GREEN CHEMISTRY AND ENVIRONMENTAL SUSTAINABILITY: RECENT AND FUTURE PERSPECTIVES IN PHARMACEUTICALS AND AGRICULTURE

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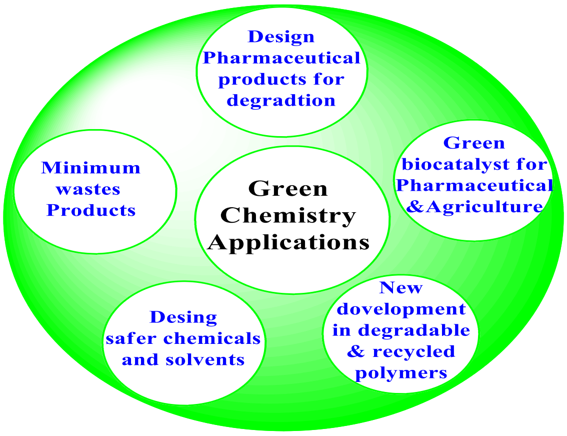
Graphical Abstract



Abstract

The Chemistry Society is now working on developing novel chemistry that is less hazardous to the environment and human health. Green chemistry, ecologically friendly chemistry, clean chemistry, and atom economy are some of the terms used to describe this innovative approach. There has been progress toward practicing chemistry using facts that go beyond the qualities of the target chemical or the efficacy of certain solvents or reagents. Green chemistry is the practice of chemistry in such a manner that it optimizes its advantages while minimizing its negative impacts. It focuses on ways for reducing the usage of dangerous items or by-products, as well as their creation. Several chemical industries are now the most polluting to the environment. As a result, efforts have been made to create and develop synthetic ways for manufacturing procedures that produce the fewest waste products, have no impact on the environment, and are easy to dispose of. Some pharmaceuticals create a large quantity of waste or by-products during their manufacture in the pharmaceutical industry, resulting in a low yield in the final goods. The reactant or starting materials, reagents, solvents, and catalysts must all be carefully chosen while executing chemical reactions. Green chemistry is crucial in pharmaceutical chemistry for the development of new medications that are less toxic, more effective, and have fewer adverse effects. In today's agriculture, green chemistry has become the new norm. Sustainable agriculture and green chemistry are two cutting-edge topics that are inextricably linked. At this time, the utilization of renewable biomass resources is increasing in agriculture to generate bio-based food products with low inputs, zero waste, significant social value, and reduced environmental effects. The purpose of this paper is to analyze and clarify the notion of green chemistry, as well as its implications for environmental sustainability.

Keywords: Green and clean chemistry, agriculture, environmental sustainability, atom economy, chemical hazards.

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1. Introduction

Green chemistry (GC) or sustainable chemistry (SC) is a method of creating chemical products that avoid the usage and production of toxic substances. The branch of chemistry that maximizes profit while minimizing negative consequences is known as GC or SC. There should be three green portions in the "green" reaction: solvent, reagent/catalyst, and energy expenditure. As a new discipline of chemistry with environmental improvements, it entails minimizing harmful intermediates and products and eliminating the usage of hazardous chemicals in chemical synthesis procedures. Finally, GC is a method of risk reduction and pollution control that focuses on the underlying risks of chemicals rather than the contexts and conditions in which they are used that may increase their risk. Because benzene is carcinogenic, it must be avoided as a solvent. If at all feasible, carry out reactions in the aqueous phase. Synthesis procedures should be devised such that the greatest amount of starting materials are used in the end products and no harmful by-products or wastes are produced. The GC is built on twelve principles that may be utilized to build or reform goods, reactions, and procedures that are safer for persons as well as the environment [1-3]. GC procedures have been developed in all fields of chemistry, including organic, biological, inorganic, physical, toxicological, polymeric, and environmental chemistry, among others. GC is a chemist's pledge to protect natural resources and the environment, and it examines the methodologies and materials utilized in information and development from an economic standpoint. When no hazardous materials are utilized or generated, the danger is nil, and there is no need to worry about harmful chemicals being removed from the environment. Reduced raw materials, waste, hazards, energy, environmental effect, and expense are all part of GC [3-6]. Sustainability and environmental concerns are quickly becoming the most essential subjects in product development and manufacturing [7]. Green chemistry executions are just a few of the efforts that may be made to enhance the environment's quality. Future issues in resource, economic, environmental, and societal sustainability will necessitate more competent and methodical chemical procedures and manufacturing technologies. Greener chemicals that are inherently, ecologically, and environmentally friendly have been formed using GC, which has overcome these challenges by opening up a diverse scope to maximize preferred substances and reduce by-product equipment used in the formation of greener chemicals that are inherently, ecologically, and environmentally friendly [8]. The goal of GC research has been to decrease or eliminate the use or production of hazardous compounds that are harmful to the environment and human health. The GC also aspires to replace nonrenewable raw materials with renewable ones to reduce the risks to human health and the environment [9].

