2nd International Conference on Emerging Trends in Science, Engineering & Technology
Mahratta Chamber of Commerce, Industries and Agriculture, Pune (India)
29th - 30th September 2018 www.conferenceworld.in ISBN :978-93-87793-46-0

Green Chemistry- Promising Step towards Sustainable Development

Dr. Revika Arora

Assistant Professor in Chemistry, Govt. PG College for Women, Gandhi Nagar Jammu, J&K, India.

ABSTRACT

The role of chemistry is essential in ensuring that our next generation of chemicals, materials and energy is sustainable. Worldwide demand for environment-friendly chemical processes and products requires the development of novel and cost-effective approaches for preventing pollution. The most important goals of sustainable development are to reduce the adverse consequences of the substances that we use and generate. It is a challenge before chemists to develop synthetic methods that are less polluting i.e. to design clean or 'green' chemical transformations. The area of chemistry which is particularly directed to achieve such goals is termed as 'green chemistry'. Green chemistry is a central issue, in both academia and industry, with regard to chemical synthesis in the 21st century. This review paper presents a brief description on green chemistry principles and its developments as well as applications in daily life.

***Key Words*: Green Chemistry, Sustainable Development.**

INTRODUCTION

The first principle of the Rio Declaration on Environment and Development states that "*Human beings are at the centre of concerns for sustainable development they are entitled to a healthy and productive life in harmony with nature*[1]", which highlighted the challenge to all of us to define the objectives of sustainable development and to provide scientific, technological and social tools to achieve those objectives. We do not have to look too far back to see how a society could lose its sustainability the rise and decline of Easter Island, discovered by Polynesians around 400 A.D.[2] Its population reached a peak at perhaps more than 10,000 far exceeding the capabilities of the local system. The forests were cleared for agriculture and to move the giant stone monoliths, known as "Moais" from 1400 to 1600. Core sampling from the island has shown deforestation, soil depletion, and erosion resulting in over population, food shortage, and ultimately the collapse of the society. Thus, the history of Easter Island indicates that the sustainability of our civilization depends on whether we can supply the rapidly increasing population with enough energy, food and chemicals simultaneously without compromising the long term health of our planet.

The role of chemistry is essential in ensuring that our next generation of chemicals, materials and energy is sustainable. Worldwide demand for environment-friendly chemical processes and products requires the development of novel and cost-effective approaches for preventing pollution. The most important goals of sustainable development are to reduce the adverse consequences of the substances that we use and generate. Foremost among the fundamental changes this calls for, is the shifting of the production of energy and carbon based chemicals from fossil fuels to renewable resources. While it is difficult to predict the exact date of depletion of fossil fuels, the transition to renewable materials should be accelerated because of the frequently and unexpectedly changing political/ economical environments resulting in limited access and rising costs. But perhaps of equal significance is the need to deal with toxicities that are threatening the welfare of essentially all living things in real time. At the apex of these predicaments sits the need of the chemical enterprise to adjust to the threats of anthropogenic chemicals that disrupt the chemical signals controlling cellular development i.e. the so-called "endocrine disruptors."

It is a challenge before chemists to develop synthetic methods that are less polluting i.e. to design clean or 'green' chemical transformations. Industries and scientific organizations have put clean technology as an important R & D concern. The area of chemistry which is particularly directed to achieve such goals is termed as 'green chemistry'. Green chemistry is a central issue, in both academia and industry, with regard to chemical synthesis in the 21st century[3]. Without this approach, industrial chemistry is not sustainable. Our health and daily life relies on man-made substances such as pharmaceuticals, fine chemicals, synthetic fibres, and plastics which are produced by multistep chemical conversion of petroleum or biomass based feedstocks. Many existing chemical processes, though beneficial produce unwanted wastes along with target products and inefficient recovery of solvents causes environmental problem[4]. Thus, the development of environmentally benign and clean synthetic technology is a goal of research and industry.

