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Green Chemistry Drift: A Review

Garima Singh[1*], Sharad Wakode[2]
[1]Department of Pharmaceutical Chemistry, Delhi Institute of Pharmaceutical Sciences and Research (DIPSAR), Delhi, India
[2]Professor, Pharmaceutical Chemistry, Delhi Institute of Pharmaceutical Sciences and Research (DIPSAR), Delhi, India

Review Article

***Corresponding author**
Garima Singh

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Abstract: The green chemistry mutiny is furnishing an enormous number of challenges to those who practice chemistry in industry, education and research. The genesis of green chemistry recognised as a retort to the need to reduce the damage to the environment by human-made materials and the processes used to produce them. It provides innovative latitudes for upheaval via product substitution, new feedstock generation, catalysis in aqueous media, utilisation of microwaves, and scope for alternative or natural solvents. It is the depiction, buildout, and prosecution of chemical products and processes that prune or eliminate the use and kindling of substances perilous to human health and the environment. The inherent challenge that we face in this new century is the transmutation of a society based on expenditure and controlled only by demand and market zings into a sustainable community based on more realistic needs and natural resources. This article depicts the prologue of some aspects of Green Chemistry and some new Trends &attempts are being made not only to appraise the greenness of a chemical process but also to stand in other variables such as chemical yield, the price of reaction components, safety in handling chemicals, hardware demands, energy profile and ease of product arouse and purification.

Keywords: Green Chemistry, Environmentalism, Sustainability, Environmental Chemistry, Future trends.

INTRODUCTION

Green chemistry (also called sustainable chemistry) is a type of chemical scrutiny and engineering. It is a footprint of chemistry and chemical engineering enrapt on the designing of products and processes that downplay the use and generation of hazardous substances [1]. It is the study, advancement, and implementation of chemical products and manners that reduce or banish the use and generation of essences perilous to human health and the environment [2].

As the name insinuates, endorses for green chemistry seek to make humanity's approach to chemicals—especially synthetic organic chemicals—environmentally sustainable. The focus is on the deterrence of problems before they transpire by (re)designing chemicals and chemical production processes at a molecular level. With little quarrel or publicity, in the past few years, there has commenced emerging what could turn out to be a profound overhaul in the methods, raw materials, by-products, and end products of chemical synthesis[3].

The term 'Green Chemistry' was minted by Anastas [4] of the US Environmental Protection Agency (EPA). In 1993 the EPA officially arrogated the name 'US Green Chemistry Program' which has served as a focal point for activities betwixt the United States, such as the Presidential Green Chemistry Challenge Awards and the annual Green Chemistry and Engineering Conference. That does not suggest that research on green chemistry did not endure before the early 1990s, solely that it did not have the name. Since the early 1990s both Italy and the United Kingdom have pioneered substantial initiatives in green chemistry and, more promptly, the Green and Sustainable Chemistry Network was introduced in Japan. The maiden edition of the journal Green Chemistry, aided by the Royal Society of Chemistry, appeared in 1999. Hence, we may surmise that Green Chemistry is here to stay. A sensible working definition of green chemistry can be contrived as follows [5]: *Green chemistry efficiently appropriates (preferably renewable) raw materials, eliminates waste and avoids the use of toxic and precarious reagents and solvents in the manufacture and application of chemical products*. As Anastas has illustrated, the guiding principle is the *design* of environmentally benign products and processes (benign by design) [6].

Principles of Green Chemistry (Figure 1)

This concept enveloped in the 12 Principles of Green Chemistry which can be numbered as [6]

- Waste prevention instead of remediation
- Atom efficiency
- Less hazardous/toxic chemicals
- Safer products by design
- Innocuous solvents and auxiliaries
- Energy efficient by design
- Preferably renewable raw materials
- Shorter syntheses (avoid derivatization)
- Catalytic rather than stoichiometric reagents
- Design products for degradation
- Analytical methodologies for pollution prevention
- Inherently safer processes

Fig-1: Principles of Green Chemistry

Green chemistry consigns the environmental thrust of both chemical products and the processes by which they are produced. In the book, we shall be concerned only with the ulterior, i.e. the product is a given, and the intent is to design a green process for its yield. Green chemistry eliminates waste at source, i.e. it is primary pollution prevention rather than waste invigoration (end-of-pipe solutions). Prevention is better than cure (the first principle from green chemistry, outlined above). A surrogate term that is currently fostered by the chemical industry is Sustainable Technologies. Sustainable development has been described as *Meeting the needs of the present generation without compromising the ability of future generations to meet their own needs*. One could say that Sustainability is the goal and Green Chemistry is the avenue to procure it [7].

