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Importance of Green Chemistry and its Implementation for Healthy Environment

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ABSTRACT

Green chemistry is the process of synthesising substances in a way that is suitable, non-polluting, and protected, uses the least amount of resources and energy, and produces little to no waste. In order to reduce the harm that anthropogenic materials and the processes used to produce them cause to the environment, green chemistry is necessary. It aims to reduce or even eliminates the production of any harmful bi-products and maximizing the desired product without compromising with the environment. The twelve principles are a common way to communicate the idea of "green chemistry," which was initially developed by Paul Anastas and John Warner. Green chemistry offers a proactive approach to ensuring a safer workplace while having minimal to no negative environmental effects. To fully realise the potential of green chemistry, a coordinated revolution of numerous social, political, economic, and technological aspects is required. This literature shows a critical and clear review of green chemistry, importance, as well as its application on environment, population, analyst, company and our daily life.

Keywords: Green chemistry; Environment; Human health; Nanoscience

1. INTRODUCTION

The scientific community has been working hard over the last few years to create new chemistries that are less harmful to the environment and human health. To boost environmental protection and the economics of chemical production, innovative chemistry is necessary. For cutting-edge chemistry research and applications, the green chemistry idea offers an alluring technology and potentiality to chemists, researchers, and industrialists. Green chemistry is primarily defined as the reduction of environmental harm caused by the manufacturing of materials, as well as the corresponding minimization and appropriate disposal of wastes produced during various chemical processes. According to its definition, "green chemistry" is the practise of chemical research and manufacturing in a way that is secure, environmentally friendly, and non-polluting, uses the least amount of resources and energy, and generates little to no waste. The practise of green chemistry began when it was realised that improper chemical reaction generation, processing, usage, and final disposal of chemical compounds may be harmful. Green Chemistry, which embodies sustainable development, saw a surge in during the 1990s and continues to draw interest today. With the idea of "green chemistry," many new terms have been created, including "renewable energy source," "eco-efficiency," "sustainable chemistry etc.

In 1991, Paul T. Anastas was the first individual to use the term "green chemistry." In a unique programme put up by the US Environmental Protection Agency (EPA) to implement sustainable development in chemistry and chemical technology by business, academia, and government, he used the phrase "green chemistry." Similar prizes have also been established in various European nations. The 12 principles of "green chemistry," still in use today, were proposed by Paul Anastas and John Warner in the 1990s. They are based on the idea that chemical processes and analyses should utilise as few harmful solvents as possible and should not produce waste. These principles suggest ecologically friendly actions at every stage of the product's development, including its design, synthesis, processing, analysis, and final destination[1]. The major goal is to reduce the environmental and safety hazards connected to industrial activity[2][3]. Green chemistry offers a proactive approach to ensuring a safer workplace while having minimal to no negative environmental effects. To fully realise the potential of green chemistry, a coordinated revolution of numerous social, political, economic, and technological aspects is required. This viewpoint promotes the development of novel sustainable technology through transdisciplinary design. The significance of green chemistry is multifaceted. Every analytical system has an impact on the end product as well as everything in its immediate environment, including the environment, the people, the analyst, and even the company. Thus, this literature shows a critical review of green chemistry, importance, as well as its application on environment, population, analyst, company and our future.

2. SALIENT FEATURES OF GREEN CHEMISTRY

Green chemistry considered sustainable due to several important respects:

- When compared to other traditional synthesis methods, green chemistry typically has lower costs at a high level of sophistication. than chemistry as it is generally practised (not to mention environmental expenses).
- By effectively utilising materials, maximising recycling, and utilising minimal amounts of new raw materials, green chemistry is also sustainable in terms of materials.
- In terms of wastes, green chemistry is sustainable by minimising or even completely eliminating their generation.

Prior to gaining their current importance, environmental, health, and safety issues were less important from an economic standpoint than they are today. Costs of feedstock, energy requirements, and product marketability were among the economic considerations at play. However, expenses now have to take liability, end-of-pipe waste treatment, compliance with regulations, and disposal costs into account.

