

Applications of Green Chemistry in Daily Life: A Review

Dr. Pushpraj Singh

Assistant Professor- Department of Chemistry,
Govt. Girls Degree College,
Chhibramau, Kannauj-209721,
(Affiliated to CSJM University, Kanpur), Uttar Pradesh, India
Email: pushpraj1509@gmail.com

Abstract- Green chemistry, also called sustainable chemistry, is an area of chemistry and chemical engineering focused on the design of products and processes that minimize or eliminate the use and generation of hazardous substances. It is a modern science that deals with the application of environmental friendly chemical compounds and materials in the various areas of our life such as industrial uses and many others. The beginning of green chemistry is considered as a response to the need to reduce the damage of the environment by man-made materials and the processes used to produce them. Green chemistry could include anything from reducing waste to even disposing of waste in the correct manner. Chemistry plays a pivotal role in determining the quality of life. The chemicals industry and other related industries supply us a huge variety of essential products, from plastics to pharmaceuticals. However, these industries have the potential to seriously damage our environment. Green chemistry therefore serves to promote the design and efficient use of environmentally benign chemicals and chemical processes. All these points will be discussed in this article.

Keywords- Green Chemistry, Sustainability, Environment, Safer chemicals, Hazardous wastes.

I. INTRODUCTION

Green Chemistry (also known as Sustainable chemistry) is the design of chemical products and processes that reduce or eliminate the use and generation of substances hazardous to humans, animals, plants and the environment. The term Green Chemistry was coined¹ by Paul T. Anastas in 1991. The purpose is to design chemicals and chemical processes that will be less harmful to human health and environment. Green chemistry protects the environment, not by cleaning up, but by inventing new chemical processes that do not pollute.

The origin and basis of Green Chemistry for achieving environmental and economic prosperity is inherent in a sustainable world. 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 synthetic approaches using alternative feedstock; Eco friendly reaction conditions, energy minimization, design of less toxic and inherently safer chemicals and to improve the economics of chemical manufacturing and to enhance the much-tarnished image of chemistry.

Green chemistry is a philosophy and study of the design of products or substances that will not involve materials harmful to the environment.

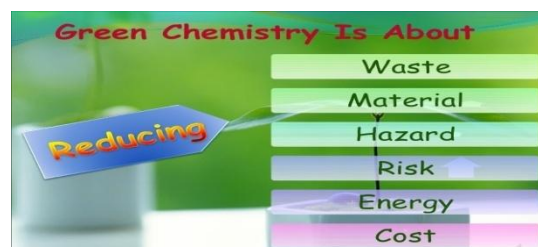


Fig 1. Purpose of Green Chemistry

The ideal scenario is to virtually stop pollution before it can even begin through the use of non-pollutants. Green chemistry is a relatively new area of chemistry that emerged by the need to reduce the hazardous effect of chemicals and to reduce the amount of environmental pollution that chemicals have.



Fig 2. Green Chemistry to Save Earth

II. GREEN CHEMISTRY AND SUSTAINABLE DEVELOPMENT

"Green chemistry" and "sustainability" are not just sound bites, but a new paradigm that promises to have a deep and lasting impact on the science of chemistry. Green chemistry and sustainability essentially go hand in hand.

Sustainable development is meeting the needs of the present generation without compromising the ability of future generations to meet their own needs.

We need greener chemistry- chemistry that efficiently utilizes renewable raw materials, eliminates waste and avoids the use of toxic and or hazardous solvents and reagents in both products and processes-in order to achieve this noble goal. Green chemistry embodies two main components.

First, it addresses the problem of efficient utilization of raw materials and the concomitant elimination of waste. Second, it deals with the health, safety and environmental issues associated with the manufacture, use and disposal or re-use of chemicals. 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.

From the beginning Paul Anastas and John Warner emphasized the new principles of Green Chemistry and the new philosophy that has to be followed to achieve the sustainable eco-development of the chemical industry in the future. Green Chemistry is commonly presented as a set of twelve principles proposed by Anastas and Warner¹. The principles comprise instructions for professional chemists to implement new chemical compound, new synthesis and new technological processes.

The following list of twelve principles outlines an early conception of what would make a greener chemical, process or product.

1. Prevention:

It is better to prevent waste than to treat or clean up waste after it is formed. It goes back to the old saying "prevention is better than cure". It is better to prevent waste than clean it up after the fact².

2. Atom Economy:

Synthetic methods should be designed to maximize the incorporation of all materials used in the process into the final product.