Basic Principles of Green Chemistry

The concepts of green chemistry (GC) focus on reducing or eliminating toxic chemicals from chemical production and application. As a result, the usage of harmful compounds has been reduced or eliminated, which has a positive impact on human health and the environment. It is impractical to convene the necessity of all method principles at the same time when designing a GC process, but efforts to apply various principles at different stages of synthesis are just as promising [10-14].

- Prevention of waste or by-products
- Use of biotechnology alternatives
- Designing safer chemicals
- Design of degradation
- Least energy necessity for any synthesis
- Use of innovative techniques to recognize industrial methods.
- Prevention or minimization of toxic substances.
- Most incorporation of the reactants and reagents into the final products.
- Whenever possible, evade the use of the protecting group.
- Needless derivatization should be evaded whenever achievable.
- Select the most appropriate solvents, reagents, and catalysts.
- The environmental and economic implications of energy needs should be acknowledged and reduced.
- Chemical substances should be designed to break down into harmless degradation chemicals and not linger in the environment.
- Analytical procedures need to be developed to permit real-time procedures examining and controlling previous the development of toxic compounds.

- Raw materials should be renewable rather than depleting, whenever scientifically and cost-effectively feasible.
- Design manufacturing units to eliminate the chance of accidents during processes escalation of analytical practices to control toxic compounds.
- Whenever feasible, synthetic procedures should be designed to use and form a compound that causes little or no harm to human health and the environment.
- Chemical compounds should be designed to save the effectiveness of utility while decreasing toxicity.
- Substances used in chemical methods should be chosen to decrease the potential for chemical accidents, explosions, and fires.

Pharmaceutical Green Chemistry

Pharmaceutical firms are the most active players in the chemical industry. It is at the forefront of major shifts toward "greener" feedstock, safer solvents, alternative processes, and innovative concepts. All of these changes will improve pharmaceutical businesses' environmental credentials while also reducing expenses and chemicals used in manufacturing processes, putting them on the path to sustainability [15-18]. The use of GC principles in the pharmaceutical industry may be seen as a duty as well as a significant opportunity to increase our positive influence on the global population. Pharmaceutical chemists work with drug companies to create pharmaceuticals and therapies with fewer negative side effects by employing processes that produce less hazardous waste or by-products. The chemical innovation of pharmaceuticals for economic usage differs significantly from traditional bulk chemical manufacture. Manufacturing advancements have a lot of potential. To promote medication research, several businesses bring together environmental specialists, pharmaceutical and medicinal chemists, and chemical engineers. For years, the pharmaceutical firm has accepted a growing number of "green" approaches and activities. Various advancements in innovative methodologies, enhanced bio-catalysis reactions, fewer solvents, and fewer waste products were produced by the research divisions of numerous large pharma firms in industrialized nations. Researchers discovered that pharmaceutical businesses have been interpreting green concepts with significant goals for environmental research, process, and production for some years. Drug companies have implemented precise safety and health systems to safeguard their employees as well as environmental guidelines for their goods. The four pillars of modifying are safety, effectiveness, consistency, and economy, and their support is assessed as a competitive advantage, enhanced environmental credentials, and economic profit.