The term "Green Chemistry" was coined by Professor Paul Anastas who is known as the father of Green Chemistry. Green Chemistry is defined as: *The invention, design and application of chemical products to reduce or to eliminate the use and generation of hazardous substances*[5]. Looking at the definition of green chemistry, the first thing that one sees is the concept of invention and design. Another aspect of definition of Green Chemistry is found in the phrase "*Use and Generation*", rather than focusing only on those undesirable substances that might be inadvertently produced in a process, green chemistry also includes all substances that are part of the process. Therefore, Green Chemistry is a tool not only for minimizing the negative impact of those procedures aimed at optimizing efficiency, although clearly both impact minimization and process optimization are legitimate and complementary objects of the subject. Green Chemistry, however also recognizes that there are significant consequences to the use of hazardous substances ranging from regulatory, handling and transport and liability issues. To limit the definition to waste only would be to address only a part of the problem.

Green Chemistry approach is also known as :

- Environmentally benign Chemistry
- Clean Chemistry
- Atom Economy

ISBN :978-93-87793-46-0

- Benign by design Chemistry

Finally, the definition of green Chemistry includes the term "hazardous". It is important to note that green chemistry is a way of dealing with risk reduction and pollution prevention by addressing the intrinsic hazards of the substances rather than those circumstances and conditions of their use that might increase their risk. Risk, in its most fundamental terms is the product of hazard and exposure[6].

Risk = Hazard x Exposure

The definition of green chemistry also illustrates another important point about the use of the term "hazard". This term is not restricted to the physical hazard such as explosiveness, flammability and corrodibility, but certainly also includes acute and chronic toxicity, carcinogenicity and ecological toxicity. Furthermore, for the purpose of this definition, hazards must include the global threat such as global warming, stratospheric ozone depletion, resource depletion and persistent chemicals. But more importantly, intrinsically hazardous properties constitute those issues that can be addressed through the proper design or redesign of chemistry and chemicals.

According to a US award programme, 'green chemistry' is one that encompasses all aspect and types of chemical processes-including synthesis, catalysis, analysis, monitoring, separations and reaction conditions that reduce impacts on human health and the environment relative to the current state of the art.

Principles of Green Chemistry

The Principles of green Chemistry, as articulated by Anastas and Warner, can guide chemists towards fulfilling their unique and vital role in achieving sustainable development. These principles are:-

1. **Prevention:** It is better to prevent waste than to treat or clean up waste after it has been created.
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:** Wherever practicable, synthetic methods should be designed to use and generate substances that possess little or no toxicity to people or the environment.
4. **Safer solvents and auxiliaries:** The use of auxiliary substances (e.g. solvents or separation agents) should be made unnecessary whenever possible and innocuous when used.
5. **Designing safer chemicals:** Chemical products should be designed to effect their designed function while minimizing their toxicity.
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.
7. **Use of renewable feedstocks:** A raw material or feedstock should be renewable rather than depleting whenever technically and economically practicable.

 ISBN :978-93-87793-46-0

8. **Reduced derivatives:** Unnecessary derivatisation (use of blocking groups, protection/de-protection, and temporary modification of physical/chemical processes) should be minimized or avoided if possible because such types require additional reagents and can generate waste.
9. **Catalysis:** Catalytic reagents (as selective as possible) are superior to stiochiometric reagents.
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.
11. **Real time analysis for pollution prevention:** Analytical methodologies need to be further developed to allow for real time, in process monitoring and control prior to the formation of hazardous substances.
12. **Inherently safer chemistry for accidental prevention:** Substances and the form of a substance used in a chemical process should be chosen to minimize the potential for chemical accidents, including releases, explosions and fires.

Areas of Green Chemistry

Economic considerations and environmental evaluations have pushed the chemical industry to adopt new eco-friendly technologies to survive in a market that becomes more demanding everyday.