3. Less Hazardous Chemical Synthesis:

Synthetic methodologies should be designed to use and generate substances that possess little or no toxicity to human health and environment³. Some toxic chemicals are replaced by safer ones for a green technology.

4. Designing Safer Chemicals:

This principle is aimed at designing products with desired function while minimizing their toxicity⁴.

5. Safer Solvents:

This principle focuses on creating Safer Solvents and auxiliaries substances (e.g., solvents, separation agents, etc.) for workers and the environment⁵. It is obvious that water is the most inexpensive and environmentally benign solvent.

6. Design for Energy Efficiency:

This principle focuses on creating products and materials in a highly efficient manner and reducing associated pollution and cost⁶.

7. Use of Renewable Feed Stocks:

Raw materials or feedstock should be renewable rather than depleting. Biodiesel is an example of this where researchers are trying to find alternative fuels that can be used for transportation⁷.

8. Reduce Derivatives:

Unnecessary derivatization (blocking group, protection/deprotection) should be avoided whenever possible, because such steps require additional reagents and can generate more waste⁸.

9. Catalysis:

Catalysis and new catalytic reagents (enzymes, as selective as possible) are superior to stoichiometric reagents⁹.

10. Design for Degradation:

Chemical products should be designed so that at the end of their function they break down into innocuous degradation products and do not persist in the environment¹⁰.



Fig 3. Principles of Green Chemistry

11. Pollution Prevention:

Everyone knows that prevention is better than cure from this pollution is better than pollution control. Pollution prevention is using materials, process or practices that reduce or eliminate pollution or wastes at the source.

12. 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, light on fire, ignite in air, etc. when making a product¹¹.

III. THE CHALLENGES TO CHEMISTS

Sustainable development is now accepted by governments, industry and the public as a necessary goal for achieving social, economic and environmental objectives. Within this, chemistry has a key role to play in maintaining and improving our quality of life, the competitiveness of the chemical industry and the natural environment. This role for chemistry is not generally recognized by government or the public. In fact chemicals, chemistry and chemists are actually seen by many as causes of the problems.

The challenge for chemists and others is to develop new products, processes and services that achieve the social, economic and environmental benefits that are now required. This requires a new approach which sets out to reduce the materials and energy intensity of chemical processes and products, minimize or eliminate the dispersion of harmful chemicals in the environment, maximize the use of renewable resources and extend the durability and recyclability of products in a way which increases industrial competitiveness.

Some of the challenges for chemists include the discovery and development of new synthetic pathways using alternative feed stocks or more selective chemistry, identifying alternative reaction conditions and solvents for improved selectivity and energy minimization and designing less toxic and inherently safer chemicals.

In chemical synthesis, the ideal will be a combination of a number of environmental, health and safety and economic targets.

Although many chemists, and some large and smaller companies, are actively pursuing 'green chemistry' there are still many barriers to progress. These include a general lack of awareness and training in schools, universities and industry and a management perception that green chemistry is a cost without benefits. The drive towards clean technology in the chemical industry with an increasing emphasis on the reduction of waste at source will require a level of innovation and new technology that the chemical industry has not seen in many years.

Mature chemical processes that are often based on technology developed in the first half of the 20th century may no longer be acceptable in these environmentally conscious days. 'Enviro-economics' will become the driving force for new products and processes. This can be seen by considering the ever-escalating and various 'costs of waste'. The costs of waste can truly be enormous.

The term green chemistry¹ was first used in 1991 by Poul T. Anastas in a special program launched by the US Environmental Protection Agency (EPA) to implement sustainable development in chemistry and chemical technology by industry, academia and government. In 1995 the annual US Presidential green chemistry challenge was announced. Similar awards were soon established in European countries.

In 1996 the working party on green chemistry was created, acting within the framework of International Union of Pure and Applied Chemistry (IUPAC). One year later the Green Chemistry Institute (GCI) was formed with chapters in 20 countries to facilitate contact between governmental agencies and industrial corporations with universities and research institutes to design and implement new technologies.

The first conference highlighting green chemistry was held in Washington in 1997. Since that time other scientific conferences have been soon held on a regular basis. The first book and journals on the subject of green chemistry were introduced in 1990, including the Journal of Clean Processes and Green Chemistry, sponsored by the Royal Society of Chemistry. The concept of green chemistry incorporates a new approach to the synthesis, processing and application of chemical substances in such manner as to reduce threats to health and environment.

