ISSN NO. 2320-5407

Journal homepage: http://www.journalijar.com

INTERNATIONAL JOURNAL OF ADVANCED RESEARCH

RESEARCH ARTICLE

GREEN CHEMISTRY: FUTURE PILLARS OF SUSTAINABLE DEVELOPMENT

Divya G. Nair

Research Scholar, Department of Chemistry, Bishop Moore College, Mavelikkara Kerala

Manuscript Info

Manuscript History:

Received: 15 May 2015
Final Accepted: 25 June 2015
Published Online: July 2015

Key words:

GREEN CHEMISTRY, ECOFRIENDLY CHEMICALS, EMERGING GREEN TECHNOLOGIES

***Corresponding Author**

Divya G. Nair

Abstract

Green Chemistry is considered as a frontier area of research for the design of chemical products and processes that reduce or annihilate the use and genesis of hazardous substances is an overarching approach which is applicable to all facets of chemistry. Green chemistry manifests methodologies that protect humans and environment in a cost effective manner. In short, the economic benefits of green chemistry are central drivers in its advancement today.

INTRODUCTION

Green chemistry is defined as the employment of a set of principles that will help to reduce the use and generation of hazardous substances during the manufacture and application. Green Chemistry has pivotal roles in asseverating and bettering quality of life, competitiveness of the chemical industry and the natural environment. Green chemistry aims to protect the environment not by cleaning up, but by devising new chemical processes with less pollution. In short, green chemistry is a rapidly growing and an important area in chemical sciences with multifaceted applications (Roger, 2006; Hassan and Maryam, 2009). Green chemistry is also referred as environmentally benign chemistry, clean chemistry, atom economy and benign-by-design chemistry.

The term *Green Chemistry* was proposed in 1991 by Anastas aiming to design chemicals and chemical processes which are less harmful to human health and environment (Anastas and Warner, 1998). Valuable and awesome materials in the form of medicines, food products, cosmetics, dyes, paints, agrochemicals, biomolecules, polymers, liquid crystals and nano particles are contributed by chemistry from time immemorial. However, these contributions not only produce required products but also enormous quantities of unsought and harmful substances were a biggest challenge today.

Green chemistry has a versatile approach to pollution prevention as it applies innovative scientific solutions. Green chemistry has 12 principles as its foundation which offers a myriad of applications.

1. **Prevention -** It is better to prevent waste than to treat or clean up waste after it has been created.

2. **Atom Economy -** This principle states that it is best to use all the atoms in a process. Synthetic methods should be designed to maximize the incorporation of all materials used in the process into the final product. Choosing transformations that incorporate most of the starting materials into the product are more efficient and minimize waste.

3. **Less Hazardous Chemical Syntheses** - Synthetic methods should be designed, wherever possible, to use and generate substances that possess little or no toxicity to health and ecology.

4. **Designing Safer Chemicals** - Chemical products should be designed to achieve their desired function while minimizing their toxicity.

5. **Safer Solvents and Auxiliaries** - Unnecessary use of auxiliary substances (e.g., solvents, separation agents, etc.) should be avoided wherever possible and made innocuous when used. According to green chemistry, a green solvent should be natural, nontoxic, cheap, and readily available. This principle centres on creating products in such a way that they use less hazardous solvents.

6. **Design for Energy Efficiency** - Energy requirements of chemical processes should be recognized for their environmental and economic impacts and should be minimized. If possible, synthetic methods should be conducted at ambient temperature and pressure. In short, this principle focuses on creating products and materials in a highly efficient manner but considerable reduction in associated pollution and cost.

7. **Use of Renewable Feedstocks** - Whenever technically and economically practicable, raw material or feedstock should be renewable rather than depleting it. This principle attempts to shift the excessive dependence on petroleum and to make products from renewable materials which are gathered locally like the biodiesel.
8. **Reduce Derivatives** - Unnecessary derivatization (use of blocking groups, protection/ deprotection, temporary modification of physical/chemical processes) should be minimized or avoided if possible, because such steps require additional reagents and can generate waste.

9. **Catalysis** - In a chemical process catalysts are used in order to reduce energy requirements and to make reactions happen more efficiently and quickly. Catalytic reagents (as selective as possible) are superior to stoichiometric reagents. If the catalyst is truly a "*green*" catalyst it will have little or no toxicity in the process.

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 environment. This principle seeks to design products in such a way that they perform their designated function and perishes without much harm to ecology.
11. **Real-time analysis for Pollution Prevention** - Analytical methodologies need to be developed to allow for real-time, in-process monitoring and control, prior to the formation of hazardous substances.

12. **Safer Chemistry for Accident Prevention** - Substances and the form of a substance used in a chemical process should be chosen so as to minimize the potential of chemical accidents, including releases, explosions, and fires. This principle envisages use materials and chemicals that will not explode, light on fire, ignite in air, etc. when making a product.

