ORIGINAL RESEARCH PAPER

Chemistry

KEY WORDS: Harmful side-effects, environmental protection, hazardous substances, applications, reduce waste.

GREEN CHEMISTRY- A PROMISING STRATEGY FOR SUSTAINABLE DEVELOPMENT

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ABSTRACT

This paper explores the principles and processes of Green Chemistry. Green Chemistry is the process of developing of chemical products and processes that reduce or eliminate the use and generation of hazardous substances. Green Chemistry helps preventing the harmful effects that various chemical processes produce on the environment. It also helps improving the financial gains of companies and offer them market competitiveness. Therefore, it is desirable for every single companies to adopt Green Chemistry as part of their businesses strategy. It appears that Green Chemistry is the need of the day as increasingly large quantities of different types of chemical substances are being poured into the environment each day that have great potential to damage the biosphere. Green Chemistry has enormous contribution in making the world safer and healthier, hence, is inevitable for sustainable development.

I. Introduction

Although we are living in the world of great advancement and enormous comfort, the environment in which we live in are vulnerable to many challenges and problems. Human activities, individual and commercial actions, tend to release large quantities of chemical substances into the atmosphere that have many negative impacts on environment and this trend is on the rise (Schulte et al, 2013). Therefore, increasingly more attention is paid to protect and maintain stability of the environment. Governments, international organizations, non-governmental organizations, and scientific communities are trying to adopt measures and devise strategies to preserve the environment in the best possible way. Protecting environment is now recognized as a responsibility of every individual. The global concern on environmental protection has culminated into several strategies and Green Chemistry one of such strategies aimed at preserving the environment. This paper explores the principles and processes of Green Chemistry.

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II.Green Chemistry

Green Chemistry is relatively a new concept. This concept was originally coined by two American researchers named Paul Anastas and John Warner in 1998 (Scott, 2010). It is the process of designing of chemical products and processes that reduce or eliminate the use and generation of hazardous substances (Bryner & Scott, 2007). The major objective of Green Chemistry is to reduce or eliminate the use or generation of hazardous substances (Anastas & Warner, 1998). It might involve changing the design or process, or replacing the materials, components, or solvents. It may be practically impossible to entirely stop releasing of chemicals into the environment. However, it is possible to reduce it to a great extent or satisfactory level. Successful approaches such as the use of alternate substances and changing the design or application are important strategies in this direction (Mestres, 2005).

The Green Chemistry is based on 12 important principles as mentioned below:

1. **Prevent waste:** Design chemical syntheses to prevent waste. Leave no waste to treat or clean up.
2. **Maximize atom economy:** Design syntheses so that the final product contains the maximum proportion of the starting materials. Waste few or no atoms.
3. **Design less hazardous chemical syntheses:** Design syntheses to use and generate substances with little or no toxicity to either humans or the environment.
4. **Design safer chemicals and products:** Design chemical products that are fully effective yet have little or no toxicity.
5. **Use safer solvents and reaction conditions:** Avoid using solvents, separation agents, or other auxiliary chemicals. If you must use these chemicals, use safer ones.
6. **Increase energy efficiency:** Run chemical reactions at room temperature and pressure whenever possible.
7. **Use renewable feed stocks:** Use starting materials (also known as feed stocks) that are renewable rather than depletable. The source of renewable feed stocks is often agricultural products or the wastes of other processes; the source of depletable feed stocks is often fossil fuels (petroleum, natural gas, or coal) or mining operations.
8. **Avoid chemical derivatives:** Avoid using blocking or protecting groups or any temporary modifications if possible. Derivatives use additional reagents and generate waste.
9. **Use catalysts, not stoichiometric reagents:** Minimize waste by using catalytic reactions. Catalysts are effective in small amounts and can carry out a single reaction many times. They are preferable to stoichiometric reagents, which are used in excess and carry out a reaction only once.
10. **Design chemicals and products to degrade after use:** Design chemical products to break down to innocuous substances after use so that they do not accumulate in the environment.
11. **Analyze in real time to prevent pollution:** Include in-process, real-time monitoring and control during syntheses to minimize or eliminate the formation of byproducts.
12. **Minimize the potential for accidents:** Design chemicals and their physical forms (solid, liquid, or gas) to minimize the potential for chemical accidents including explosions, fires, and releases to the environment (EPA, 2014, October 16).

