Review **Article**

The development of green chemistry and its numerous effects, a Review

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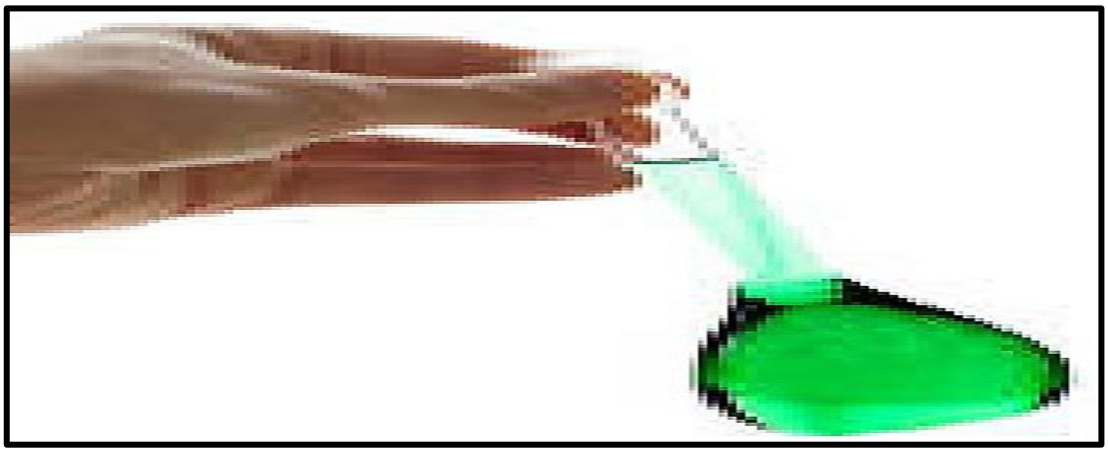
Abstract:-

The acceleration of industrialization was a turning point in the development of the global economy. Social movements have revolutionized green chemistry since the 1940s and brought about changes in industrial positions and sustainable processes with breakthroughs in environmental effect and population and company awareness. The 12 principles of Green Chemistry were proposed by Paul Anastas and John Warner in the 1990s. These principles center on the reduction or elimination of harmful solvents from chemical analyses and processes, as well as the avoidance of residue production. The creation of analytical techniques, which gave rise to the field known as "Green Analytical Chemistry," is one of the most active areas of research and development in green chemistry. This paper describes the multifaceted effects of green chemistry on pharmaceutical analysts, the environment, the public, analysts, and companies. Every decision and mindset have an impact on the finished product as well as everything around it. This work also considers the future of green chemistry, our future, and the environment.

Keywords : Sustainable Chemistry ، Green Chemistry، Green Analytical Chemistry.

Introduction

The practice of chemical science and manufacturing in a way that is safe, non-polluting, sustainable, and that uses the least amount of energy and materials while creating little to no waste is known as "green chemistry," or "GC." The realization that improper chemical product manufacture, processing, usage, and disposal might have negative effects is the first step towards the application of green chemistry.



Green chemical engineering and chemistry may alter or completely rethink chemical processes and products in order to achieve their goals of reducing waste and the usage of or production of especially hazardous ingredients[1]. Green chemists understand that any impact their chemicals or chemical processes may have on the environment is their responsibility. Green chemistry aims to promote innovation and boost profits while safeguarding the environment and public health, far from being economically regressive and a burden on earnings. We are still learning a lot about green chemistry. This is due to the fact that it is a quickly expanding and changing area within the study of chemistry. And for those who work in this emerging field of science, this is an extremely exciting moment. In essence, green chemistry applies a wealth of chemical knowledge to the creation, usage, and final disposal of chemicals in a way that reduces material consumption, exposure of living things—including humans—to toxins, and environmental harm. Furthermore, it accomplishes this in a way that is both inexpensive and efficient. When all of the expenses associated with practicing chemistry, including risks and potential environmental harm, are considered, green chemistry is, in one sense, the least expensive and most efficient method of doing so[2].