The fundamental challenge that we grimace in this new century is the conversion of a society hinged on consumption and controlled only by exigency and market forces into a sustainable community based on more rational needs and natural resources. The procession of our relationship with the planet must occur while we are facing an unrivalled rate of growth in demand for resources, as the new spurt economies in Asia and Latin America move toward the standards and demands prominent in the past century in the West. The chemical industry that has been so productive for much of the twentieth century is now under epic pressure to change in almost all facet of how it operates [8]. The last years of the twentieth century saw a mounting growth in legislation prevailing chemical manufacturing processes [9,10]. Manufacturing is also facing amplifying costs for energy and the riddance of hazardous waste; these costs are increasing at a rate higher than the price of their consorted products. The early years of the twenty-first century have also seen a vivid increase in the firm about the human and environmental safety of products. This is mostly a repercussion of general concerns about the environment and reports, principally from nongovernmental organizations, on the exploration of synthetic chemicals in animals and humans (as much a result of improvements in analytical science as of any increase in exposure to chemicals) [11]. Throughout both of these periods, we have seen a prompt increase in the price of the primary raw material of the organic chemicals industry—oil. Alternatives to oil for long-term, sustainable chemical manufacturing are essential [11-13]. Thus, chemical manufacturing faces an unprecedented grade of pressure at all laps in the life cycle or supply chain of chemical products (Figure 2).

Attempts are being made not only to quantify the *greenness* of a chemical process but also to

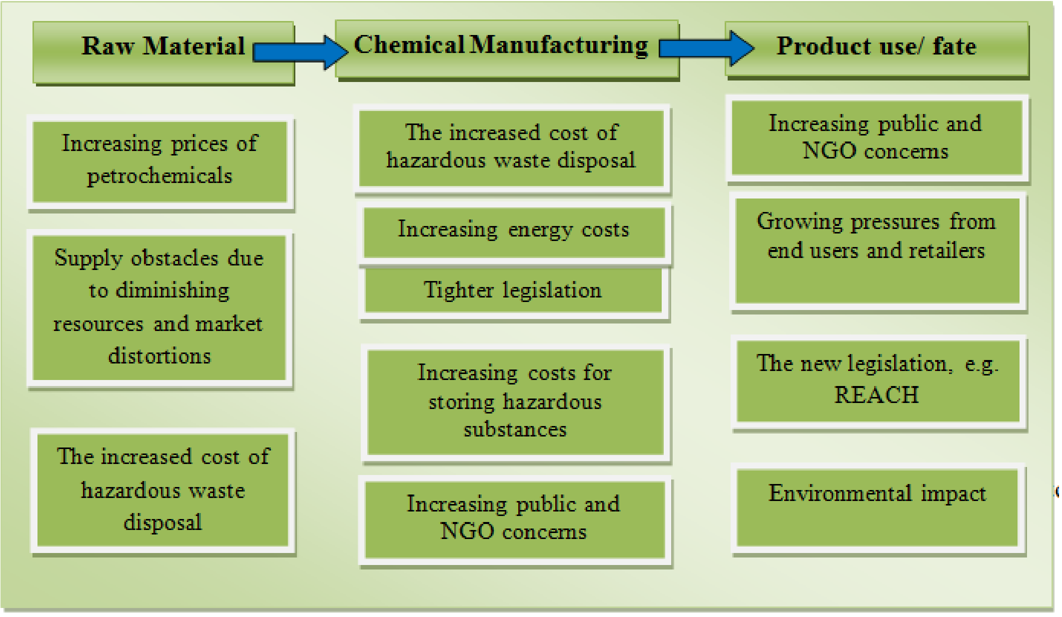

Fig-2: Supply chain of chemical products

Reeve in other variables such as chemical yield, the price of reaction segments, safety in handling chemicals, hardware demands, energy profile and inertia of product workup and purification. In one quantitative
study[12], the reduction of nitrobenzene to aniline
redeems 64 points out of 100 marking it as an inept synthesis overall whereas synthesis of an amide using HMDS is only reported as adequate with a combined 32 points.

The ancillary advantage of green chemistry is that all its discoveries/synthesis are environmentally genial. There are however specific areas of investigations that are empirically challenging to chemists. These areas have power for considerable benefits as green chemistry alternatives.