The areas for the development of Green Chemistry have been identified as follows:-

- Use of alternative feedstock
- Use of innocuous reagents
- Employing natural processes
- Use of alternative solvents
- Design of safer chemicals
- Developing alternative reaction conditions
- Minimizing energy consumption.

The challenge for chemists and others is to develop new products, processes, procedures and services that achieve the societal, economic and environmental benefits. 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, maximizing the use of renewable resources and extend the durability and recyclability of products in a way which increases industrial competitiveness. Mature chemical processes that are often based on technology developed in the first half of the 20^{th} century, may no longer be acceptable in these environmentally conscious days. 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.

Green chemistry concerns the development of chemical technology and processes that are designed to be incapable of causing pollution. We humans have dealt with toxicity and pollution throughout our entire history, but only recently have armed with an understanding of its sources and consequences (Fig. 1).

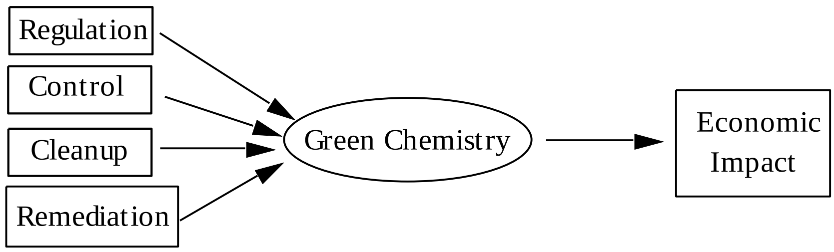

Fig. 1 Environmental protection activities that require the intervention of green chemistry to minimize their impact

HISTORY DEVELOPMENT

Green chemistry was founded very earlier. It can be linked to trembled activities of environment like Rachel Carlson. She published “Silent Spring,” in 1962 which was directly helpful to the public’s awareness related to pesticides and also their ties to environmental pollution. After some time of this publication, The EPA was established in 1970.The EPA shows it presence as the extended shadow of Rachel Carlson who is acknowledged as a foremost pioneer of environmental protection, a reason that has paved the way to current green chemistry practices. After a decade, act for the prevention of pollution was employed in 1990. This act was helpful for the reduction of pollution in an innovative way and this made the path for green chemistry . Paul Anastas along with John Warner framed word “green chemistry” and on behalf of that they originated the twelve principles of green chemistry.

Then Ryoji Noyori selected three points for developments in green chemistry, in 2005:

1. Employ green solvent like supercritical CO2 (carbon dioxide),
2. For clean oxidations the use of aqueous hydrogen peroxide and
3. The application of hydrogen in asymmetric production.

Applications of Green Chemistry

1.**Green Dry Cleaning of Clothes** Perchloroethylene (PERC), $Cl_2C{=}CCl_2$ 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[7].

2. **Green Bleaching Agents:** Conventionally during manufacturing of good quality white paper, lignin from wood used for it, is removed by placing small pieces of wood into a bath of sodium hydroxide and sodium sulphide followed by its reaction with chlorine. Chlorine during the process also reacts with aromatic rings of the lignin to form chlorinated dioxins and chlorinated furans. These compounds being carcinogens, cause health problems. Terrence Collins of Cambegie Mellon University developed a green bleaching agent which involves

use of H_2O_2 as a bleaching agent in the presence of some activators such as TAML[8] which catalysis the fast conversion of H_2O_2 into hydroxyl radicals that cause bleaching. This bleaching agent breaks down lignin in a shorter time and at much lower temperature .It can be used in laundry and results in lesser use of water[9].