The primary idea behind green chemistry is the application of chemical expertise and knowledge to minimise risks to the environment and human health by reducing or eliminating the use or manufacture of hazardous substances during the design, production, and application of chemicals. Thus, rather than simply treating the garbage that has already been produced, it is now more important to stop or reduce the development of toxic waste[1].

The 12 principles of green chemistry proposed by Paul Anastas and John C. Warner serve as the cornerstone of green chemistry and aid in reaching the following prerequisites.

- To create procedures that maximise the conversion of raw materials into finished goods in order to get the highest possible yield of final products.
- Whenever possible, adopt the use of such environmentally friendly or derived from the environment substances, such as solvent.
- Disposal of waste material so avoided that it should not produce in the reaction or if not possible should be treated in such a way that it should not harm the environment.
- Designing of energy efficient processes.

Green chemistry is basically presented as a set of 12 principles proposed by Anastas and Warner[4]. The principles include guidance for practising chemists on how to use novel chemical substances, syntheses, and technical procedures. The first tenet of green chemistry is the preservation of the environment from pollution. The remaining principles concentrate on matters like atom economy, toxicity, solvent and other media utilising energy usage, use of raw materials from renewable sources, and degradation of chemical products into simple, nontoxic, and environmentally beneficial chemicals.

Green chemistry 12 principles as below-

i. Prevention: It is better to prevent waste than to try to clean it up after it is formed.

ii. Atom economy: Synthetic methods should be designed to incorporate, in the final product, a maximum of all the materials used in the process, minimizing the formation of byproducts.

iii. Using methodologies that generate products with reduced toxicity: Whenever possible, synthetic methods should be designed to use and generate substances that possess little or no toxicity to human health and the environment.

iv. Generate effective but non-toxic products: Chemical products should be designed to maintain efficacy while reducing toxicity.

v. Reduce the use of auxiliary substances: Wherever possible, avoid using solvents, reagents for performing separations, and other non-essential substances, and make those that are used as safe as possible.

vi. Reduce energy use: Energy needs should be examined for their effects on the economy and the environment. It is best to reduce this effect. Methods for synthesis should be used at r.t. and atmospheric pressure.

vii. Utilisation of renewable raw resources: Whenever it is technically and financially practicable, raw materials should be renewable rather than exhaustible.

viii. Avoid unnecessary derivatization: Derivatization (blocking groups, protection / deprotection, temporary modification of physical / chemical processes) should be avoided where possible.

ix. Enhancing catalysis: Instead of using stoichiometric reagents, catalysts should be used because they are more selective and can be used again.

x. Create biodegradable products: Chemicals are made to break down into harmless degradation products when their purpose is completed, preventing them from remaining in the environment.

xi. Create analytical methods for real-time monitoring: The analytical methods will be improved to enable monitoring and real-time control of the process, before hazardous compounds are formed.

xii. Reduce the potential of chemical accidents: Materials are chosen based on chemical processes to reduce the risk of chemical accidents, such as leaks, explosions, and fires.

The chemical industry's economic health is greatly influenced by catalyst, and the clean technology revolution in the sector will open up new possibilities for catalysis and catalytic processes. A solid acid catalyst, i.e., H2F, has successfully replaced the conventional catalyst hydrogen fluoride, a very corrosive, dangerous, and poisonous chemical utilised in the manufacture of linear alkylbenzenes. Fluorided silica-alumina catalyst eliminates the requirement for an acid scrubbing system and calcium fluoride waste disposal, does not require special construction materials, and minimises running costs[4]. Compounds and the compound's formula used in chemical reactions should be selected to reduce the possibility of anomalies involving chemical discharge, explosions, or fire creation.

The selected examples for utilizing the 12 principles in laboratory and company are presented in table 1.