Some of the new areas are

- Oxidation Reagents and Catalysts
- Biomimetic, Multifunctional Reagents
- . Combinatorial Green Chemistry
- The proliferation of Solventless Reactions
- Non-Covalent Derivatization
- Green Chemistry in Sustainable Development

Oxidation Reagents and Catalysts

Though there is a glaring advancement in oxidation chemistry, it is still one of the most blighting chemical technologies. Oxidative transformations, as we know are the keystone of constant percolation of organic molecules. It is the oxidation procedures that enable petroleum-based feed wares to become chemical products, which are the stimulating materials of several chemical industries. Over the years, in the past, many of the oxidation reagents and catalysts engross of toxic substances like heavy metals (e.g. chromium). These substances have been used in large amounts for the manufacture of billions of kilograms of petrochemicals. All these processes have to lead to the exemption of vast quantities of these metals into the environment. Further, these toxic substances affect the human health. During the past 2-3 decades, eminent attention has been admonished towards the blooming of green chemistry techniques that will be environmentally benign and will also bring economic welfare to the industries. The oxidation techniques to be evolved will need catalysts so that there are high row rates. Even if some heavy metals/transition metals have to be used, should be made to use some of the most innocuous metals, e.g. iron etc. The objective of green oxidation chemistry will, of course, be to use and generation of non-hazardous substances, with maximum efficiency of atom incorporation.

Biomimetic, Multifunctional Reagents

In the human system, there are thousands of reactions going on due to which the body survives. The scientists are trying to perceive the mechanism that the biological methods used to carry out their functions. The chemists approach to mimic such reactions in the laboratory. In case of synthetic chemists, most of the transformations are sustained with the help of catalysts, e.g. oxidation, reduction and methylation. However, biological systems often carry out various manipulations with the same reagent. These collaborations may include activation, confirmation and other transformations. In the laboratory, it has now been feasible to carry out biochemical oxidations, biochemical reductions and enzyme catalysed the hydrolytic process. Different types of proteins, e.g. hydrolase, Lyases, isomerases, Ligases, transferases, oxidoreductases are available.

The biocatalytic conversions have many advantages in relevance to green chemistry. Some of these are – Most of the reactions are performed in an aqueous medium at ambient temperature and pressure.

- The biocatalytic transformations usually involve only one step.
- Protection and deprotection of functional group are not necessary.
- The biocatalytic reactions are fast, and the conversion is stereospecific.

Combinatorial Green Chemistry

Combinatorial chemistry is an enactment of being able to make a large number of chemical compounds rapidly on a small scale through reaction matrices. This practice is performed on a large scale in the pharmaceutical sector. The pharmaceutical company identifies a lead compound, which has substantial promise (as far as its biological activity is concerned) then the company would pursue in making a large number of derivatives of the lead compound and test their efficacy. In this way, the potential of a compound will be optimised. The combinatorial chemistry has enabled a large number of substances to be made and screened for their activities without having any adverse effect on the environment. This approach is very beneficial to assess the biodegradability of the products.

For example, if a company has struck on a biodegradable pesticide, the combinatorial approach will be helpful to make a large number of other compounds, which will have the required pesticidal activity along with biodegradability.

The proliferation of Solventless Reactions

A large number of reactions befall in a solid phase without the use of solvents is not harmful to the environment. In fact, some solventless reactions occur more productively with more selectivity scrutinised to reactions carried out using solvents. Such responses are simple to handle, reduce pollution and are cheaper to operate[14].

Non-Covalent Derivatization

Any chemical synthesis involving formation and breaking of covalent bonds. The philosophy of making and breaking covalent bond must change. In fact, without bond making, physical/chemical properties can be modified and performance measured. Through the formation of dynamic complexation (which temporarily allows modification of the chemical structure) the features of the molecules can be changed for in a short period to carry out a particular function. In this case, no waste will be generated if full derivatisation were accomplished[15].

Green Chemistry in Sustainable Development

Green chemistry can play a vital role sustainable development. Green chemistry as we know is environmentally benign synthesis. Chemical manufacturing is the source of many useful and enjoyable products, which has not only improved the quality of life of the people but also increased their life expectancy. Some of these products include antibiotics and other medicines, plastics, gasoline and other fuels, agricultural chemicals like fertilisers and pesticides, and a variety of synthetic fabrics including nylon, rayon and polyester. All these products are made by chemical industrial processes, which are mainly responsible for pollution of the environment. This, in fact, the green chemistry works toward sustainability by –

- Making chemical products that do not harm unless the environment or our health.
- Using industrial processes that reduce or eliminate hazardous chemicals.
- Designing more efficient processes that minimise the production of waste materials.
- Using the most appropriate offset materials, reagents and catalysts.
- New products designed should be biodegradable.
- The waste products should be salvaged as far as possible.