3. **Green Solution to Turn Turbid Water Clear** Tamarind seed kernel powder, discarded as agriculture waste, is an effective agent to make municipal and industrial waste water clear. The present practice is to use Al-salt to treat such water. It has been found that alum increases toxic ions in treated water and could cause diseases like Alzheimer's. On the other hand kernel powder is not- toxic and is biodegradable and cost effective. For the study, four flocculants namely tamarind seed kernel powder, mix of the powder and starch, starch ad alum were employed. Flocculants with slurries were prepared by mixing measured amount of clay and water. The result showed aggregation of the powder and suspended particles were more porous and allowed water to ooze out and become compact more easily and formed larger volume of clear water. Starch flocks on the other hand were found to be light weight and less porous and therefore didn't allow water to pass through it easily. The study establishes the powder's potential as an economic flocculants with performance close more established flocculants such as $K_2SO_4Al_2(SO_4)_3.24H_2O$ (potash alum).

4. **Solar Array** One of the best known examples of green technology would be the solar cell. A solar cell directly converts the energy in light into electrical energy through the process of photovoltaics. Generating electricity from solar energy means less consumption of fossil fuels, reducing pollution and greenhouse gas emissions.

5. Reusable Water Bottle Another simple invention that can be considered green is the reusable water bottle. Drinking lots of water is healthy. Reducing plastic waste is great for the environment. Hence, trendy reusable water bottles that you can refill yourself are health-promoting, eco-friendly, and green.

6. Solar Water Heater Installing a solar water heater can be a great way to cut down on energy costs at a much lower initial expense. The costs associated with the installation of a solar water heater are actually recouped much faster than the costs associated with photovoltaic technology for power generation. This is due to the increased efficiency of solar water heating systems, as well as their reduced expense when compared to the large solar array required for powering a home.

7. Wind Generator The costs of a home wind generator vary greatly. Some have built their own wind generators with off-the-shelf parts from their local hardware stores. Others have purchased kits or paid for professional installation to supplement the power purchased from their local electrical grid. The power production capability of a home wind generator varies about as much as the initial expense. Many kit based generators will produce only enough power to offset 10-15% of your Home energy costs.

8. Rainwater Harvesting System Rain collector systems are extremely simple mechanical systems that connect to a gutter system or other rooftop water collection network and store rain water in a barrel or cistern for later nonpotable use (like watering plants, flushing toilets, and irrigation). These systems are extremely inexpensive.

9. Insulation of House Based on EPA estimates, 10% of household energy usage a year is due to energy loss from poor insulation. We will get an excellent return on investment from sealing our home to prevent energy escape.

10. Building with Green Technology Green buildings use a variety of environmentally friendly techniques to reduce their impact on the environment. Reclaimed materials, passive solar design, natural ventilation and green roofing technology can allow builders to produce a structure with a considerably smaller carbon footprint than normal construction. These techniques not only benefit the environment, but they can produce economically attractive buildings that are healthier for the occupants as well. The chief benefit of building green is reducing a building's impact on the environment. Using green building techniques can also reduce the costs associated with construction and operation of a building. Green ventilation techniques involve open spaces and natural airflow, reducing the need for traditional air conditioning and preventing many of these problems.

Green Organic Analysis

In conventional organic analysis, organic compound is fused with sodium metal which is very hazardous as may cause fire if come in contact with moisture or water. Sometimes it violently explodes and even strikes the eyes of the students causing damage. A safe and non-hazardous procedure, which can be alternatively performed, has been proposed to use zinc dust and sodium bicarbonate instead of metallic sodium.