The Green chemistry has a wide range of application. Given below are some of the important practical contexts in which Green chemistry program is successfully implemented.

Computer Chips:

The computer chip manufacturing requires several chemicals, large quantities of water, and huge amount of energy. However, the scientists at the Los Alamos National Laboratory have devised a new process in 2003 that makes use of supercritical carbon dioxide in one of the major manufacturing steps. The use of supercritical carbon dioxide helped reducing the amount of water, energy and chemicals significantly in producing the chips (American Chemical Society, 2014). Similarly, the University of Delaware professor, Richard Wool, devised a process in which chicken feathers are used in making the computer chips. The chips manufactured using the protein, and keratin from the feathers are lighter and tougher than the traditional ones and they have great resistance to mechanical and thermal stresses. Moreover, they offer much faster speed than the traditional ones (American Chemical Society, 2014).

Medicine:

The pharmaceutical firms have great application of Green Chemistry to develop medicines with less harmful side-effects and producing less toxic waste. For instance, the pharma firms Merck and Codexis in USA developed a process called "enzymatic process" in producing the medicine for type 2 diabetes. The new

process helped reducing wastage and improving yield and safety and it also helped eliminating the need for a metal catalyst in the production of medicines (American Chemical Society, 2014).

Biodegradable Plastics:
The Green Chemistry application helped making plastics from renewable, biodegradable sources. The scientists at "NatureWorks" in USA developed a method in which microorganisms are used to convert agricultural waste (cornstarch) into a resin which is as strong as the petroleum-based plastic used for making water bottles and yogurt containers. The similar techniques is used to make strong, puncture-resistant, waterproof, printable, elastic, and biodegradable bags from agricultural and other wastes (American Chemical Society, 2014).

Paints:
Another application of Green Chemistry is in the manufacturing of paints. Typically, the Oil-based "alkyd" paints releases great amounts of volatile organic compounds (VOCs) that are harmful to the environment. However, the researchers at Procter & Gamble and Cook Composites and Polymers developed a new mixture using soya oil and sugar that replaces the fossil-fuel-derived paint resins and solvents. The new mixture helped reducing the dangerous volatiles by about 50 percent. Besides, the paints made from this mixture are much safer and its production process produce much less quantity of toxic waste than petroleum based processes (American Chemical Society, 2014).

Although the major goal of Green Chemistry is to reduce the harmful environmental impacts of chemical processes, it has several other positive benefits as well. Adoption of Green Chemistry will also help achieving significant financial gains. The firms with improved designs will be able to make considerable saving in the processing cost and develop better products that in turn offer competitive advantages to companies. It is reported that the major pharmaceutical companies such as Pfize, GlaxoSmithKline, and SiGNa Chemistry Inc., that have extensive Green Chemistry programs, have made significant financial gains. While Pfizer and GlaxoSmithKline have made saving from the improved processing, it helped the SiGNa Chemsitry Inc to improve product quality and reduced manufacturing cost. Further, adoption of the principles of Green Chemistry has made company's materials safer to handle, stable in air, and easier to transport and also the company could reduce waste and use of raw materials and solvents (Scott, 2010).

III. Conclusion
Green Chemistry is the process of developing of chemical products and processes that reduce or eliminate the use and generation of hazardous substances. It appears that Green Chemistry is the need of the day as increasingly large quantities of different types of chemical substances are being poured into the environment each day that have great potential to damage the biosphere. Green Chemistry helps preventing the harmful effects that various chemical processes produce on the environment. It also helps improving the financial gains of companies and offer them market competitiveness. Therefore, it is desirable for every single companies to adopt Green Chemistry as part of their businesses strategy. We need to salute the researchers Paul Anastas and John Warner for their valuable contribution to make the world safer and healthier. In short, Green Chemistry is inevitable for sustainable development.

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