Sr. no.	Principle	Example
i.	Prevention	Use of a solvent-free sample preparation method[5]
ii.	Atomic Economy	Hydrogenation of carboxylic acid to aldehyde using solid catalyst
iii.	Less Hazardous Chemical Syntheses	Adipic acid synthesis by oxidation of cyclohexene by using hydrogen peroxide[6]
iv.	Designing Safer Chemicals	New, less Hazardous pesticide (eg. Spinosad)[7]
v.	Safer Solvents & Auxiliaries	Supercritical fluid extraction, synthesis in ionic liquid
vi.	Design For Energy Efficiency	Polyolefens polymers alternative to PWC (polymerization may be carried with lower energy consumption)
vii.	Use of Renewable Feedstocks	Production of surfactants[8]
viii.	Reduce Derivatives	On-fiber derivatization vs derivatization in solution in sample preparation
ix.	Catalysis	Efficient Au (III) catalyzed synthesis b-enaminones from 1,3-dicarbonyl compounds and Amines
x.	Design For Degradation	Synthesis of biodegradable Polymers
xi.	Real Time Analysis For Pollution Prevention	Use of in line analyzers for water waste monitoring
xii.	Inherently Safer Chemistry for Accident Prevention	Di-Me carbonate (DMC) is an environmentally friendly substitute for di-Me sulfate Me halides in methylation reaction[9]

Table 1 Example of utilization for green chemistry principles into practice [10]

In addition to attempting to evaluate a chemical process's "greenness," additional factors are being taken into account, including chemical yield, the cost of reaction components, the safety of handling chemicals, hardware requirements, energy profile, and the simplicity of product workup and purification. In one quantitative analysis, the synthesis of an amide using HMDS is only characterised as satisfactory with a combined score of 32 points, in contrast to the reduction of nitrobenzene to aniline, which earns 64 points out of 100, explaining it as an overall acceptable synthesis[11].

Figure 1 depiction of green chemistry principle given by Anastas & Warner,(source google)

3. BENEFITS OF GREEN CHEMISTRY

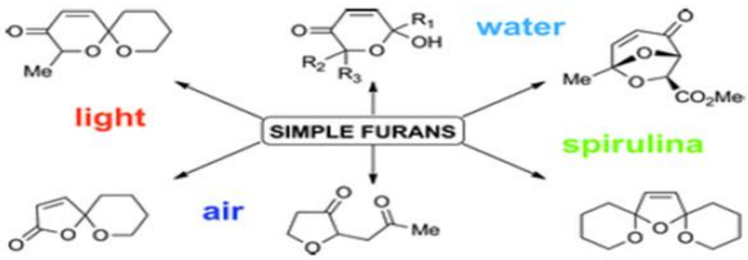
Environment: Many chemicals are released into the environment either on purpose (like insecticides) while being used, unintentionally (like emissions during manufacturing), or through disposal. Green chemicals are either recycled for additional use or breakdown into harmless compounds. When harmful substances are present in the environment, plants and animals are less harmed. less chemistry to disturb ecosystems and use of landfills should be reduced, especially those for hazardous waste.

Human health: Elimination of persistent toxic chemicals that may enter the system of food chain; less toxic pesticides that are toxic only to specific pests and degrade rapidly after use. Clean water as less release of hazardous chemical wastes to water leading to cleaner drinking and recreational water. Increased worker safety in the chemical sector; decreased use of dangerous substances; reduced need for personal protective equipment; and decreased risk of mishaps (such as fires or explosions). Safer consumer goods of all kinds will be produced: new, safer products will be sold; some products, like medications, will be produced with less waste; and some products, like insecticides and cleaning supplies, will take the place of less safe alternatives.