Green chemistry incarnates two main components - it addresses the problem of efficient and maximum utilisation of raw materials and the consequent elimination of waste and it also deals with the health, safety and environmental issues altogether. The overall frame work of green chemistry was given in Fig.1.

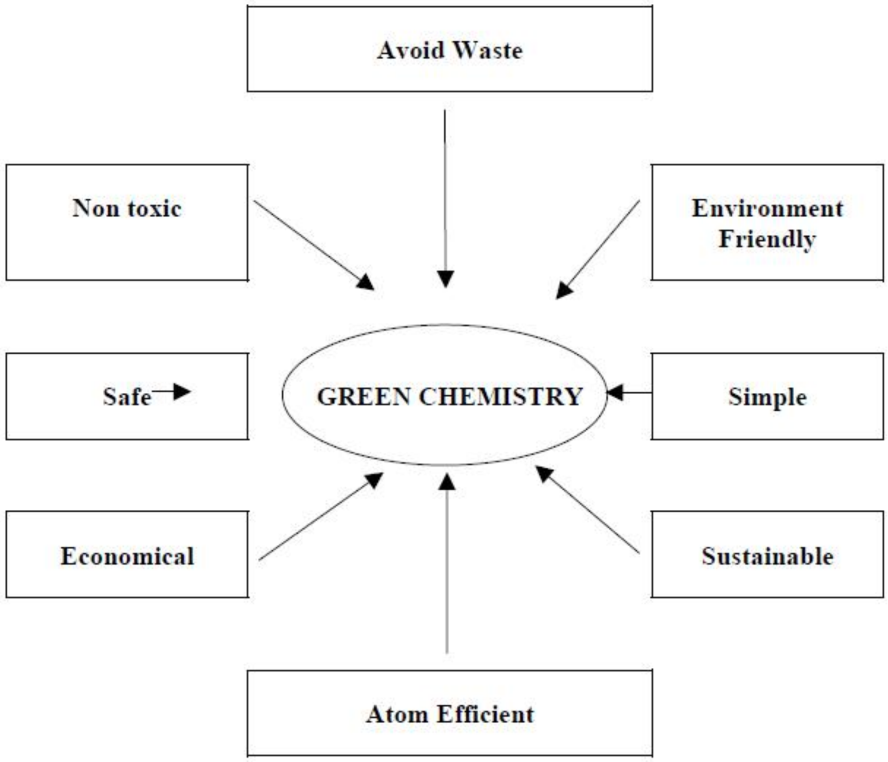

Fig.1. Overall framework of green chemistry

Green chemistry in pharmaceutical industry

Green chemistry is employed to develop radical drug delivery methods which have more efficiency and less toxicity. Phosphoramidite-based, solid-phase synthesis of antisense oligonucleotides has been modified with principles of green chemistry by eliminating the use and generation of toxic materials and allowing reuse of valuable materials such as amidites, solid-support and protecting groups, thus improving the atom economy and cost-effectiveness (Yogesh *et al*., 2001). The green synthesis for a key intermediate of atorvastatin has been developed *via* the biocatalytic reduction of ethyl-4-chloroacetoacetate using a ketoreductase in combination with glucose and a NADP-dependent glucose dehydrogenase (GDH) for cofactor regeneration yielding (S)ethyl-4-chloro-3-hydroxybutyrate. In the second step, a halohydrindehalogenase (HHDH) is employed to catalyze the replacement of the chloro substituent with cyano, by reaction with HCN at neutral pH and ambient temperatures. These natural enzymes were highly selective for the reactions (Steven *et al*., 2010). Synthesis of amines (Talaviya and Majmudar, 2002) and aspirin (Ingrid *et al.*, 2006) are also commendable achievements by employing green chemistry.

Emerging green technologies

More sustainable products and energy efficient processes with reducing waste generation are treated as emerging green technologies. By employing these technologies reduced energy input, improvement of selectivity and shortening of reaction time are possible. Energy sources like light, microwave, ultrasound and electricity are more clean and efficient. Emerging green techniques can be addressed under following heads.

I. Photochemistry

A photochemical reaction occurs when an atom or molecule absorbs light and activated photons are absorbed by a molecule or atom. Then it must transfer all its energy to atom or molecule and promoted to higher energy state. Solar furnace is used for isomerisation, catalytic cyclisation and purification of water. Dithianes, benzyl ethers and related compounds have been rived by visible light and dye. A combination of visible light and water was used in cyclization to produce substituted pyridines. Oxidation of hydrocarbons in zeolites, Photo oxidation of cyclohexane, Acylhydroquinones production from 1,4-benzoquinone and aldehyde using light are other major photochemical reactions employing commonly today.

