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6. Environmental Protection and Sustainability in 21st Century

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Figure 6.1: Green Chemistry Principles

Abstract:

Chemistry is really very helpful to us as its applications are used worldwide for several purposes. We cannot really imagine a world without chemistry and its applications. However, we should now concentrate on green chemistry which refers to reducing the damage done to the environment around us. Green chemistry is the implementation of innovative chemical technologies that prevent pollution. Green chemistry represents the pillars that hold up our sustainable development. Sustainable development is meeting the needs of the present generation without compromising the ability of future generations to meet their own needs.

It is clear that many industries and research of many academics recognize the significance of green chemistry. In the practice of green chemistry, a set of principles that reduces or eliminates the use of hazardous substance in the design, manufacture and applications of chemical products are utilized. All chemical wastes must be disposed in the best possible manner without causing any damage to the environment and living beings. We need green chemistry that efficiently use renewable raw materials, eliminates waste and avoids the use of toxic and or hazardous solvents and reagents in order to achieve this noble goal. Green chemistry is one of the most fundamental and powerful tools to use on the path to sustainability. In fact, without green chemistry and green engineering, there is no path to sustainability. In this paper an overview on applicability of 12 Principles of green chemistry, applicability is covered, along with their developments and some applications are discussed.

Keywords:

Green Chemistry, Principle of green chemistry, Green Synthesis, Green Solvents, Environmental pollution.

6.1 Introduction:

Green chemistry[1-8] is one of the powerful tools to use on the path to sustainability. In fact, without green chemistry, there is no path to sustainability. The term **Green Chemistry** was coined in 1991 by **Paul Anastas**.

The purpose is to design chemical processes that will be less harmful to human health and environment. Green chemistry protects the environment, not by cleaning up, but by creating new chemical processes that do not pollute.

Green Chemistry is an emerging area to contribute to economic growth while protecting the environment and human health. The primary goal of green chemistry is that prevention of waste. Green chemistry is the means to achieving sustainability, according to some. The 12 principles (Figure 6.1) of green chemistry offer a comprehensive framework for scientists, engineers, and researchers to create novel solutions that not only satisfy the needs of contemporary society but also drastically lessen the environmental impact of chemical processes[9-15]. For better understanding of the principles of green chemistry and some examples of their applications to basic and applied research are illustrated below:

A. **Prevention**: It is better to prevent waste than to treat or clean up waste after it is formed. The ability of chemists to redesign chemical transformations to minimize the generation of hazardous waste is an important first step in pollution prevention. It goes back to the old saying "**prevention is better than cure**". It is better to prevent waste than clean it up after the fact.
B. **Atom economy:** This principle gets into the actual chemistry of how products are made. This principle states that it is best to use all the atoms in a process. And, those atoms that are not used end up as waste. Choosing the right transformations that incorporate most of the starting materials into the product are more efficient and minimize waste.
C. **Less hazardous chemical synthesis:** The goal is to reduce the hazard of the chemicals that are used to make a product. Chemists have traditionally used whatever means necessary. Today we are finding that less hazardous reagents and chemicals can be used in a process to make products. Synthetic methodologies should be designed to use and generate substances that possess little or no toxicity to human health[16-29] and environment. Some toxic chemicals are replaced by safer ones for a green technology. For example, in the manufacture of polystyrene foam sheet packing material, chlorofluorocarbons which contribute to O_3 depletion and global warming, have now been replaced by CO_2.
D. **Designing safer chemicals:** Everyone wants safe products. This principle is aimed at designing products that are safe, and non-toxic. Pharmaceutical products often consist of racemic. For example, racemic Thalidomide when administered during pregnancy, leads to horrible birth defects. Evidence indicates that only one of the enantiomers has the curing effect while the other isomer is the cause of severe defects.
E. **Safer solvents:** We use solvents regularly in our daily lives (cleaning products, nail polish, cosmetics, etc.) and in the chemistry laboratory. Many chemical reactions are done in a solvent. And traditionally organic solvents have been used that pose hazards and many are highly toxic. Solvents are extensively used in most of the syntheses. Widely used solvents in syntheses are toxic and volatile – alcohol, benzene (known carcinogenic), CCl_4, $CHCl_3$, CH_2Cl_2. Purification also utilizes large amounts of solvents (e.g., Chromatography) which add to pollution and can be highly hazardous to human health. This principle focuses on creating products in such a way that they use less hazardous solvents. It is obvious that water is the most inexpensive and environmentally benign solvent.
F. **Design for energy efficiency:** Today there is a focus on renewable energy and energy conservation. We use energy for transportation purposes and to provide electricity to our homes and businesses. Traditional methods for generating energy have been found to contribute to global environmental problems such as Global Warming and the energy used can also be a significant cost. This principle focuses on creating products and materials in a highly efficient manner and reducing associated pollution and cost.
G. **Use of renewable feedstocks:** Around 90-95% of the products we use in our everyday lives are made from petroleum. Our society not only depends on petroleum for transportation and energy, but also for making products. This principle seeks to shift our dependence on petroleum and to make products from renewable materials. Polylactic acid (**PLA**) is one plastic that is being made from renewable feedstocks such as corn and potato waste. Benzene used in the commercial synthesis of adipic acid which is required in the manufacture of nylon, placticizers and lubricants, has been replaced to some extent by the renewable and nontoxic glucose and the reaction is carried out in water.