Green Synthesis

Green synthesis (GS) is a phrase used to describe the process of synthesizing goods that do not affect the environment at any point during the process [19]. The GS has been demonstrated to be a crucial concept for reducing industrial waste and pollution. Avoiding waste may provide inexpensive advantages and competitive outcomes, and GS attempts to enable the effective use of wealth while also improving ecological performance [20]. Green technology is defined as the use of one or more environmental, GC, environmental assessing, and electrical instruments to study, model, and preserve the natural environment and resources, to minimize the negative effects of human concerns [21]. In the narrow meaning, GS is linked with the synthesis of green goods, such as those employed in the energy system, renewables, and clean skills of equipment; in the wider sense, it refers to the greening of synthesis with the reduction of waste and conservation of resources. External variables including policy climate, business awareness, and stakeholder performance might impact the application of GS practices in the synthesis process. The use of GS in a company has economic, social, and environmental implications [22]. Environmental synthesis methods such as reducing raw material usage, reusing solid wastes, and repurposing components can help make it more environmentally sustainable [23]. The term GS refers to a study that reflects a new synthesis pattern that employs various green strategies or techniques to make products or systems that use less substance and energy, replace input materials (non-toxic to toxic, renewable to non-renewable), reduce unnecessary production, and change the output to input or recycling [24]. The GS can shorten the product life cycle, which lowers synthesis costs. Because of its environmental duties, the firm aspires to reuse, replicate, and recycle discarded items to reduce the negative impact on the environment, particularly among manufacturers of electric consumer products. As a result, the reverse synthesis problem, which affects all stages of product development, is a serious issue for the computer and power industries at all levels. To know the worth of linked elements in the policy and to locate the control of cost goods in semi-green supply chains, the best possible inventory system was designed [25].

Green Chemistry and Environmental Sustainability

Green chemistry (GC) is a strategy for combating environmental issues including chemicals, methodologies, and reaction stages. This concept outlines a method for reducing harmful chemical usage and synthesis in design and procedures [26]. Chemical risk is part of the GC concept and comprises a variety of dangers to human health and the environment, as well as physical hazards such as toxicity, natural resource exhaustion, and global climate change [27]. The goal of the GC is to investigate the use of various chemical principles in the design or synthesis of chemicals to reduce the usage or production of harmful molecules that can harm human health while also conserving the environment [28]. The GC is an important component of a comprehensive approach to protecting human health and the environment. The GC is associated with issues such as waste reduction at the source, the use of catalysts, safe reagents, greater economic efficiency, the use of renewable resources, and solvents that are both safe and recyclable [29]. The goal of the GC is to enhance the industry's environmental and employee health [30]. Environmental and disaster occurrences sparked the concept of sustainability, which was concerned with pollution from chemical and resource exhaustion. The triple-bottom-line notion of three areas – social, economic, and environmental – has been used to promote sustainability. This idea emphasizes the need of ensuring the addition and balance of the economy, society, and environment to achieve progress [31]. The use of natural resources and the human cycle should not result in a reduction in the value of life, and environmental inequality should be reduced [32]. Sustainability is the design of human and industrial systems that ensures that the use of natural resources and the human cycle does not result in a reduction in the value of life and reduces environmental inequality. Lowering solid/liquid waste, emissions, resources, and consumption of dangerous materials, reducing the occurrence of environmental mishaps, and enhancing human health are all examples of environmental sustainability [33]. Sustainable progress was defined as growth that meets current demands without jeopardizing the ability to satisfy the needs of future generations. There are two fundamental concepts: I the concept of "needs" to sustain human existence, and (ii) the concept of "limits" deriving from the technological and social association conditions of the environment's capacity to satisfy present and future demands [34]. The environmental advantages of GC are notable; GS execution has a significant positive influence on the environment. Acceptance of GS can lead to reduced waste, less resource and energy use, and less pollution. Assessing GS processes and products, such as identifying probable sources of contamination or pollution, is critical. These pollutants, such as greenhouse effects, toxic emissions from drug manufacturing, and waste disposal, pose a threat to the environment in the future [35]. Designing for sustainability in the chemical industry entails more than the continuous development of green chemical processes, process escalation, and process redesign, as well as extensive research and development initiatives at all levels of chemistry. The main goal of ecological techniques has been widely recognized as sustainability [36].