This new approach is also known as:

- Environmentally benign chemistry
- Clean chemistry
- Atom economy
- Benign-by-design chemistry

IV. GREEN CHEMISTRY IN DAY-TO-DAY LIFE

Chemists from all over the world are using their creative and innovative skills to develop new processes, synthetic methods, reaction conditions, catalysts etc., under the new Green chemistry concepts. Commercial applications of green chemistry have led to novel academic research to examine alternatives to the existing synthetic methods.

Some of these are:

- The use of phosgene and methylene chloride in the synthesis of polycarbonates has been replaced by diphenylcarbonate.
- The most polluting reaction in industry is oxidation. Implementation of green chemistry has led to the use of alternative less polluting reagents viz., metal ion contamination is minimized by using molecular O₂ as the primary oxidant and use of extremely high oxidation state transition metal complexes.
- A convenient green synthesis of acetaldehyde is by Wacker oxidation of ethylene with O₂ in presence of

acatalyst, in place of its synthesis by oxidation of ethanol or hydration of acetylene with H_2SO_4 .

- Conventional methylation reactions employing toxic alkyl halides or methyl sulfate leading to environmental hazard are replaced by dimethylcarbonate with no deposit of inorganic salts.
- In 1996, Dow Chemical won 1996 Greener Reaction award for their 100% carbon dioxide blowing agent for polystyrene foam production. Polystyrene foam is a common material used in packing and food transportation. Traditionally, CFC and other ozone depleting chemicals were used in the production process of the foam sheets, presenting a serious environmental hazard. Dow Chemical discovered that super critical CO_2 works equally as well as a blowing agent, without the need for hazardous substances, allowing the polystyrene to be more easily recycled. The CO_2 used in the process is reused from other industries, so the net carbon released from the process is zero.
- Propylene oxide (PO) is a chemical building block for a variety of products including detergents, polyurethanes and food additives. Traditional PO production uses chlorohydrin which leads to co products such as t-butyl alcohol, styrene monomer or cumene. Its manufacture creates by-products, including a significant amount of waste. Dow and BASF have jointly developed a new route to make propylene oxide with hydrogen peroxide and propylene that eliminates most of waste. Dow and BASF have jointly developed a new route to make propylene oxide with hydrogen peroxide and propylene that eliminates most of waste.
- Historically, chlorofluorocarbons (CFCs) have been used as refrigerants in air conditioners and refrigerators. CFCs have the advantages of safe incombustibility, high stability, and low toxicity, but unfortunately they destroy the ozone layer. In the past decade, various hydrochlorofluorocarbons (HCFCs) and hydrofluorocarbons (HFCs) have replaced CFCs. HCFC and HFCs are, indeed, safer for the ozone layer.
- Chelates are complex that interact with metal ions, often increasing the solubility of the metal ion. They are used in many types of cleaners and industrial processes. Conventional chelates are based on amino carboxylic acids (e.g., ethylenediaminetetraacetic acid, EDTA) and phosphates (e.g., sodium tripolyphosphate). Unfortunately, because EDTA is not readily biodegradable and because phosphates can cause pollution via eutrophication, these conventional materials are often viewed as environmentally unfriendly. Akzo Nobel has developed a readily biodegradable chelating agent that is manufactured principally from a renewable feed stock. This new chelate, called tetrasodiumLglutamicacid, N, N-diacetic acid (GLDA), will replace phosphates in automatic dish washing detergents. GLDA is manufactured from the flavor enhancer monosodiumglutamate (MSG) in an essentially waste-free synthesis. MSG is made by fermenting readily available corn sugars and is considered a renewable material. The synthesis of GLDA includes classic cyanomethylation of the primary amino nitrogen on the MSG followed by in situ alkaline saponification. In contrast with EDTA whose carbon is fossil-based, but in GLDA is biobased. Because GLDA is highly soluble, it will be offered at a significantly higher concentration (approximately 30 percent higher molar aqueous concentration) than EDTA, reducing transport and packaging costs as well as packaging waste. Most significantly, GLDA is readily biodegradable and will reduce pollution by replacing phosphates in dish washing detergents.
- Spinosad is a low-risk pesticide in wide spread use on crops. Spinosad adsorbs strongly to soils and organic matter, degrades photochemically at the site of application, and is inherently unstable in water. These characteristics make it excellent for use on land, but had prevented its use in aqueous environments. Spinosad is an environmentally safe pesticide but is not stable in water and so therefore can not be used to control mosquito larvae. Clarke launched Natular in the U.S. market in December 2008. Natular, a spinosad based mosquito larvicide that provides excellent control in aquatic environments. It is 15 times less toxic than the organophosphate alternative, does not persist in the environment and is not toxic to wild life.
- Green Dry Cleaning of Clothes Perchloroethylene (PERC), $\text{Cl}_2\text{C}=\text{CCl}_2$ is commonly being used as a solvent for dry cleaning. It is now known that PERC contaminates ground water and is a suspected carcinogen. A technology, known as Micell technology developed by Joseph De Simons, Timothy Romark, and James McClain made use of liquid CO_2 and a surfactant for dry cleaning clothes, thereby replacing PERC. Dry cleaning machines have now been developed using this technique. Micell Technology has also evolved a metal cleaning system that uses CO_2 and a surfactant thereby eliminating the need of halogenated solvents.
- Versatile Bleaching Agents is common knowledge paper is manufactured from wood (which contains about 70% polysaccharides and about 30% lignin). For good quality paper, the lignin must be completely removed. Initially, lignin is removed by placing small chipped pieces wood into a bath of sodium hydroxide (NaOH) and sodium sulphide (Na_2S). By this process about 80-90% of lignin is decomposed. The remaining lignin was so far removed through reaction with chlorine gas (Cl_2). The use of chloriner moves all the lignin (to give good quality white paper) but causes environmental problems. Chlorine also reacts with aromatic rings of the lignin to produce dioxins, such as 2,3,4-tetrachlorodioxin and chlorinated furans.

