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A review on promoting green chemistry for advance sustainability

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Abstract
A crucial instrument for attaining sustainability is green chemistry. If the rising world population is to enjoy an improved level of life without harming the environment, green chemistry-the creation of chemical products and processes that decrease or eliminate the usage and generation of hazardous substances-must be implemented. Cleaner technology will make it possible for the chemical industry to deliver the commodities and services that society needs in an eco-friendly way. Global issues like climate change, sustainable agriculture, energy, environmental toxins, and the depletion of natural resources can be addressed with the help of green chemistry. To encourage the use of the green chemical technologies required to create a sustainable society, industry, academia, and the government must work together. In this update article I will introduce an individual perspective on how the region has improved - for the most part - and what we want to do now. I will consider how the vital drivers for significant changes in the manner that we practice science have reinforced, how the scope of applicable examination has expanded, how the contextual analyses from industry have expanded and, maybe in particular, how our enthusiasm for what green science ought to mean has developed. I will likewise be looking forward at the prompt and longer-term difficulties and open doors as I currently see them - in research and in modern application and furthermore in training and advancement.

Keywords: Sustainability, green chemistry, green chemical technologies, sustainable development, environment pollution

Introduction
The concept of sustainable development was defined by the Brundtland Commission as "development that satisfies the requirements of the present without compromising the ability of future generations to meet their own needs" [1]. However, current societal practices are not sustainable, as the world's population continues to grow, natural resources are being depleted faster than they can be replenished, and harmful substances are being released into the environment.

In response to this challenge, scientific discoveries are playing an increasingly important role in addressing issues related to sustainability. Despite the environmental concerns raised by technological advancements, many of these issues can be resolved thanks to scientific progress. Green chemistry is one such area of scientific discovery that has the potential to promote sustainability by reducing or eliminating the use and production of hazardous substances through the design of chemical processes and products [2].

The Green Chemistry & Engineering Conference, which has been held annually for the past 25 years, highlights advancements towards more sustainable chemistries. The theme of the 2021 conference, "Sustainable Production to Promote the Circular Economy"[3], emphasizes the need to take a systems approach to reducing environmental impact through the intentional design of chemical products. This involves considering not only how raw materials are sourced and used in the production and use of industrial and consumer goods but also how these materials and products can be reused, recycled, or upcycled.

The "molecular basis of sustainability" refers to the understanding of how current and future generations can live within the boundaries of the natural world, with a particular focus on the material foundations of our society and economy [4]. Given the pressure on the planet's resources from a growing global population and a rising standard of living, scientific discoveries are critical in finding solutions to sustainability challenges.

The 12 Principles of Green Chemistry provide a framework for the design of goods and procedures that are environmentally friendly [5]. These principles categorize the key strategies used to attain the green chemistry objectives of benign products and processes. Molecular scientists have utilized these principles as standards and design criteria for their work. The past decade has seen significant progress in research, application, education, and outreach related to green chemistry, leading to the current state-of-the-art in this field. The use of green chemistry technology can help reduce the use of substances that are harmful to the environment and human health, as well as increase efficiency and reduce energy and water consumption. However, the implementation of green chemistry requires cooperation between academia, industry, and government. It is important for these stakeholders to work together to ensure that the methods and practices of green chemistry are adopted widely across various industries. The following sections highlight the methods to sustainability in various industries that use green chemistry.

Green Chemistry for Advanced Sustainability

A. Academia

1. Renewable Resources

Renewable resources, such as biomass, have been suggested as a potential source for sustainable chemical production. Wang *et al*. (2021) investigated the use of corn stover as a feedstock for producing a platform chemical, levulinic acid, which is an important precursor for a range of products [6]. The researchers found that the process was highly efficient and sustainable, with a high yield of levulinic acid and minimal waste. This study demonstrates the potential of using renewable resources for sustainable chemical production.

2. Sustainable Processes

Numerous studies have focused on the development of sustainable processes for the production of various chemicals. For instance, Zeng *et al*. (2019) [7] proposed a sustainable and efficient method for the synthesis of pharmaceutical intermediates using a combination of solvent-free grinding and mechanochemistry [7]. The process not only minimized waste and energy consumption but also improved the yield of the final product.

3. Mitigation of Environmental Pollution

Green chemistry has been studied for the mitigation of environmental pollution. One research paper proposed the use of bioremediation, which is the use of microorganisms to remove pollutants from the environment. Pandey *et al*. (2020) [8] demonstrated the effectiveness of using indigenous microbial strains for the bioremediation of tannery effluent [8]. The study showed a significant reduction in pollutants, including total dissolved solids and chemical oxygen demand, demonstrating the potential of bioremediation as a sustainable approach to pollution control.

B. Industries

Companies are adopting cleaner technologies to reduce hazardous substances in their products and processes due to favorable economics, resulting in significant environmental and economic benefits. Pharmaceutical and polymer industries have also been adopting more sustainable practices, with examples such as Pfizer redesigning the synthesis of several pharmaceuticals [9] and Asahi Kasei Corporation developing a new manufacturing process for a polycarbonate used in various products [10]. PVC is a concern because of disposal issues; burning a PVC-containing product in an incinerator, for example, releases toxic dioxins. To avoid this problem, Shaw Industries (Ritter, 2003) developed a carpet backing using polyolefin resins and waste fly ash. The backing is PVC-free [11]. Dow Agro Sciences has developed a number of pesticides that are more selective and less persistent. Instead of creating a chemical barrier around a structure to keep out termites, Dow's Sentricon TM Termite Colony Elimination System (2002) [12] employs traps baited with hexaflumuron, a substance that disrupts the molting cycle of termites.

C. Governments

Government organizations can support sustainability by funding research and education, and offering regulatory relief for adopting cleaner technologies. In the US, the Green Chemistry Research and Development Act of 2004 coordinates green chemistry efforts across federal agencies. Government agencies also adopt more sustainable technologies to address immediate needs, such as the US Bureau of Engraving developing an alternative solvent for cleaning postage stamp presses [13]. Los Alamos National Laboratory has found new uses for supercritical carbon dioxide in the semiconductor industry, which reduces the consumption of organic solvents and energy during integrated circuit manufacturing [14].

D. Future challenges & implementations

Despite the proven benefits of green chemistry, there are still challenges that need to be addressed. These include the need for more research, regulations to encourage sustainable practices, and education and training for professionals and the public [15] To overcome these challenges, collaboration between researchers and industry professionals is essential, as well as the establishment of government policies and education programs to promote sustainable practices.

E. Education and Awareness

Several research papers have focused on the education and awareness of green chemistry. One study proposed the inclusion of green chemistry in the school curriculum to educate the younger generation on the importance of sustainable practices. Bhasin *et al*. (2017) demonstrated the effectiveness of incorporating green chemistry experiments in high school chemistry classes [16]. The study showed that students had a better understanding of green chemistry concepts and principles after performing the experiments.

Conclusions

Green chemistry plays a crucial role in building a sustainable society by addressing environmental concerns at

the atomic and molecular level through scientific innovations. Collaboration among academia, industry, and government is necessary for the adoption of sustainable products and processes, which will require the optimal use of available resources and minimize duplication of effort. The implementation of green chemistry is vital for developing advanced sustainability, as demonstrated by the research papers reviewed in this paper. Key aspects of green chemistry include the use of renewable resources, sustainable processes, and reducing environmental pollution. Education and awareness of green chemistry are also crucial for promoting sustainable practices in society.

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