Pharmaceutical Applications

Using the knowledge linked with green chemistry, pharmaceutical businesses may improve their environmental performance (GC). The GC is working on creating new medication release mechanisms that are less toxic and more effective, with the potential to treat millions of people [37-55],

Examples: -

1. Phosphoramidite; solid-phase, which is a mixture of antisense oligonucleotides, has been modified to conform to GC principles by eliminating the use and generation of hazardous materials and recycling primary materials such as protective group amenities and solid support, thereby improving cost-efficiency and atom economy.
2. The synthesis of Naproxen with a chiral metal catalyst containing 2,2'-bis[diphenylphosphino]-1,1'-binaphthyl ligand with an excellent quantity of products.
3. Water and other green solvents may be used to replace a variety of hazardous solvents in a variety of chemical processes, including the production of benzothiazoles and benzothiazoline. Glycerol, on the other hand, has been identified as a key green solvent. Glycerol has the potential to combine the benefits of water with low toxicity, cheap cost, high accessibility, and renewability. Because of its strong polarity, glycerol may be used to reduce a variety of carbonyl compounds using sodium borohydride.
4. Supercritical carbon dioxide ($ScCO_2$) is a main commercial and industrial solvent due to its role in chemical extraction in addition to its low toxicity and ecological impact. The $ScCO_2$ is a fluid state of CO_2 where it is detained at or above its critical temperature (31.10 ^{0}C) and critical pressure (72.9 atm) increasing to fill its container like a gas but with a density like that of liquid. The $ScCO_2$ works correspondingly with other challenging chemicals without toxic effects with the advantage of water. The hydrogenation, epoxidation, radical reactions, palladium-mediated C-C bond development, ring-closing metathesis, polymerization, and various other reactions can be performed with $ScCO_2$ as a reaction medium. The use of $ScCO_2$ to form micro- and nanoscale particles for pharmaceutical uses.

5. Water and other green solvents can be used to replace a variety of hazardous solvents in organic processes, such as the production of benzothiazoles and benzothiazoline. In contrast, glycerol has been identified as a significant green solvent. Glycerol may combine the advantages of water with low toxicity, cheap cost, widespread accessibility, and renewability. Glycerol's strong polarity makes it possible to use sodium borohydride to reduce a variety of carbonyl compounds.

6. In the synthesis of anthraquinone by the dyestuffs company aluminIum chloride ($AlCl_3$) is the key catalyst in the initial step, acylation of benzene. It is a Friedel-craft type reaction in which the used catalyst is useless along with the waste. A fresh catalyst is required for the subsequent batch of reactants. The $AlCl_3$ complexes strongly bind to the products, i.e. Cl^- forming [$AlCl^-$] and cannot be cheaply recycled, resulting in large amounts of corrosive waste. A new catalyst with superior ecological credentials is now being tried out. Compounds such as the highly acidic triflate (trifluoromethane sulfonate), and dysprosium (iii) offer the option of breaking away from the sacrificial catalyst by permitting the catalyst to be recycled.

7. Pharmaceutical company discovers and produces drugs for use as medicines. The pharmaceutical company is measured now as the most dynamic sector of the chemical company. Anti-inflammatory and analgesic drugs are produced in high amounts every year. Some important medicines are aspirin (acetylsalicylic acid), acetaminophen (Paracetamol), and Ibuprofen.

In three processes, paracetamol was made from phenol. The solvent from step two was maintained in the synthesis pathway to aid minimize atom economy. To make 4-nitrophenol, the initial step included electrophilic aromatic replacement of phenol with nitric acid. In the second stage, an iron (catalyst) was hydrogenated to form p-aminophenol. Finally, the aminophenol was acylated to produce paracetamol. This process incorporates a green stage as well as little chemical waste. Ibuprofen is a nonsteroidal anti-inflammatory drug (NSAID). This six-step synthesis produces 60% of undesirable waste or by-products, which must be disposed of or handled. Several of the wastes are generated and end up as undesirable by-products rather than the intended ibuprofen.