Sustainable chemistry is termed "green chemistry." There are numerous significant ways that green chemistry is sustainable[3]:

• Economical: At a high degree of sophistication, environmentally friendly chemistry is typically less expensive than conventional chemistry from an economic standpoint (not to mention the costs to the environment).

• Chemicals: Green chemistry is sustainable in terms of materials because it makes effective use of materials, maximizes recycling, and uses minimal amounts of virgin raw materials.

• Waste and Recycling: Green chemistry is sustainable in terms of wastes since it minimizes or even completely eliminates the production of wastes.

GAC stands for green analytical chemistry.

It's interesting to see how the particular GC concepts related to the analytical discipline have evolved from the basic ones. These are the "milestones" of GAC, denoted by the abbreviation "SIGNIFICANCE" and enclosed. The following is a summary of the 12 GAC principles as described by Gałuszka and colleagues:

- It is best to use direct analytical methods to prevent sample treatment.
- Reduction of reagent usage and energy savings through integration of analytical operations and processes
- Large-scale analytical waste generation should be prevented, and appropriate analytical waste management should be offered.
- The objectives are a minimum sample size and a minimum number of samples.
- Miniaturized and automated techniques ought to be chosen.
- It is best to use agents derived from renewable sources.
- The operator's safety needs to be improved.
- In situ measurements should be performed.
- It is best to avoid derivatives.
- Energy use ought to be kept to a minimum.

- Methods that use more than one analyte or parameter at once are preferable over those that use just one.
- Reagents that are toxic ought to be changed or removed[4].

Preparing green samples (GSP)

As demonstrated before, the "funnel effect," which is frequently noticed in many scientific fields, has resulted in the development and consolidation of GC and its tenets, in addition to GAC, which was created especially for the analytical field, and the "bottleneck" that is represented by GSP. The latter takes into account and derives from both GC and GAC, but it implements and articulates its concepts in a very particular and comprehensive manner with regard to the methods used in sampling and sample preparation[5]. The following could be used to express the ten GSP guiding principles[6]:

- Prefer in situ processing of samples
- Make use of safer reagents and solvents.
- Aim for reusable, renewable, and sustainable materials.
- Cut down on waste.
- Reduce the quantity of materials, chemicals, and samples.
- Boost the throughput of samples.
- Encourage automation and integrate steps.
- Reduce how much energy you use.
- Select the configuration for post-sample preparation for analysis that is the greenest feasible.
- Make sure the operator follows safe procedures.

Green Chemistry's Past

Green chemistry gained popularity in the US after the Pollution Prevention Act was passed in 1990, which aimed to protect the environment by reducing harmful emissions from the same source. The US government funded organizations and colleges to produce chemical products in compliance with the law, hoping to reduce the risks connected with these compounds. The objectives of the grants granted now include the production of chemicals that neutralize harmful substances, reduce pollution, and offer alternatives to chemicals whose extraction processes hurt the environment [7]. Green chemistry aims to reduce chemical industrial pollution and prevent it from ever occurring in the first place. This is significant for the plastics, petroleum, pharmaceutical, and pharmaceutical industries. Green chemistry is about making chemistry an integrated science. The field of green chemistry sprang from a range of pre-existing research concepts and initiatives (including catalysis and maize economics) during the years preceding the 1990s, when awareness of the issues around resource depletion and chemical pollution increased [8]. A change in approaches to resolving environmental issues is connected to the emergence of green chemistry in Europe and the US: the shift from command and control regulation and pipeline-level industrial emission reduction to efficient pollution prevention achieved by creative production technology design. The collection of ideas that came to be known as "green chemistry" in the mid-to-late 1990s has finally been acknowledged, and the phrase has become more widely used (eclipsing rival terms like "clean" and "sustainable chemistry)[9]. With funding, professional coordination, and pollution prevention programmers, the US Environmental Protection Agency has been a major force in advancing green chemistry in the US. Researchers from the University of York helped found the Green Chemistry Network inside the Royal

Society of Chemistry at that time, and the Journal of Green Chemistry was also launched in the UK [10].

