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Invited Article

Green chemistry and sustainable development

Margaret E. Kerr*

Dr. Kerr received her B.S. degree in chemistry from the University of Maine and her Ph.D. from Wesleyan University in Middletown, CT (USA) in inorganic chemistry. She did post-doctoral research at the University of Florida and was offered a position as a Senior Staff Scientist at Fina Oil and Chemical in Houston, TX. She worked for two years developing metallocene catalysts for polypropylene synthesis before taking a position as a faculty member at Worcester State College in Worcester, MA. She is currently an Associate Professor with a focus on green chemistry in education. She was awarded a Fulbright Senior Scholar Grant in 2007 to go to Thailand to promote green chemistry curriculum development at Chulalongkorn University in Bangkok.

* E-mail : Margaret.Kerr@worcester.edu

I am writing this article at the end of a 5-month Fulbright Senior Scholar grant that has provided me the opportunity to live in Bangkok, Thailand. I have worked closely with Thai scholars at my host institution, Chulalongkorn University, and at other institutions including Maejo University, Ubon Ratchatani University and Silpakorn University. During my stay in Thailand, I have been fortunate to interact with scientists and citizens who care deeply about the future of Thailand and of the world. As I have learned more about Thailand, I have been struck by how important the ideals of self-sufficiency and sustainability are in relation to the predominant culture. In the first edition of Maejo International Journal of Science and Technology, Dr. Thep Pongparnich, president of Maejo University, wrote an invited article that discussed some of the links between science and Thai culture and suggested that "Thai scientists should focus more on research that leads to self-dependency with a certain degree of freedom and on how to live a moderate life that is friendly with nature." If we take that a step further, the question becomes not whether we should promote sustainability and self-sufficiency but rather how do we attain that goal? As someone with a specialty in the field of green chemistry in education, I have become very interested in how the ideal of sustainable science can fit into a message that is acceptable by society as a whole.

My perspective as an American might be somewhat different than that of a Thai, but the fundamental role of science in the future will be the same everywhere. As chemists, we are concerned about the future of our field and are worried about what will happen when petroleum based starting materials

become scarce and more expensive. Scientists have both the burden and the privilege of being on the forefront in the development of solutions that will aid society in its progression into the future. As we work to train students and develop research programs, it is imperative that we teach students in concepts in sustainability. The practice of green chemistry, or sustainable chemistry, is a powerful tool that provides students with the opportunity to learn about how they can promote practices that are favorable to the environment and to humans when they get into the working world.

Green chemistry, by definition, promotes the reduction or elimination of hazardous substances in chemical processes [1]. Chemistry as it has been traditionally practiced is not on a sustainable trajectory and will be a major contributor to environmental degradation unless changes are made. According to Professor Walter Leitner [2], scientific editor of the journal *Green Chemistry*, "As the principles of green chemistry and the concepts of sustainability in chemical manufacturing are becoming part of the explicit corporate policy and aims in the chemical industry, there is a rapidly growing need for the education of chemists in the field." Increasingly, corporations are looking for employees who have training in areas such as hazard and risk management, toxicity, and life cycle assessment that are not taught in traditional chemistry programs.

Green chemistry has been defined as "the utilization of a set of principles that reduces or eliminates the use or generation of hazardous substances in the design, manufacture and application of chemical products." It has been referred to in numerous sources as "molecular-level pollution prevention". Green chemistry is not related to a specific discipline in chemistry, but instead provides any chemist with a framework in which to design molecular processes. The major difference between a green chemistry approach to environmental issues and more traditional approaches is that green chemistry utilizes the creativity of the scientists and engineers to develop novel and benign approaches to processes from the start rather than relying on regulatory restrictions after the process has been discovered to be toxic or polluting [3]. There are twelve principles associated with green chemistry and if all principles are utilized, a process can be considered benign [1].

Why is it important for students to study these concepts? If we focus on Thailand and Asia, we find that the Asian market is so vast that the future of the planet depends considerably on what happens there in the next generation [4]. There has been substantial economic growth in most countries in Asia over the previous 15 years. In Thailand for example, the economic growth averaged 6.2% from 2002-2004 and is expected to show continued growth of around 5% per year in the future [5]. A measure of economic growth worldwide is indicated by the Global Chemical Index. The 2003 Global Chemical Index showed East Asia, which includes China, with an annual growth of 11.0%. This can be compared with Central and Eastern Europe at 6.7% and the United States at 0.2%. While China shows the largest growth in eastern Asia, countries such as Thailand, Malaysia and Vietnam are also expected to see high growth [6]

While this growth has resulted in an overall reduction in poverty in Asia, it has also placed significant strains on the environment. In a study by the Asian Development Bank, Asian cities have substantially higher air pollution than other industrial countries. Higher levels of water and ground pollution also contribute to the overall environmental degradation of the area. In the Thailand Human Development Report 2007, written by the United Nations Development Program, it was found that Thailand imported

nearly two times the amount of pesticides in 2004 than it did in 2003. Additionally, samples taken from over 100,000 farmers showed dangerous levels of toxins from exposure to pesticides. While many overall quality of life indicators are improved there are growing problems with environmental issues. Factors such as water quality and industrial waste management indicate that unless changes are made, Thailand will show marked environmental deterioration in the future [7].

As we read statistics such as those above, the question becomes one of how to balance economic growth and environmental degradation. Sustainable development has been defined by the World Commission on Environment and Development as "a process in which the exploitation of resources, the direction of investment, the orientation of technological development, and institutional change are made consistent with future and present needs." According to *Sustainable Development in Asia* [5], "Sustainable development is an act of balancing economic, social, and environmental benefits through implementation of development policies, programs, and projects that will not enhance one type of benefit at the cost of others. Sustainable development also requires a major overhaul in the mindset, attitude, and behavior of the local people as well as of the international community." If the 11% growth of the Global Chemical Index of Asia in 2003 is compared with the percentages of hazardous wastes that are dumped in landfills or oceans, it becomes apparent that changes in the way chemistry and chemical manufacturing are done will have a major impact in the goal of sustainable development.

Research and education efforts in academic institutions and industrial laboratories throughout the world recognize the importance of designing more benign chemical processes and of utilizing sustainable development practices in order to bring about necessary changes. It is encouraging to read articles in leading journals describing the development of greener processes and to visit universities with ongoing programs in sustainable development. In Thailand, institutions such as Maejo University and Chulalongkorn University are on the forefront of the work being done in these areas. Green chemistry, coupled with the Thai ideal of self-sufficiency and living in harmony with nature, can provide a way to navigate the path toward a future where we can have the comforts we all as humans desire while at the same time not compromising the future of upcoming generations.

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