II. Electrochemistry

Electrochemistry has wide use in industry for effluent treatment, corrosion prevention and electroplating as well as in electrochemical synthesis (aluminum and chlorine production). When iodine is reduced to hydroiodic acid by electrochemistry no waste products are formed. Likewise, Naphethalene can be oxidized to naphtoquinone with 98% selectivity using a small amount of cerium (III) that forms is reoxidized to cerium (IV) electrically. Electrochemistry also provides means to produce radicals and anions. Treatment processes involving electrochemistry can provide awful contribution to the protection of environment through the minimization of waste and toxic materials in effluents. Thus the future of electrochemistry was promising with a deluge of applications in daily life.

III. Sonochemistry

Sonochemistry is the study of effects of ultrasound (above 16 KHz) on chemical reactions. Various researches reported that chemical reactivity of a system increases on irradiating it with power ultrasound. Sonochemistry assisted organic synthesis like addition reaction, oxidation, reduction, hydroboration and coupling reactions are also documented. The roles of sonochemistry in treatment of effluents are well reported (Teo *et* al., 2001; Peters, 2011).

IV. Microwave

The use of microwave energy instead of conventional heating, often results in better yields within short span of time. The reactions under microwave can manifest in several ways like highly accelerated reaction time, improved yield, reduction in waste products, limited amount of solvents, successful product formation in some reactions that fail under conventional conditions and simplification and improvement of classical synthetic method. Microwave reactions can be classified in two categories in microwave such as reaction with solvent and solvent free reactions.

Green Chemistry - The future Pillars

The green chemistry concept got due consideration globally and chemists are using their creative and innovatory skills in the development of new processes, synthetic methods, reaction conditions, catalysts etc., under the emerging Green chemistry concepts. Commercial applications of green chemistry have led to fresh academic research to examine alternatives to the existing synthetic methods.

Sl. No.	Existing strategy	Innovations
1.	use of phosgene and methylene chloride in the synthesis of polycarbonates	replaced by diphenylcarbonate
2.	Oxidation reactions	metal ion contamination is minimized by using molecular O_2 as the primary oxidant and use of extremely high oxidation state transition metal complexes
3.	methylation reactions employing toxic alkyl halides or methylsulfate	dimethylcarbonate with no deposit of inorganic salts
4.	use of CFC and other ozone depleting chemicals for Polystyrene foam production	Supercritical CO_2 works equally as a blowing agent
5.	Propylene oxide production uses chlorohydrin	propylene oxide production with hydrogen peroxide and propylene
6.	phosphates in automatic dishwashing detergents	tetrasodium L-glutamic acid, N,N-diacetic acid (GLDA) replaced phosphates
7.	carboxylic acids production	carboxylic acids production by fermentation
8.	ethyl lactate production	cost-effective method of producing ethyl lactate, a non-toxic solvent derived from corn.
9.	metals recovery from spent acid wastes	new ecofriendly technology to recover zinc and ferrous chloride from pickle liquor
10.	plastic wastes	recycling of plastic wastes into valuable chemicals useful as fuels or raw materials

Table 2. Innovations in green chemistry

Conclusion

Green chemistry has developed into a new impendent for scientifically based environment protection. By employing green chemistry technologies we can minimize the waste of materials, maintain the atom economy and prevent the discharge of risky chemicals. Pharmaceutical sectors are encouraged to conceive the principles of green chemistry while designing the products and processes.

References

Anastas P. T., Warner J. C. Green Chemistry: Theory and Practise. Oxford University Press, Oxford 1998.

Hassan ZB and Maryam EK. Highly efficient synthesis of thioesters in water. Green Chem 2009;11:1987-1991

Ingrid M, David S, Marilyn G, Joaudimir C and Johanna F. A Greener Approach to Aspirin Synthesis using Microwave Irradiation. J Chem Edu 2006;83(4):628

Perets D. Sonolytic degradation of volatile pollutants in natural ground water: Conclusions from a model study. Ultrason Sonochem. 2001; 8:221.

Roger MS. Superheated water:the ultimate green solvent for separation science. Anal Bioanalchem 2006;385:419-421.

Steven KM, John G, Chris D, Lisa N, David G, Alica W et al. A green-by-design biocatalytic process for atorvastatin intermediate. Green Chem 2010;12:81-86.

Talaviya S, Majmudar F. Green chemistry: A tool in Pharmaceutical Chemistry. NHL Journal of Medical Sciences. 2002; Vol. 1/Issue 1:7-13.

Teo KC, Xu Y, Yang C. Sonochemical degradation for toxic halogenated organic compounds. Ultrason Sonochem. 2001; 8:241.

Yogesh SS, RavikumarVT, Anthony NS and Douglas LC. Applications of green chemistry in the manufacture of oligonucleotide drugs. Pure Appl Chem 2001;73(1):175-180.