The Fundamentals of Green Chemistry

Green chemistry is a novel approach to the synthesis, processing, and use of chemicals with the goal of minimizing risks to human health and the environment. This novel strategy is also referred as as[11]:

▪ harmless chemicals for the environment

▪ pure chemical

▪ Atomic economy

▪ By design, benign chemical

The design of chemical products and processes that minimise or completely do away with the use and production of hazardous materials is known as "green chemistry," or environmentally benign chemistry. The necessity to counteract the harmful effects that poisonous substances have on the body led to the development of green chemistry. Water is the medium used in this relatively new branch of chemistry for in-lab chemical reactions[12]. Solvent is the term for the medium in which chemical reactions are often conducted. Reactions that occur in the gas phase, where a medium is not required, are an exception. Chemical reactions can occasionally be carried out neatly. Namely, the reactive chemicals are combined and reacted together with the need for a solvent[13]. This is one of the techniques used in "green chemistry" to prevent pollution and the volatile solvent's potentially harmful effects. Green chemistry is a chemical philosophy that aims to reduce waste and make use of renewable resources in the fields of organic, inorganic, biochemistry, analytical, and physical chemistry[14].

Principles of Green Chemistry

The 12 principles of green chemistry proposed by Paul Anastas and John C. Warner serve as the foundation for green chemistry and aid in achieving the following fundamental goals [15]:

a) To create and develop such procedures that optimize the conversion of raw materials into products in order to achieve the highest possible product yield.

b) whenever feasible, to put into practice the use of environmentally friendly or naturally derived compounds, including solvents.

c) Creating processes that are energy-efficient.

d) Waste material should be disposed of so as to prevent it from producing in a reaction, or if that is not possible, it should be managed so as to prevent environmental damage[16].

Green chemistry's twelve guiding principles are

1. Waste Management

Preventing waste is preferable to managing it once it has been generated [17].

2. Atomic efficiency

The goal of engineered planning must be to improve every material used in the process of creating the product [18].

3. Application of reagents that are not harmful

This includes using manufactured methods and reagents to reduce the risk and produce environmentally friendly products that don't negatively impact people or the environment [19].

4. Safer Chemicals Scheming

Chemicals and reagents should accomplish their coveted ability while limiting their harmfulness.

5. Better Auxiliaries and Solvents

Commonly used toxic and unstable solvents in unions include alcohol, benzene (which is known to cause cancer), CCl_4, $CHCl_3$, perchloroethylene, and CH_2Cl_2. More secure green solvents have now taken their place.

6. Create with Energy Efficiency in Mind

The energy requirements of synthetic processes should be considered in light of their financial and environmental implications and kept to a minimum.

7. Utilizing Renewable Feedstocks

Although they must be practically and financially feasible, sustainable raw materials and feedstock are preferred. With reference to the situation where exhausted feedstock consists of crude supplies collected from non-renewable energy sources (coal, oil, and gaseous fuel), and sustainable feedstock consists of agricultural products.

8. truncated combinations

If at all possible, unnecessary derivatization should be kept to a minimum or handled in a strategic area. These actions call for extra reagents and may result in waste.

9. Using catalytic reagents rather than stoichiometric ones

Accelerants are used in little amounts and can often finish a single reaction; they are preferred over stoichiometric reagents, which are used in large amounts and labour. This will increase the reagent's selectivity, lower its temperature of change, reduce the amount of waste it produces, and maybe prevent unfavorable side effects, leading to a clean invention.