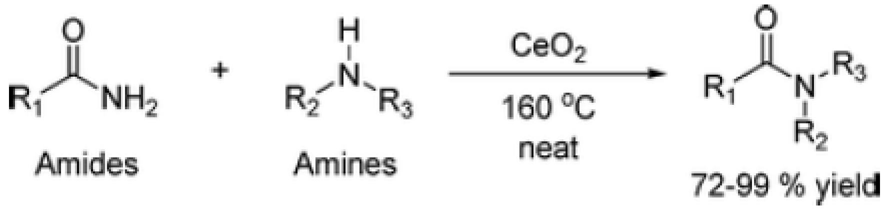
Economy: Permit the replacement of a waste product for a purchased feedstock. greater chemical yields, which require less feedstock to produce the same amount of product. waste reduction by doing away with expensive remediation, hazardous waste disposal, and end-of-pipe treatments. Fewer synthetic stages frequently enable quicker product manufacturing, higher plant capacity, and energy and water savings. improved performance, using less product to fulfil the same function. increased ability of chemical producers and their clients to compete. Reduced use of petroleum products, slowing their depletion and avoiding their hazards and price fluctuations.

Some chemical benefits of reactions:

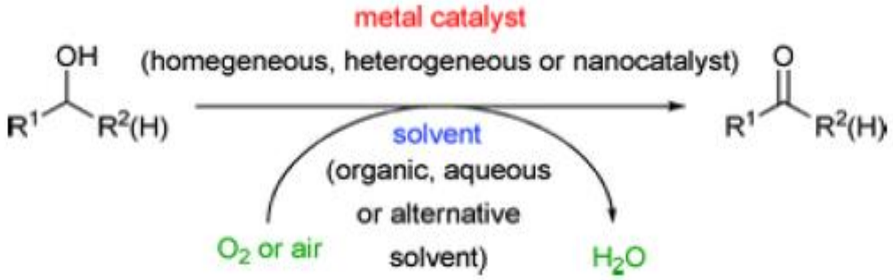
a) With the help of green chemistry, it is now possible to convert easily accessible furan derivatives into a variety of synthetically valuable polyoxygenated molecules that are frequently present in natural materials[12].



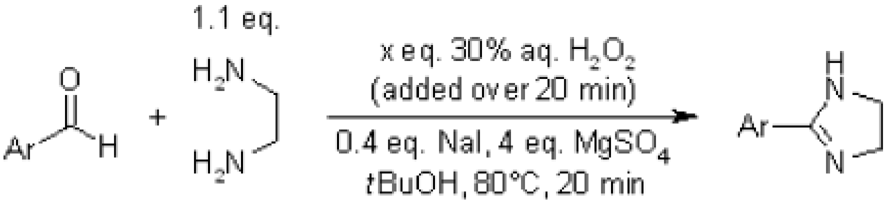
b) Cerium oxide (CeO2), which demonstrates the highest catalytic activity, has been employed for the transamidation of picolinamide with n-octylamine. This process was carried out in an environment without any solvents[12].



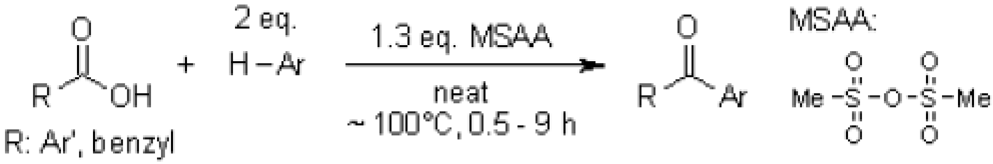
c) Alcohol is oxidised using oxygen or, even better, air as stereomeric oxidants to produce the appropriate carbonyl molecules. Only water is created as a byproduct with this procedure. Transition metals are used in this reaction as a catalyst in the form of either homogeneous, heterogenous, or even better nanocatalysts[12].



