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Green Chemistry Drives Opportunities for Innovation

Promising Results Challenge the Mindset That Green Cannot Be High Performing

by Bernard Tulsi

Leading experts in the field view green chemistry as tantamount to preventative medicine for the environment. It entails the careful design of efficient processes that use resources optimally, and which generate products and applications with no or significantly lower levels of associated waste.

In the first of this two part series on green chemistry (March 2007), several academic laboratories alluded to their hefty savings from the elimination or reduction of the number of fume hoods in their facilities. In a recent report making the case for sustainable laboratories, a team drawn from Harvard Green Campus Initiative and the Department of Environmental Health at Harvard School of Public Health cited evidence that in the U.S., laboratories typically used about four to five times the amount of energy consumed in the average commercial setting, per square foot.

The report notes that a typical fume hood in the U.S. runs 24 hours a day, 365 days a year and uses 3.5 times more energy than the average house. Citing Lawrence Berkeley National Laboratory data (LBNL 2002), the report noted that in normal U.S. climate, the average fume hood burns more than $4,300 in fuel a year.

“In the roughly 75,000 fume hoods that exist across the country, this amounts to $3.2 billion each year in energy expenses (including the cooling load), and this requires the equivalent electrical output of roughly 20 electric power plants (assuming they are 250 megawatts each). In addition, these 75,000 fume hoods nationwide consume roughly 200 trillion cubic feet of natural gas annually to heat the make-up air in laboratories,” according to the Harvard report.

A major initiative that strikes at the heart of the energy question is the use of microwave heating instead of thermal heating mantles or blocks. With microwave heating, some reactions can be completed in minutes instead of hours, says University of Oregon’s chemistry professor Jim Hutchison.

Microwave heating is still quite new but it is steadily making its way into academic settings. Hutchison notes that this constitutes a green differentiation, “The capital costs for the installation of a microwave reactor may be more but because of its efficiency, based on the more direct transfer of heat, it requires less energy, which in turn translates into less waste,” says Hutchison.

Meanwhile, in an initiative to research green microwave chemistry scale-up methods, CEM Corporation (Matthews, NC), a top developer of microwave laboratory instrumentation, entered into a Cooperative Research and Development Agreement (CRADA) with the U.S. Environmental Protection Agency (EPA) “to develop large-scale, microwave chemistry methods for a wide variety of chemistries using solvents that are more environmentally friendly, such as water or polyethylene glycol (PEG),” according to a CEM statement.

“These environmentally-friendly solvents could be employed to produce valuable intermediates and products useful in the development of pharmaceuticals, fine chemicals, and nanomaterials,” according to the CEM statement.

“Microwave energy is a highly-effective green chemistry technology,” says Michael Collins, CEM’s president and chief executive. “It is clean, fast, efficient, and applicable to numerous types of chemistries.”

CEM has more than 200 patents for microwave technology in chemistry. One area covered by the CRADA is the use of CEM’s patented simultaneous cooling while heating technology (PowerMAX), which lets chemists work with temperature-sensitive or highly-reactive intermediates and still achieve the same type of yield and rate-enhancing benefits seen in microwave-assisted, high-temperature chemistries.

In August last year, CEM Publishing, a division of CEM Corporation, released Clean, Fast Organic Chemistry: Microwave-Assisted Laboratory Experiments, an undergraduate laboratory manual for microwave-assisted organic synthesis. Co-authors Nicholas Leadbeater, PhD, University of Connecticut, and Cynthia McGowan, PhD, Merrimack College, incorporated microwave synthesis techniques into their teaching curriculum and developed a series of experiments specifically for college classes.

While industrial chemists have been effectively employing microwave energy in chemical syntheses and for cutting down on reaction times, the technology has only recently become affordable enough for use in teaching laboratories, according to CEM.

“Microwave energy has become the method of choice for many industrial chemists because it is significantly faster and cleaner than conventional heating methods,” says Prof. Leadbeater. “By integrating microwave chemistry into undergraduate courses, it is possible not only to train students in a new technique, but also to widen the scope of the reactions they can perform.”

“In the undergraduate lab, the speed of the reaction dictates what you can teach. Decreasing reaction times allows students time to design, optimize, characterize, and analyze reaction processes and products,” says Prof. McGowan. “Thus, microwave technology opens new avenues for teaching chemistry that were previously unavailable to most professors in the allotted class time.”

“Additionally, microwave-assisted reactions are often run neat or in aqueous solutions minimizing the need for organic solvents and simplifying the work-up process, which provides more environmentally friendly ‘green chemistry’ conditions,” according to CEM Publishing.

The ‘low hanging fruit” in the process, product and application segments of green chemistry has been the process portion, according to Prof. Hutchison. “Designing greener products is more challenging. Products distribute materials into the environment through commerce. As a result, it is important to understand what structural materials end up as waste and strategically design products that will reduce such waste,” says Hutchison.

Strategic initiatives to reduce or eliminate waste constitute part of the overall philosophy at Rohm and Haas, a top maker and seller of specialty materials including electronic materials, polymers for pains and personal care products, and a recipient of one of the first Presidential Green Chemistry Challenge Awards (1996). “We have a strong commitment to the reduction of emission and waste and promoting conservation throughout the life cycle of products,” says William Drummer, Environmental Manager at company’s Spring House (Pennsylvania) Technical Center, a large R&D laboratory facility.

“We view waste minimization and resource reduction as a continuum that goes from research through production, that is a very broad based approach to waste minimization,” says Drummer.

Noting the long standing commitment of the company to efficiency and waste reduction, Drummer notes that programs to achieve such objectives have been in place for some time now. “The terminology has changed to some extent. We have gone from phrases like waste minimization to pollution prevention, from resource reduction to sustainable development and green chemistry, but to a great extent, a lot of our processes have remained very similar,” says Drummer.

“When a new process comes on site, it goes through an environmental safety and health review process with a view towards minimizing the hazards,” says Alisa Kreft, Health and Safety Manager at Rohm and Haas Spring House Technical Center.

Part of the review seeks to determine whether the minimum amount of material is being used, whether the experiment can be done by modeling rather than actual bench work, if the size of the reaction can be minimized, if the energy consumption can be minimized, if the amount of water used could be minimized—all with a view to minimizing waste, according to Kreft.

To be sure, this kind of review, though not necessarily an identical one, could be readily found these days at most research laboratories as part of the standard operating procedures.

Based on the review, a process is deemed successful if it “has low emissions based on accepted thresholds in air, water and waste, has no odor issues, researcher exposure is minimized and the researcher is appropriately protected,” says Drummer.

In identifying current and future challenges, Kreft says that improving energy efficiency is a key area. “There are lots of ways to do that but one is through modeling—the ability to enter technical questions and use modeling rather than actual experimentation.”

Other challenges include the need to keep the workspace safe without the use of hoods and how to run the existing hoods with the greatest energy efficiency.

“These are still major challenges for the R&D facility in terms of improving sustainable development and minimizing waste,” says Kreft.

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