A Study on Educational Progress of Green Chemistry

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***Abstract*— Chemistry has improved our quality of life, and made thousands of products possible. Unfortunately, this achievement has come at a price: our collective human health and the global environment are threatened. Our bodies are contaminated with a large number of synthetic industrial chemicals, many of which are known to be toxic and carcinogenic while others remain untested for their health effects. Green chemistry refers to the redesign of chemical products and processes with the goal of reducing or eliminating any negative environmental or health effects. Sustainable development is now accepted by governments, industry and the public as a necessary goal for achieving societal, economic and environmental objectives.**

Many students today are profoundly interested in the sustainability of their world. With growing public concern over global warming and greenhouse gases, students want to understand how human actions affect the health of our planet. Green Chemistry has evolved from its roots in academic research to become a mainstream practice supported by academia, industry, and government.

Keywords*— *Green Chemistry; Green Chemistry Institute; Curriculum; Resources.

I. INTRODUCTION

The green chemistry revolution is providing an enormous number of challenges to those who practice chemistry in industry, education and research. With these challenges however, there are an equal number of opportunities to discover and apply new chemistry, to improve the economics of chemical manufacturing and to enhance the much-tarnished image of chemistry.

II. WHAT IS GREEN CHEMISTRY?

Green chemistry is an approach to the design, manufacture and use of chemical products to intentionally reduce or eliminate chemical hazards. The goal of green chemistry is to create better, safer chemicals while choosing the safest, most efficient ways to synthesize them and to reduce wastes.

"Green Chemistry" is the universally accepted term to describe the movement towards more environmentally acceptable chemical processes and products. It encompasses education, research, and commercial application across the entire supply. Paul Anastas, then of the United States Environmental Protection Agency, and John C. Warner developed 12 principles of green chemistry, which help to explain what the definition means in practice[1]. The principles cover such concepts as:

- The design of processes to maximize the amount of raw material that ends up in the product;
- The use of safe, environment-benign substances, including solvents, whenever possible;
- The design of energy efficient processes;
- The best form of waste disposal: not to create it in the first place.

III. THE INSTITUTE OF GREEN CHEMISTRY

A major force in taking the concept and the practice of green chemistry around the world has been the Green Chemistry Institute (GCI). Created in 1997, the Institute flourished by promoting and fostering the furtherance of Green Chemistry through research, education, conferences/deliberative symposia/meetings, and information dissemination including public awareness. The organization itself is made up of institutions from around the world that represent all aspects of the chemical enterprise: industry, academia, non-governmental organizations, and government. At the 220th Meeting of the American Chemical Society in August 2000, the Board of Directors unanimously approved an alliance between ACS and the Green Chemistry Institute. A key objective of the ACS/GCI alliance is establishing Green Chemistry as a national research priority by aligning the interests of policy makers, business leaders, and the scientific community in new initiatives [2].

IV. EDUCATIONAL MATERIALS AND RESOURCES

One factor that is greatly speeding the incorporation of pollution prevention into industrial manufacturing processes is the development of green chemistry curriculum materials. The chemical industry is discovering that when their chemists are knowledgeable about pollution-prevention concepts, they are able to identify, develop, and implement techniques that reduce pollution and costs. To facilitate the inclusion of green chemistry into the classroom, the ACS Division of Education and International Activities and EPA-OPPT jointly designed materials to provide succeeding generations of chemists with the skills and knowledge to practice green chemistry. While the primary audience of these materials is undergraduate and graduate chemistry students, the audience may also include professional chemists, K–12 students, and the general public [2].

Additional key educational tools in shaping interest in Green Chemistry are dedicated fellowships, scholarships, and research grants. These funds allow students and faculty to focus sustained attention on specific research tasks. Similarly, attending workshops, symposia, and conferences allows students, teachers, and researchers alike to gain an in-depth understanding of green chemistry.

The GCI also disseminates information through a Web site and email list-server. The Web site provides information on GCI; Green Chemistry activities worldwide; and links to government, industry, and academic Web sites with related information. The email list-server links more than 300 participants in a common system, allowing rapid dissemination of information such as job openings and upcoming conferences as well as a venue through which to pose questions to subject-matter experts.

V. CURRICULUM FOR GREEN CHEMISTRY

An important consideration often mentioned when curriculum modifications are proposed is the already overwhelming amount of information incorporated in chemistry and chemical engineering education. The authors believe that GC is not meant to replace existing class material or be taught as a separate section altogether. Instead, existing classes should be taught in a new way, incorporating key concepts into the curriculum to make chemistry inherently green. In a series of discussions, the authors identified a number of concepts that should be used to enhance the chemistry and chemical engineering curriculum.

A. General Concepts

- GC is not intended to be a solo discipline, but rather a means for conducting science in a responsible manner. As researchers, we need to be aware that the current state-of the art processes are not perfect, and only the constant drive for improvement will lead to a sustainable future.
- Knowledge of what is considered to be sustainable, renewable, and environmentally benign should be considered a requirement for professionals who design reactions and processes.
- Chemical safety is critical. Students should develop an understanding of the dangers associated with chemicals without retreating to universal fear of chemistry. Adoption of GC principles can lead to safer and more efficient work environments on both the laboratory and industrial scale [3].
- Objectivity and rationale are imperative when conducting scientific work. However, creativity—especially during the early stages of education—is often neglected. GC offers a systematic approach to sustainable science while promoting innovative research and creative solutions.