10. Create for horrible circumstances

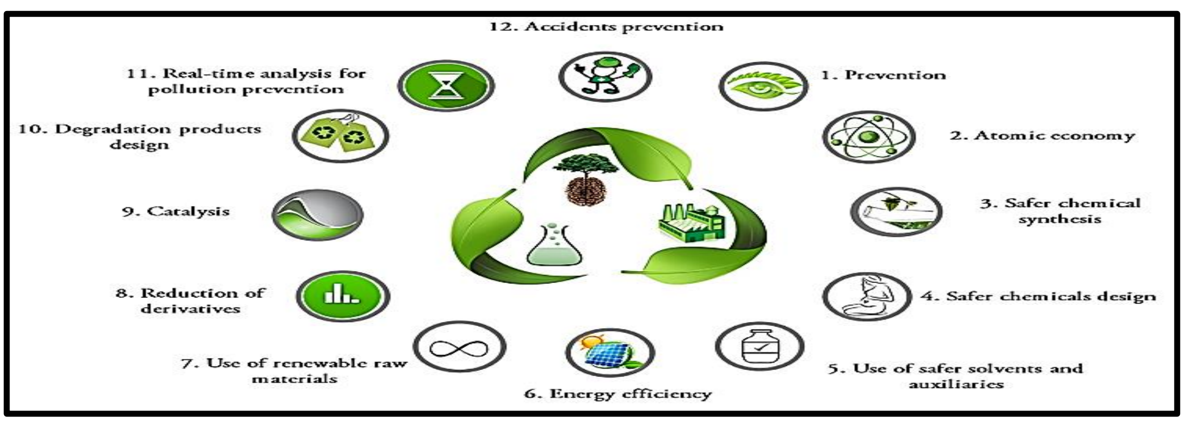
When compound objects reach the end of their useful life, they should be designed to break down into innocuous corruption items rather than persisting in their natural state.

11. Methods for reducing pollution

It is necessary to create several ways for the real-time, in-process monitoring and control of hazardous material generation.

12 . Using Safer Processes and Chemicals

When using substances in a chemical process, care should be taken to select them in a way that reduces the possibility of releases, explosions, and fires.



Green Chemistry Objectives[20]

• Encouraging the creation of novel chemicals for industrial use that pose fewer risks to the environment and health of people.

• Make effective use of energy and material resources.
• Diminishing hazards and perils.
• Stop molecular contamination from occurring.

• Reducing or doing away with the usage of or production of ecologically hazardous materials.

• Managing garbage in a way that is more environmentally friendly.

Green chemistry in daily existence

Green Dry Cleaning of Clothes: A common solvent for dry cleaning is perchloroethylene, or PERC. We now know that PERC is a possible carcinogen that contaminates ground water. Micell technology, created by Joseph De Simons, Timothy Romark, and James McClain, replaced PERC by using liquid CO_2 and a surfactant for dry cleaning garments. This method has now being used to develop dry cleaning machines. Additionally, Micell Technology has developed a metal cleaning solution that does not require halogenated solvents by using CO_2 and a surfactant [21].

The use of green chemistry in the production of chemicals and medications

To create an environmentally favorable Synthesis using microwaves: Organic synthesis has been transformed by microwave aided methods. It is possible to construct small molecules in a fraction of the time needed for traditional thermal procedures. Consequently, this methodology has swiftly acquired recognition as an advantageous instrument for expediting the procedures involved in drug discovery and development. At the lower end of the electromagnetic spectrum, microwaves are described as electromagnetic energy with frequencies between 300 and 300,000 Megahertz, or wavelengths between 1 cm and 1 mL.

The electromagnetic spectrum's microwave area is located between radio and infrared frequencies. Chemists once believed that chemicals could only react when they were dissolved or in a liquid condition. As a result, solvents are now widely utilized in chemical synthesis; however, many of the chemicals used in these reactions have been shown to be environmentally harmful. Reactions carried out without a solvent under microwave irradiation (MWI) have solved the solvent waste disposal issue[22]. Clean chemical processes with improved reaction speeds, higher yields, greater selectivity, and easier manipulation are produced when mineral-supported catalyzed reactions are combined with MWI in solvent-free environments[23].