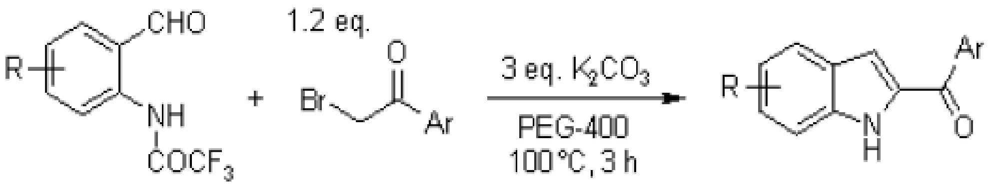
d) The synthesis of 2-imidazolines can now be done in a new, more efficient, and simple way that aims to produce better results by reacting aldehydes with ethylenediamine while using hydrogen peroxide as an oxidant and sodium iodide and anhydrous magnesium sulphate as catalysts. This synthesis did not result in the formation of any biproducts[13].



e) Now that methanesulfonic anhydride (MSAA) is available, it is possible to perform friedel craft acylation of aryl and alkyl carboxylic acid. This method clearly distinguishes itself from other approaches by enabling the production of aryl ketones in a good yield with little waste and no metallic or halogenated components[14].



f) Using N-(2-formylphenyl)trifluoroacetamides and -bromoacetophenones as starting materials in the presence of potassium carbonate and PEG-400 as an effective and reusable solvent enables a straightforward and environmentally friendly method for the production of 3-unsubstituted 2-aroylindoles[15].



g) Researchers are currently using used and exhausted vegetable oil as a fuel for vehicles with very minor modifications to the currently in use cars, and a startling result was found that using vegetable oil has reduced CO_2 emissions to almost 67% without compromising the efficiency of the vehicle.

4. IMPLEMENTATION OF GREEN CHEMISTRY

Green chemistry has become the new paradigm in agriculture, pharma industry, and environment today. In recent years, the utilisation of renewable biomass resources has increased in agriculture for sustainable production in order to provide bio-based food items with low inputs, zero waste, significant social values, and minimal environmental effect. Agriculture's sustainability is the primary area that calls for the implementation of green chemistry techniques in the agrochemical field for the prudent use of pesticides and fertilizers. The chemical, pharmaceutical, paper, polymer, apparel, and colour industries all employ green chemistry extensively. It is essential to the development of new energy technologies and manufacturing processes for batteries, fuel cells, and solar cells, which are used to store energy. Green chemistry is also widely used in nanoscience and technology. Since reducing or eliminating waste in the chemical industry is the primary objective of green chemistry, several green "next generation" catalysts have been developed as a result.

In pharma industry: Green chemistry is a significant force and a revolution in the pharmaceutical sector. Ibuprofen (a painkiller) is now produced by the chemical company BASF in three steps instead of to the previous six steps[16]. Simvastatin, the main medication used to treat high cholesterol, was traditionally created via a multi-step process involving large amounts of dangerous chemicals that produced a lot of harmful waste. Codexis, a bio-catalysis startup, created a novel method for producing the medication utilising an engineered enzyme and a cheap feedstock. The chemotherapeutic medication paclitaxel (sold under the brand name Taxol) was extracted from the yew tree's bark, a procedure that required a significant amount of solvent to kill the tree. Now, tree cells are grown in a fermentation vat to create the medication[17].

Making turbid water clean: Clean sand filtering is a quick and easy pre-treatment solution. Users pour water through a sand container with pebbles and a spout at the bottom using a transport container. The water then pours into a holding tank. Sand filtration has the advantages of being simple and quick for the user, effective at removing some microorganisms, and inexpensive if sand is locally accessible. Sand filtration has the disadvantage of requiring three containers and a spigot. Sand filtering greatly decreased the turbidity and chlorine demand of turbid water in laboratory trials.

Eco-friendly dry clean-up of clothes: Dry cleaning with perchloroethylene (PERC), a carcinogen, pollutes the environment. Today's extremely essential CO_2 and a surfactant for washing clothing were first created by Joseph De Simons, Timothy Romark, and James to address this issue. Additionally, Micell Technology has created a metal cleaning system that uses CO_2 and a surfactant in place of halogenated solvents.

