure specific impacts. "LCA also identifies trade-offs, hot spots and opportunities for resource optimization. It provides a better understanding of theenvironmental impacts of processes for a better decision-making for production systems."

Carbohydrates to platform chemicals

Dr. Jayant Sawant, Program Leader, Praj Matrix Innovation Centre, pointed out that the Centre has developed an innovative process for ethyl levulinate – an important platform chemical – from sugars, starches and molasses, using proprietary catalysts and technologies. Salient features of the process include zero discharge, high feed & productflexibility and more than 80% carbon conversion. The company is now seeking complimentary partners with global outlook in renewable green chemistry and sustainable access to feedstock streams, such as carbohydrates, biomass and oil. "We are looking at technology and commercial risk sharing ability in the bargain of long-term economic gains."

Drivers for innovation changing

Mr. Rajiv Kumar, Innovation Center, Tata Chemicals. Ltd., pointed out that innovation leads the way for industrially important green manufacturing. "Affordability and sustainability are replacing premium pricing and abundance drivers of innovation, but few executives know how to cope with the shift." He stressed that companies must make their offerings to a greater number of people by selling them cheaply and must develop more products and services with fewer resources. According to him, the key questions that must be answered in any innovation are:

Does it provide wide range of business opportunities? Is it disruptive, changing the rules of the game? Does it provide sustainable and inclusive solutions? FOLLOWING THE LEADER

Global regulatory trends define future course

Bhutan, pointed out that regulation, like the European Union's chemicals policy, REACH, have led to several innovations in the chemical industry, and how the concepts of substitution and precautions underpins the system. He emphasized the need for technologies to identify chemicals in waste, and introduction of innovative business models for reducing waste and cleaner processes. "The raw material, water, energy and transportation impacts need to be integrated into green chemistry principles to ensure sustainability."Mr. Donkers also pointed out that manufacturing and accidents laws in India mainly address site-specific issues. Other problems include multiple laws and authorities, with limited coordination, and partial and scattered data, with little sharing. "Enforcement is very poor, especially with small and medium enterprises, with States having limited capacity and knowledge".

"India has huge potential, but needs to focus on substance risk managementand conduct a review of competences."

Short-sighted view of treaties According to him, India has been a very reluctant partner in key global treaties and has a short-sighted view of treaties – seeing them essentially as a trade barrier – even as many sections of the industry operate outside global standards. He stressed the need to improve coordination at Government of India level amongst ministries, create laboratory infrastructure and invest in augmenting human resources.

'Regulations driving innovation'

Mr. Robert Donkers, Minister Counsellor Environment, Delegation of the European Commission to India and Addressing global regulatory regimes and key concerns, Mr. RaviRaghavan, Editor, *Chemical Weekly,*

spoke about the complex issues related to global regulatory regimes and how they impact global trade.

Discussing the dual risks from chemicals, he said that risk from chemicals have two components: One from its intrinsic properties and the other from exposure (or risks). While risks cannot be eliminated, they can be assessed and managed. He elaborated on the key multi-lateral legally-binding agreements and discussed the voluntary initiatives of OECD and SAICM. Touching on glo-bal initiatives on classification and labeling he said, "In India, no steps have been taken as yet, though it has been decided to implement it."

Mr. Raghavan discussed the evolution and impact of REACH at length, while expressing his concerns about the regulation. "REACH is hazard- and not risk-based and key decisions are based on just intrinsic properties and volumes."