Utilizations in Analytical Chemistry:

In the food, polymers, pharmaceutical, and petroleum and fuels industries, microwave heating is widely used for aching. In the majority of these sectors, aching is done in microwave-powered muffle furnaces designed especially for use in laboratories[24].

Green chemistry's industrial uses

The global economy has grown astronomically throughout the 20th century, and the industrialized world's quality of living has continued to rise. There is an urgent need to cut back on energy use and trash creation due to the world's natural resources becoming depleted and the economy becoming more competitive. One of the key forces behind innovation in the technical sectors is sustainability, which enables them to contribute to customer well-being in a safe and healthy environment. The most appealing idea for attaining sustainability is "Green Chemistry," a phrase that Anastas and Warner created at the US Environmental Protection Agency[25]. Green chemistry is not a scientific curiosity; rather, its main goal is to build a sustainable future. Businesses are able to commercialise these concepts thanks to the growing number of green approaches that academic and corporate researchers have created. Through the adoption of green chemistry concepts, industry, ranging from small firms to huge multinationals, has already taken strategic moves towards sustainability. The creation of less dangerous commercial products and processes, the transition from ineffective chemical pathways to bio-based synthesis, and the substitution of renewable starting materials for oil-based feed stocks are just a few examples of the significant choices made that will ultimately have a significant impact on the global chemical markets [26]. By using green chemistry principles, the US drug sector reduced its use of volatile organic compounds (VOCs) by 50% between 2004 and 2013, according to an analysis by the Environmental Protection Agency. According to the EPA's Toxics Release Inventory (TRI), throughout the same period, the quantity of chemical waste released into the air, land, and water dropped by 7% [27].

Use of Catalyst with Solvent

Up to now, a wide range of methods have been developed to help establish the fundamental cornerstones of green chemistry. A few of these methods are included here [28]:

1) As of right now, it is regarded as one of the most crucial aspects of green chemistry. Using "green catalyst" is primarily motivated by the fact that it

functions similarly to nature, since all natural synthesis is the result of enzyme-catalyzed reactions. This aids in the creation of a highly stereospecific, stereoselective, and enantioselective product and causes these reactions to occur in natural environments. Among the catalysts that are frequently employed in green chemistry are Pd and CeO_2. N-hydroxyphthalimide (NHPI), Ru-salen complexes, nickel(II) complexes, and others are some of the catalysts that have been utilized recently in green chemistry [29].

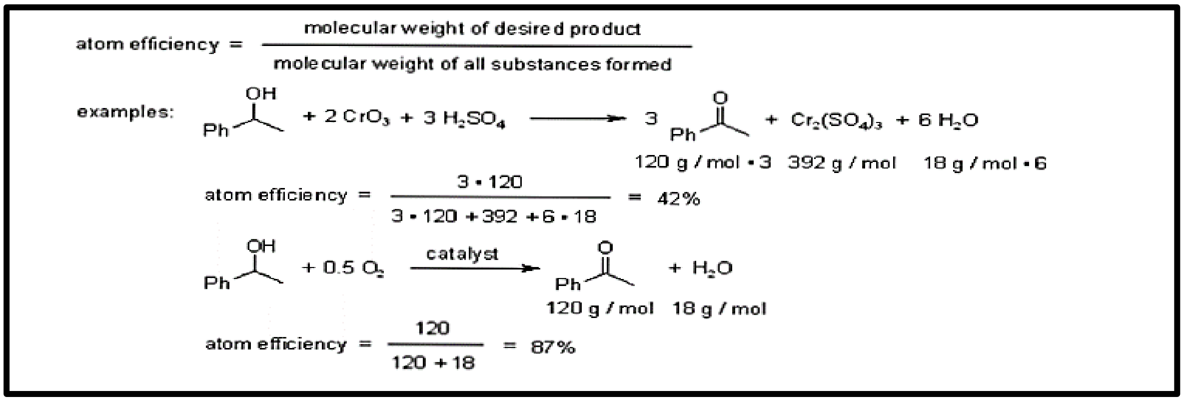
2) Typically, organic synthesis uses solvents like carbon tetra chloride, DMC, and chloroform, which are not only expensive but also extremely dangerous for the people handling them. The worst solvent among them is carbon tetrachloride because of how damaging it is to the environment. Using water as a solvent has been one attempt in "green chemistry" to reduce or eliminate these impacts. In addition to supercritical carbon dioxide, which is produced by raising the gas's temperature and pressure over its critical values while keeping it below the pressure needed to condense into a solid. In this instance, the Tc of CO_2 is 304.10 K, and the Pc is 72.8 atm [30]. Additional supercritical fluids utilized in green chemistry include water, xenon, ethane, and ethene. Although these super critical fluids (SCFs) have the disadvantage of being too less polar to continue organometallic catalyzed processes, they perform significantly better than conventional solvents [31].