Modification of chemical process: There are numerous possibilities to enhance traditional industrial processes. For instance, a novel pathway to the Nylon-6,6 precursor o-caprolactam has been developed using nanoporous aluminophosphate catalysts with a distribution of acidic and redox active sites. Hazardous reagents are eliminated during the one-step, solvent-free process, which also lowers the production of waste byproducts.

Energy science aspect: Organic solar cells (OSCs) are low-cost and potentially ecologically friendly sources of energy. -Polymers and conjugated compounds employed in OSC creation. The synthesis of conjugated systems followed the green chemistry tenets. From this angle, scientists typically choose for procedures that need fewer stages and utilise biofeedstock.

Application in nano-science: There are several applications for nanomaterials in every field. Low dimensional material products are being developed by researchers for use in diverse technical applications. Nanotechnology is also environmentally mindful. For the treatment of waste water and air purification employing nanofiltration techniques, mechanical and chemical methods have been developed. One of the key techniques for the synthesis of low dimensional materials in recent years is the use of green chemicals. Regarding the choice of reducing agent, avoiding surfactants, solvent selection, and enhancing yields, size distribution, and purity, green chemical processes earn praise. In the context of green chemistry, there are various methods for creating chemicals, such as the citrate technique, the tollens method, the ionic liquid method, the polysaccharide method, the ligand exchanging method, and the polyoxometalate method. The reduction of gold salts by citrate anions was established few decades before, yielding almost mono dispersed gold particles in nano range[18]. As a stabilising agent during the creation of silver nanoparticles and as a reducing agent for silver ions, carboxymethylcellulose (CMC) derivatives were used[19]. One of the most alluring features of contemporary material science is the synthesis of nanomaterials employing bio-inspired, environmentally friendly greener technologies. Only a biological approach will be able to meet the growing demand for high-yield, low cost, nontoxic, and environmentally friendly processes for the synthesis of low dimensional materials. In nature, there are a wide variety of biological resources that can be used for the green synthesis of low dimensional materials, including plant extract or biomass, bacteria, fungi, algae, yeast, and even viruses.

Rainwater harvesting method: Rain collector systems are incredibly straightforward mechanical devices that attach to gutter systems or other rooftop water collecting networks and collect rainwater to be used for irrigation, flushing toilets and other non-potable purposes. These systems are incredibly affordable[20].

Solar water heater: A fascinating approach to reduce energy bills at a much lower initial cost is to install a solar water heater. Compared to the expenditures connected with photovoltaic technology for power generation, the costs of installing a solar water heater are actually recovered far more quickly. This is because solar water heating systems are more cost-effective and efficient than the substantial solar array needed to power a whole home[20].

Using green technology when building: To decrease their influence on the environment, green buildings employ a number of eco-friendly practices. With the use of recycled materials, passive solar architecture, natural ventilation, and green roofing technology, construction companies may create buildings with a lot less carbon footprint than usual. These methods not only improve the environment, but they can also create structures that are more appealing from an economic standpoint and healthier for the occupants. Reduced environmental impact is the main advantage of green construction.

5. CONCLUSION

One area of science is green chemistry. Using alternative feedstocks, eco-friendly reaction conditions, energy efficiency, and the development of less toxic and fundamentally safer compounds are just a few of the many opportunities presented by the green chemistry revolution. It is obvious that green chemistry not only helps in the development of novel, user-friendly, cost-effective ways to synthesise the desired product but also contributes to environmental preservation. We will be able to increase our knowledge and contribute to environmental protection if there is a smooth flow of information between businesses and research organisations and universities working on these kinds of research themes. We can reduce material waste, maintain the atom economy, and prevent the use of hazardous chemicals by utilising novice chemistry techniques. Pharmaceutical companies and researchers were motivated to take into account green chemistry concepts when developing new procedures and choosing reagents.The idea and application of novice chemistry must be introduced to students at the least intermediate levels. Green chemistry is more effective and efficient overall. It is more elegant. Basically, the chemistry is better. Green Chemistry in nutshell is a cost effective approach which involve reduction in material, energy consumption and waste generation.

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