B. Chemistry

- It is not possible to track the fate of every chemical compound used and generated in a reaction or process. Environmentally benign chemicals are therefore highly desirable.
- Reactions should not only be evaluated based on conversion and selectivity, but also efficiency, sustainability, recyclability, degradation, and elimination or reduction of hazard.
- The connection between chemical structure and compound activity should be made clear to students. Chemical functionality (sterics, electronics, hydrophobicity / philicity, toxicity) can provide a basic understanding of how chemicals impact the environment.
- An enhanced understanding of ecotoxicity and fates and transport of chemicals released to the environment is essential for the overall evaluation of chemical substances.

C. Engineering

- All industrial processes are imperfect and can always be improved, economically as well as environmentally. Process design should include critical evaluation of current industrial processes with awareness for sustainability, stressing minimal waste production, use of renewable and recycled resources, and highest possible energy efficiency.
- Process evaluation is far-reaching and goes beyond the knowledge of just classical chemistry and chemical engineering. It includes many other disciplines, such as ecology, toxicology, biology, and environmental engineering. Multidisciplinary approaches to problem solving are essential and should be introduced early and supported throughout the curriculum.
- Processes should be designed as “green” when possible, with promotion of resource and energy efficiency, and complete avoidance of end-of-pipe treatments. Waste treatment is exceedingly expensive and its elimination is economically and environmentally beneficial.
- Cradle-to-grave evaluations are essential to the greater impact of processes beyond the immediate sphere of influence. Life cycle assessments must consider factors such as renewable feed stocks, feedstock acquisition, waste treatment, environmental persistence, energy requirements, and energy sources [4].

D. Global Issues

- The current strategy of “outsourcing” motivated by inexpensive labor and lax regulations does hold economic benefits, such as low-priced goods for Western nations, income for developing nations, and the opportunity to build new environmentally conscious facilities close to expanding markets.
- Concurrently, outsourcing will lead to the loss of 3.4 million U.S. jobs by 2015 [5], and extreme environmental damage in developing countries, affecting their livelihoods for many generations and

depleting natural resources, including energy and clean water [6].

- Globalization must be environmentally responsible. GC can provide knowledge and awareness through education of scientists to develop technologies for a sustainable global economy, as well as education of policy makers for environmentally responsible diplomacy.

VI. INDIAN CHAPTER

The recently constituted Green Chemistry Chapter of India has already started working to popularize Green chemistry in India. Green Chemistry Network Center (GCNC) was established in the Department of Chemistry, University of Delhi under the recommendation of World Leaders in Green Chemistry headed by Professor Paul Anastas (known as the father of Green Chemistry) with the following aims and objectives:

- Build a Network for exchange of expertise, discussion and knowledge between industrialists and academics and between chemists and engineers with interests and expertise relevant to Green Chemistry.
- Prepare and disseminate the teaching materials on Green Chemistry for school, college and university levels, with the simultaneous design of laboratory experiments for these levels as well.
- Design trainings not just to expose the chemists to the concepts, principles and methodologies of Green Chemistry but also to empower them to bring this new knowledge back to their institution or industries.
- Promoting research by taking up Green Chemistry Research Projects from Industry and Government agencies.

GCNC received prestigious IUPAC CHEMRAWN GCI-DEN Grant Award for Green Chemistry Networking in India.

As a part of environmental movement, a National Workshop on Green Chemistry was organized by the Department of Chemistry, University of Delhi in March 2009 to bring together all who are practicing Green chemistry in India for the first time. For Green chemistry education, a refresher course was organized for college teachers by the Centre for Professional Development in Higher Education in University of Delhi. Inspired by the overwhelming response of participants in these events, an IUPAC International Symposium on Green Chemistry was organized by the Department of Chemistry, University of Delhi, which proved to be an excellent event for researchers' world over to interact on the one common platform. Recently an International workshop on Green Chemistry is organized by GCNC,DU sponsored by Royal Society of Chemistry London(North India Section) in December 2013, The speakers in the workshop has presented the latest Green Initiatives in Energy, Environment & Health based on their own experiences in either industry or academia and address the challenges and opportunities in Green Chemistry. They will provide strategies for designing, adapting and incorporating new green strategies in industries as well as in academia.

Some future activities under the banner of the Green Chemistry Chapter of India have been planned. Top on the priority list is to spread the awareness of Green chemistry among researchers and young students by means of workshops, conferences scholarships, and awards. Simultaneously, there is a need to encourage industries to collaborate with academia and government for effective practice of Green chemistry. Another aim of the Green Chemistry Chapter of India is to encourage global partnership for effective environmental management [8].

VII. CONCLUSION

Today's students, and ultimately the scientific community of tomorrow, would significantly benefit from the introduction of green chemistry principles into the curriculum. Increasing communication and awareness among chemists, engineers, policy makers, and the general public will lead to a greater responsibility for environmental and global issues. Students will enter the professional world with knowledge of the weaknesses of current industrial processes, coupled with motivation for the development of solutions based on green chemistry principles in an international and interdisciplinary environment. Green chemistry education can provide the required knowledge and awareness to develop the technologies that are necessary to achieve the ultimate goal of a sustainable world. Furthermore, the success of green chemistry depends on the training and education of a new generation of chemists. Student at all levels have to be introduced to the philosophy and practice of green chemistry. Finally, regarding the role of education in green chemistry: the biggest challenge of green chemistry is to use its rules in practice.

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