- These compounds are potential carcinogens and cause other health problems. These halogenated products find their way into the food chain and finally into products, pork, beef and fish. In view of this, use of chlorine has been discouraged. Subsequently, chlorine dioxide was used. Other bleaching agents like hydrogen peroxide (H_2O_2), ozone (O_3) or oxygen (O_2) also did not give this the desired results. A versatile agent has been developed by Terrence Collins of Carnegie Mellon University. It involves the use of H_2O_2 as a bleaching agent in the presence of some activators known as TAML activators that as catalysts which promote the conversion of H_2O_2 into hydroxyl radicals that are involved in oxidation (bleaching). The catalytic of TAML activators allow H_2O_2 to break down more lignin in a shorter time and at much lower temperature. These bleaching agents find use in laundry and results in lesser use of water.

V. INDUSTRIAL INTEREST IN GREEN CHEMISTRY

Many forward-looking companies are embracing Green Chemistry, not only to protect the environment and to create good public relations, but also because it is often beneficial to the bottom line it is also estimated to cost US industries between \$ 100 and \$ 150 billion per year to comply with environmental regulations.

In addition, cleaning up hazardous waste sites will cost hundreds of billions of dollars. In many companies, the cost of dealing with environmental regulations often exceeds their expenditure for research. Larger companies budget close to \$ 1 billion per year for environmental compliance. If a company can significantly reduce this expenditure, then these funds can be spent in more productive areas and result in an improved bottom line. Thus, Green Chemistry (pollution prevention) is not only good for the environment but also for industry.

VI. GREEN CHEMISTRY IN EDUCATION

Convincing chemists to think in an environmentally friendly manner begins with education. The idea of including Green Chemistry in chemistry education was first put forward in 1994. Few Green chemistry text books have also been published. Graduates, post graduates, teachers and researchers will find these books of immense use. Both Environmental Protection Agency (EPA) and American Chemical Agency (ACS) have recognized the importance of bringing Green Chemistry to the class room and the laboratory.

Together they have launched a significant campaign to develop Green Chemistry educational materials and to encourage the 'greening' of the chemistry curriculum. Student involvement in Green Chemistry principles and

practices is essential to the integration the environmentally benign technologies in academia and industry.

ACS Student Affiliate Chapters may be recognized as "green" chapters by engaging in at least three Green Chemistry activities during the academic year. Suggestions for these activities include: Hosting a Green Chemistry speaker

- Organizing an interdisciplinary Green Chemistry workshop on campus.
- Working with a local company on a Green Chemistry project.
- Developing a Green Chemistry activity with a local school.
- Converting a current laboratory experiment into a greener one.
- Organizing a Green Chemistry poster sessions on campus.
- Distributing a Green Chemistry Newsletter to the local community.
- Designing a green Chemistry web page.

VII. GLOBAL EDUCATION AND RECOGNITION OF GREEN CHEMISTRY

1. Education:

Many institutions offer course and degrees on Green Chemistry. Examples from across the globe are Denmark's Technical University, and several in the US, e.g. at the Universities of Massachusetts-Boston, Michigan, and Oregon. A master's level course in Green Technology has been introduced by the Institute of Chemical Technology, India. In the UK at the University of York University of Leicester, Department of Chemistry and MRes in Green Chemistry at Imperial College London.