H. **Reduce derivatives:** Unnecessary derivatization (blocking group, protection/deprotection) should be avoided whenever possible, because such steps require additional reagents and can generate more waste.
I. **Catalysis:** In a chemical process catalysts are used in order to reduce energy requirements and to make reactions happen more efficiently. Another benefit of using a catalyst is that generally small amounts are required to have an effect. And, if the catalyst is truly a "green" catalyst it will have no toxicity in the process. Enzymes are wonderful examples of catalysts. Biocatalysis reactions are advantageous as they are performed in aqueous medium.
J. **Design for degradation:** Not only do we want materials and products to come from renewable resources, but we would also like them not to persist in the environment[20-24]. There is no question that many products we use in our daily lives are persistent. Plastics do not degrade in our landfills and pharmaceutical drugs such as antibiotics build up in our water streams. This principle seeks to design products in such a way that they perform their intended function.
K. **Pollution prevention:** Everyone known that prevention is better than cure from this pollution is better than pollution control. Pollution prevention is using materials, process or practices that reduces or eliminate pollution or wastes at the source.
L. **Safer Chemistry for Accident Prevention:** This principle focuses on safety for the worker and the surrounding community where an industry resides. It is better to use materials and chemicals that will not explode, ignite in air, etc. when making a product. There are many examples where safe chemicals were not used and the result was disaster. The most widely known and perhaps one of the most devastating disasters was that of Bhopal gas tragedy, India in 3rd December 1984 where a chemical plant had an accidental release that resulted in fifty thousands of lives lost and many more injuries. When creating products, it is best to avoid highly reactive chemicals that have potential to result in accidents. When explosions and fires happen in industry, the result is often devastating.

6.2 Applications and Impacts:

The principles of green chemistry have found applications across a wide range of industries, leading to numerous positive environmental and economic impacts (Figure 6.2). Some key areas of application include pharmaceuticals, materials science, agrochemical, energy production, waste management, water treatment for these research holds immense significance in addressing critical global challenges.

Research in green chemistry leads to the creation of safer chemical products, reducing the health risks posed by toxic substances. Green chemistry often results in cost savings through improved process efficiency and reduced waste, making it economically attractive. Companies that embrace green chemistry principles gain a competitive edge by responding to consumer demand for sustainable products.

Green Technologies plays important role in sustainable methods to recover resources and making bonds and materials in entirely new ways to making larger scale processes more efficient that minimize energy, waste and harmful by-products. It has revolutionized the way the products we depend on as a society are made, impacting on healthcare, food security and energy conversion.

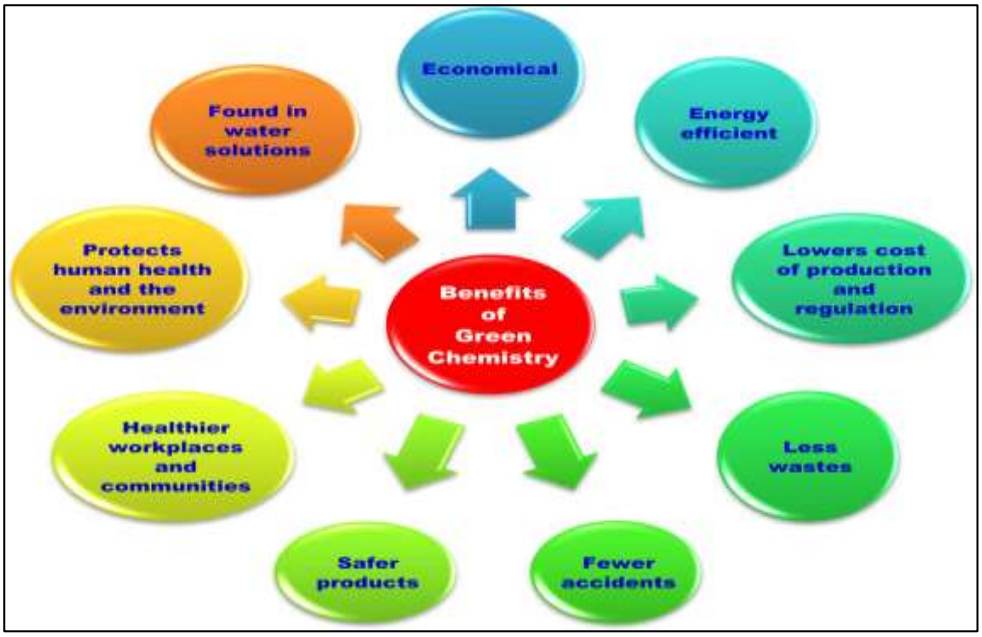

Figure 6.2: Green Chemistry Applications

6.3 Conclusion:

Green chemistry is not a new branch of science. It is a new philosophical approach that can contribute to sustainable development. Very recently, there has been an increase in the use of green chemicals in biomedical research, medicinal delivery, food industry and agriculture. And as a result, numerous methods for producing eco-friendly chemicals have been developed. Great efforts are still undertaken to design an ideal process that starts from non-polluting materials. It is clear that the challenge for the future chemical industry is based on production of safer products and processes designed by utilizing new ideas in fundamental research. student at all levels have to be introduced to the practice of green chemistry.

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