Precursor material use

There has been a concerted effort to reduce the amount of petroleum-based goods used as the starting material for various chemicals that are needed annually in tonnes, as they currently make up 95% of the cases[32]. Because of this, switching to biomass is urgently needed to meet this enormous demand. Scientists are now developing novel methods for turning biomass into raw materials, which has proven to be rather successful in some cases. For example, utilising certain enzymes to convert D-glucose to lactic acid enables us to produce aliphatic chemicals from lactic acid. Similar to this, E. Coli transforms D-glucose into catechol, which serves as an intermediate for aromatic molecules [33]. However, isomaltulose, which is abundant in biomass, can be transformed into glucosylmethyl furfural, which can be utilised to make a variety of heterocyclic chemicals. In addition to biomass, cash crops offer new hope because sugarcane ethanol has been successfully extracted, and scientists are currently attempting to harness this "bio alcohol" as a potential fuel source in the future. Corn plant exhaust has been effectively used to make biodegradable plastic [34].

Atomic synthesis

The percentage yield of the intended product is the main factor to consider in a chemical process. When a chemical process yields an acceptable result, we are rarely concerned about the generation of byproducts. By creating these catalysed reactions, whose catalyst can be removed and used again for subsequent reactions, an effort has been made to further maximise the yield of the intended products[35]. The atom efficiency of these processes is further increased by focusing them to proceed through addition reactions, rearrangements, or pericyclic reactions, which yield a single product. The molecular weight of the intended product divided by the molecular weight of all substances generated yields the atom efficiency. The example that follows helps to clarify this[36].



It is advisable to design reactions that prevent the production of racemic mixtures when the intended product is a chiral chemical. Therefore, these kinds of synthesis ought to be extremely stereo-specific or stereo-selective at all times[37].

The impact of carbon emissions

The fact that companies use nearly one-seventh of all energy production which includes electricity, coal, wood, petroleum and its byproducts, and other energy to produce chemicals is concerning. which not only accounts for a significant portion of energy use but also contributes significantly to environmental risks like global warming[38]. This is one area where lowering carbon footprint can be greatly aided by green chemistry. The energy requirements of companies can be reduced by half or more by optimising chemical conversion efficiency and lowering reaction activation energy through the use of reusable catalysts. removing the need for energy-intensive processes such ultra filtration, crystallisation, sublimation, distillation, etc. By using ultrasonic energy for specific reactions as well as microwave energy, which seeks to reach high temperatures much more quickly, can ultimately resolve this issue [39].

In addition to the "pillars of green chemistry" listed above, the following other ideas can also be included as the foundation of green chemistry [40]:

a) Use of "light" as an electron carrier has the potential to eliminate the need for other chemical agents, which are produced as waste products at the end of a redox process and function as electron carriers.

b) removing the needless application of protection-deprotection techniques.

c) Mesoporous solids with bound sulphonates are substituted for soluble Lewis acids in green synthesis.

d) Using kinder reaction conditions when conducting a chemical reaction.

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