In Spain different universities like the Universitat Jaume I or the Universidad de Navarra, offer Green Chemistry master courses. There are also websites focusing on green chemistry, such as the Michigan Green Chemistry Clearinghouse at www.migreenchemistry.org. Apart from its Green Chemistry Master courses the Zurich University of Applied Sciences ZHAW presents an exposition and web page "Making chemistry green" for a broader public, illustrating the 12 principles.

2. Awards:

Several scientific societies have created awards to encourage research in green chemistry.

- Australia's Green Chemistry Challenge Awards overseen by The Royal Australian Chemical Institute (RACI).
- The Canadian Green Chemistry Medal.
- In Italy, Green Chemistry activities center on an inter-university consortium known as INCA.

- In Japan, The Green & Sustainable Chemistry Network oversees the GSC awards program.
- In the United Kingdom, the Green Chemical Technology Awards are given by Crystal Faraday.
- In the US, the Presidential Green Chemistry Challenge Awards recognize individuals and businesses.

3. Scientific Journals Specialized in Green Chemistry:

Several scientific international journals which are specialized in the field of green chemistry.

- Green Chemistry (RSC)
- Green Chemistry Letters and Reviews (Open Access) (Taylor & Francis)
- ChemSusChem (Wiley)
- ACS Sustainable Chemistry & Engineering (ACS)

VIII. DISCUSSION

The expansion of Green Chemistry over the course of the past decade needs to increase at an accelerated pace if molecular science is to meet challenges of sustainability.

It has been said that the revolution of one day becomes the new orthodoxy of the next Green Chemistry is applied and must involve the successful implementation of more environmentally friendly chemical processes and product design.

Most importantly we need the relevant scientific, engineering, educational and other communities to work together for sustainable future through Green Chemistry.

IX. CONCLUSION

Green chemistry is not a new branch of science. It is a new philosophical approach that through application and extension of the principles of green chemistry can contribute to sustainable development. 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.

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 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"

X. ACKNOWLEDGEMENT

The author is thankful to Dr. Desh Deepak, Associate Professor, Department of Chemistry, University of Lucknow, and Lucknow for moral support, encouragement and critical suggestions.

REFERENCES

- [1] Anastas PT, Warner JC. Green Chem. Theory and Practice, Oxford Univ. Press, New York; 1998.
- [2] Namienik J, Wardencki W. Solvent less sample preparation techniques in environmental analysis. J. High Resol. Chromatogr 2000; 23: 297.
- [3] Sato K, Aoki M, Noyori R. A Green Route to Adipic Acid: Direct Oxidation of Cyclohexenes with 30 percent hydrogen peroxide. Science 1998; 281: 1646.
- [4] Singh A, Sharma R, Anand KM, Khan SP, Sachan NK. Food drug interaction, International Journal of Pharmaceutical & Chemical Science. 2012; 1(1): 264-279.
- [5] Bardley D, Dyson P, Welton T. Room temperature ionic liquids. Chem. Rev 2000; 9(5): 18.
- [6] Romano U, Garbassi F. The environmental issue. A challenge for new generation polyolefins. Pure Appl. Chem 2000; 72: 1383.
- [7] Nicolas N, Benvegnu T, Plusquellec D. Surfactants from renewable resources. ActualiteChimique 2002; 70: 11-12.
- [8] Stashenko EE, Puertas AM, Salgar W, Del Gado W, Martinez JR. Solidphase micro extraction with on fibrederivatization applied to the analysis of volatile carbonyl compounds. J. Chromatogr. A 2000; 886: 175.
- [9] Acardi A, Bianchi G, Di Giuseppe S, Marinel Li F. Gold catalysis in the reaction of 1,3-dicarbonyls with nucleophiles. Green Chemistry 2003; 5(1): 64.
- [10] Scott G. Green polymers. Polym. Degrad. Stab 2000; 68(1): 1.
- [11] Tundo P, Selva M, Memoli S. Dimethylcarbonate as a green reagent. ACS Symp. Ser, 767 Green Chemical Syntheses and Processes 2000; 87. PT Anastas, IT Horvath. Innovations and Green Chemistry, Chem.Rev 2007; 107: 2169.
- [12] Clark JH, Luque R and Matharu AS. Green Chemistry, Biofuels, and Biorefinery. Annual Review of Chemical and Biomolecular Engineering. 2012. 3: 183-207.