Commercial applications

Chemists from all over the world are using their imaginative 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 [16-23]. Some of these are:

- Diphenyl Carbonate replaced phosgene and methylene chloride in the synthesis of polycarbonates.
- Oxidation is t
- He most polluting reaction in the industry. The exertion of green chemistry has led to the use of alternative less polluting reagents viz.; metal ion contamination minimised by using molecular O2 as the primary oxidant and method of the extremely high oxidation state of transition metal complexes.
- Convenient green synthesis of acetaldehyde is by Wacker oxidation of ethylene with O2 in the ubiquity of a catalyst, in place of its synthesis by oxidation of ethanol or hydration of acetylene with H2SO4
- Conventional methylation reactions are employing toxic alkyl halides or methylsulfate leading to the environmental hazard replaced by dimethyl carbonate.
- In 1996, Dow Chemical won Greener Reaction award for their 100% carbon dioxide blowing agent for polystyrene foam production. It is a standard material used in packing and food transportation. Traditionally, for the production process of the foam sheets, CFC and other ozone-depleting chemicals were used, presenting a severe environmental hazard. Dow Chemical discovered

that with the help of supercritical CO2, as a blowing agent, we can recycle polystyrene. The CO2 used in the process is reusable so that the net carbon released from the process will be nill.

- Propylene oxide (PO) acts as a chemical building block for various products including detergents, polyurethanes, and food additives. Chlorohydrin used in traditional PO production, which directs to coproducts such as t-butyl alcohol, styrene monomer, or cumene. To eliminate the waste Dow and BASF jointly developed a new route to make propylene oxide with hydrogen peroxide and propylene.
- Akzo Nobel has developed a readily biodegradable chelating agent that is manufactured principally from a renewable feedstock. This new chelate, called tetrasodium L-glutamic acid, N, N-diacetic acid (GLDA), will replace phosphates in automatic dishwashing detergents. Most significantly, GLDA is readily biodegradable and will reduce pollution by replacing phosphates in dishwashing detergents.
- Spinosad is a low-risk pesticide in widespread use on crops. Clarke launched Natular in the U.S. market in December 2008. Natular, a spinosad-based mosquito larvicide has exceptional control in aquatic environments. It is 15 times scarce toxic than the organophosphate alternative.
- A continuous process and apparatus convert waste biomass into industrial chemicals, fuels and animal feed. A separate process converts waste biomass such as municipal solid waste, sewage sludge, plastic, tires and agricultural residues into useful products, including hydrogen, ethanol and acetic acid.
- Carboxylic acids produced by fermentation method.
- A cost-effective method of producing ethyl lactate, a non-toxic solvent derived from corn.
- A latest eco-friendly technology has been used to recover zinc and ferrous chloride from pickle liquor.
- The request for non-ionic surfactants is growing, and a new example of this is alkyl glycoside, which is obtained from saccharide. Replacement of alkylarylsulphonate anionic surfactants from shampoos can be done by this product. For the replacement of phosphorus-containing additives in washing powder, Sodium silicate can be employed as a more eco-friendly benign. Three coconut oil soap bases for liquid cleansing applications have been developed. One of these products has very light colour and low odour, making it suitable for introducing dyes and fragrances.
- Feedstock recycling of plastic wastes into valuable chemicals useful as fuels or raw materials.
- BioCnae, the first bio-pesticide for sugarcane, has recently been launched in Australia. The product is based on a naturally-occurring fungus that has been cultured on broken rice grains to provide a medium for distribution. Biocane granules are claimed to be especially effective against greyback cane grub.

Future Trends in Green Chemistry

It accommodates oxidation reagent and catalysis which is composed of toxic substances such as heavy metals. Showing substantial adverse outcomes on human health and environment which can be amended by the use of benign materials. Non-covalent derivatisation, Supramolecular chemistry research is directly on going to improve reactions which can proceed in the solid state without the use of solvents, Biometric multifunctional reagents. Combinatorial green chemistry is the chemistry of being able to make large numbers of chemical compounds rapidly on a small scale. The proliferation of solvent fewer reactions helps in the development of product isolation, separation and purification that will be solvent-less as well to maximize the benefits[24].