Green Qualitative Inorganic Analysis

In classical technique H_2S is used, which is highly toxic and has adverse effects on humans and the environment. Increasing awareness concerning a healthy environment, a green scheme has been developed for detection of cations. NH^{4+} and K^+ are detected in group zero by applying direct tests. Pb^{2+} and Ag^+ are detected by using dilute HCl as their chlorides in group I. $Ca^{2+,}$ Sr^{2+} , Ba^{2+}, and Pb^{2+} are precipitated as sulphates using Na_2SO_4(aq) and ethanol in group II. Cu^{2+}, Cd^{2+}, Fe^{3+}, Mn^{2+}, Co^{2+}, Ni^{2+}, and Mg^{2+} are precipitated in group III as hydroxides using NaOH and H_2O_2 . The precipitate is treated with NH_3(aq) which dissolves Cu^{2+}, Cd^{2+}, Ni^{2+}, Co^{2+} forming soluble ammines and are grouped as group IIIB leaving behind a residue containing Fe3+, Mn^{2+}, Mg^{2+} as hydroxides and are grouped as group IIIA. Al^{3+}, Zn^{2+}, Sn^{2+}/Sn^{4+} as soluble hydroxo complexes and Cr^{3+} as $CrO_4{}^{2-}$ are detected in group IV[10]. Also, the amount of reagents used and thus environmental pollution can be reduced by performing spot tests for cations and anions instead of conventional tests.

Green Quantitative Analysis using flower petal extracts as Indicators

The synthetic indicators like phenolphthalein, methyl orange and phenol red are not only hazardous to health but are also prominent pollutants. The Green Chemistry has proved that these unsafe chemicals can be substituted by the petal extract as an indicator for acid base titration. The accuracy of the observed results has been examined by performing titration between different acids and bases of varying normality using petal extracts which are neither harmful to the environment nor it causes any health hazards e.g. Delonix regia flower petals, Urena lobata, Hibiscus rosa sinensis, Dahlia pinnata etc[11].

CONCLUSION

The greatest challenge is to incorporate the green chemistry in industrial, laboratory and day to day processes in order to control environmental pollution and hence ocean pollution. Many successful efforts have been made but still a lot has to be done. Consumers and business purchasing departments can promote green chemistry by demanding safer, non toxic products from manufacturers. Green economic innovation for the 21st century will require green chemistry. Green chemistry has to be introduced in the syllabus of the students at all levels, so that each individual is made aware to choose greener ways in his or her life.

REFERENCES

1. Rio Declaration on Environment and Development, *Rio de Janeiro, Brazil*, June 3-14, **1992**.
2. Rapa Nui Journal, *The Journal of the Easter Island Foundation*.
3. (a) M. Eissen, J. O. Metzger, E. Schmidt and U. Schneidewind, *Angew. Chem., Int. Ed.*, **2002**, *41*, 414. (b) Green Engineering, ed, P. T. Anastas, L. G. Heine and T. C. Williamson, *ACS Symposium Ser. 766*, American Chemical Society, Washington, D. C, **2000**.
4. (a) W. M. Nelson, Green Chemical Synthesis and Processes, ed. P. T. Anastas, L. G. Heine and T. C. Williamson, *ACS Symposium Ser. 767*, American Chemical Society, Washington, D.C. **2000**, 313. (b) J. Metzger, *Angew. Chem., Int. Ed.*, **1998**, *37*, 2975.
5. P. T. Anastas and J. C. Warner, *Green Chemistry: Theory and Practice*; Oxford University Press Oxford, **1998**.
6. B. M. Trost, *Angew. Chem; Int. Ed. Engl.*, **1995**, *34*, 259.
7. P.T. Anastas and T.C. Williamson, *Green Chemistry: Frontiers in Benign Chemical Synthesis and Processes;* Oxford University Press, Oxford, **1998**.
8. J.A. Hall, L.D. Vuocolo, I.D. Suckling, C.P. Horwitz, R.M.Allison, L.J. Wright, and T. Collins; *Proceeding of 53rd APPITA Annual Conference,* Rotorua, New Zealand. April 19-22, **1999**.
9. P. Tundo and P.T. Anastas, *Green Chemistry: Challenging Perspectives;* Oxford University Press, Oxford. (**1998**).
10. I.T. Sidhwani, ; S. Chowdhury; *Journal Of Chemical Education,* **2008**,85(08),1099.
11. P. M. A. Khan and M.Farooqui: A Review; *Journal of Advanced Scientific Research*., **2011,** 2(4), 20.