- Green Nanochemistry
- Supramolecular Chemistry
- Oxidation Reagents and Catalysts
- Biometric Multifunctional Reagents
- Combinatorial Green Chemistry
- Non Covalent Derivatization Techniques

CONCLUSIONS

Our future summons in resource, environmental and societal sustainability clamour more efficient and benign scientific technologies for working with chemical processes and products. Green chemistry inscribes such challenges by inventing novel reactions that can widen the desired products and minimize byproducts. Green chemistry is not a new sphere of science. It is a new philosophical nudge for a sustainable development. Presently it is vulnerable to find in the literature many exciting paradigms of the use of green chemistry rules. Great stabs are still engaged to design an ideal process that starts with nonpolluting materials. It is clear that the challenge for the future chemical industry was hinged on the production of safer products and processes designed by promoting new ideas in fundamental research.

REFERENCES

1. Green Chemistry". *The United States Environmental Protection Agency. 2006-06-28. Retrieved 2011-03-23*
2. Anastas PT, Warner JC. Principles of green chemistry. Green chemistry: Theory and practice. 1998:29-56.
3. Amato I. The slow birth of green chemistry. Science. 1993 Mar 12;259(5101):1538-42.
4. Anastas PT, Kirchhoff MM. Origins, current status, and future challenges of green chemistry. Accounts of chemical research. 2002 Sep 17;35(9):686-94.
5. Sheldon RA, *Acad CR. Sci. Paris, IIc, Chimie/Chemistry*. 2000, *3*, 541–551.

6. Anastas PT, Heine LG, Williamson TC. Green chemical syntheses and processes: introduction.2000.
7. Brundtland CG. *Our Common Future*, The World Commission on Environmental Development, Oxford University Press. Oxford, 1987.
8. Clark JH. Green chemistry: today (and tomorrow). Green Chemistry. 2006;8(1):17-21.
9. Knight DJ. EU Regulation of Chemicals: REACH. *Rapra Rev. Rep. 181*, 2006. Rapra Technol. Ltd., Shawbury, UK
10. Hester RE, Harrison RM, editors. Chemicals in the environment: assessing and managing risk. Royal Society of Chemistry; 2006.
11. Bozell JJ, Patel MK, editors. Feedstocks for the Future: Renewables for the Production of Chemicals and Materials. American Chemical Society; 2006 Jan 12.
12. Ragauskas AJ, Williams CK, Davison BH, Britovsek G, Cairney J, Eckert CA, Frederick WJ, Hallett JP, Leak DJ, Liotta CL, Mielenz JR. The path forward for biofuels and biomaterials. science. 2006 Jan 27;311(5760):484-9.
13. Stevens CV, Verhe RV. Renewable resources. Chichester, J. Wiley & Sons. 2004.
14. Kumar V. An introduction to green chemistry, Eden. Vishal Publishing Co. Jalandhar. 2015, 90.
15. Guarrera D, Taylor LD, Warner JC. Chemistry of Materials. 1993, 1293.
16. Sheldon RA. Green solvents for sustainable organic synthesis: state of the art. Green Chemistry. 2005;7(5):267-78.
17. Bharati VB, Resonance. 2008, 1041.
18. Ahluwalia VK & Kidwai M. New Trends in Green Chemistry, Anamaya Publishers, *New Delhi*, 2004.
19. Sato K, Aoki M, Noyori R. A" green" route to adipic acid: Direct oxidation of cyclohexenes with 30 percent hydrogen peroxide. Science. 1998 Sep 11;281(5383):1646-7.
20. The Presidential Green Chemistry Challenge Awards Program. Summary of 2000 Award Entries and Recipients, www.epa.gov/greenchemistry, August 2001.
21. Hjeresen DL, Boese JM, Schutt DL. Green chemistry and education. Journal of Chemical Education. 2000 Dec;77(12):1543.
22. Lancaster M. “Green Chemistry- An Introductory Text”, Royal Society of Chemistry, Cambridge. 2002.
23. Tundo P and Anastas PT. ”Green Chemistry: Challenging Perspectives”, Oxford University Press, Oxford, 1998. 14. S. Ravichandran, Int. J. *ChemTech Res*. 2011, 3(3) 1046.
24. http://alliedacademies.com/euro-green-chemistry-2017/2017/events-list/future-trends-in-green-chemistry.