1. Paclitaxel, a chemotherapy medication, is another treatment that produces less waste (Taxol). It was first created by extracting compounds from yew tree bark, which required a lot of solvents and killed the tree. Tree cells are now grown in a fermentation vat to produce the medication.

2. The GC is used in the manufacturing of a key intermediate of atorvastatin and the procedures occur in two steps: -

A. In the first step, biocatalytic reduction of ethyl-4-chloro-3-oxobutanoate occurs with a mixture of keto-reductase and glucose for regeneration of the useful compound which is vital for the activity of the enzyme forming a compound ethyl-4-chloro-3-hydroxybutyrate with high yield.

B. In the next step, a halohydrinde halogenase is used to hasten the substitution of chloro to cyano groups, and this reaction occurs at neutral pH and atmospheric temperatures in the presence of a catalyst.

C. For a major part of medicinal compounds, created clean, rapid, and affordable procedures for amine synthesis. Industry produces amines in a two-step process at a high cost, resulting in a large volume of by-products. In the presence of a catalyst, however, the ideas of GC do not produce any waste products, and the reaction is also a rapid one-step procedure. Steps for aspirin synthesis with microwave using catalysts like H_2SO_4, $MgBr_3.O(C_2H_5)_2$, $CaCO_3$, NaOAc, Et_3N, $AlCl_3$, and solvent-free methods have been designed.

Green chemistry and agriculture

Increased desire for more productive and industrialized economies, resulting in global and local pollution as well as non-sustainable usage of natural resources. Environmental pollution problems such as air pollution, acid rain, solid waste, deforestation and desertification, ozone layer depletion, and climate change signals were all neglected. Synthetic pesticide production is expanding, and contemporary agriculture practices emit significant greenhouse gases, such as 84 percent nitrous oxide emissions annually over the world. Contamination in agricultural fields is caused by direct or indirect exposure to pesticides used improperly, which has a negative influence on animal and human health. Pesticides are employed to manage or eliminate pests, and their presence in the food chain, as well as bioaccumulation and biomagnification, has negative consequences for animals and humans. These pesticides also contaminate groundwater, induce eutrophication in rivers, lakes, and ponds, and cause hazardous substances to transfer from the environment into the organism. Some pesticides are soluble, accumulating in fatty tissues and causing biomagnifications throughout the food chain (eg. DDT). To reduce these negative consequences, organic farming should be used more frequently in place of industrial pesticides. Agriculture's sustainability is a key area where green chemistry techniques in the agrochemical industry are needed to implement pesticide and fertilizer judicious usage [56].

Agriculture Applications [57-60]

1. Start with the selection of renewable, nontoxic feedstock.
2. Design of Safe and energy-efficient synthetic methods.
3. Most inclusion of all materials in the product, reducing auxiliaries when probable.
4. Producing durable, nontoxic products with preserved utility,
5. Make sure the natural degradability of all products and by-products at the end of life.
6. Because of their direct influence on human and environmental health, the principles of GC are particularly pertinent to the manufacture of agrochemicals. Current agricultural practices, on the other hand, are still dependent on labor-intensive production systems that employ unsustainable techniques created during the "green revolution."
7. High-yielding crop types, chemical fertilizers, insecticides, and irrigation are all used extensively in green chemistry technology. The agriculture business is unclear about food production procedures, with pesticides, insecticides, animal antibiotics, and animal hormones causing the most worry.
8. As consumers' focus shifts to ensuring a sustainable and secure food supply, the agrichemical industry will require a second "green revolution," leveraging green chemistry to deliver agricultural-related products.
9. Biopesticides are scalable and environmentally friendly, with clear implications for long-term agriculture and large-scale production. Transaminases, oxidases, reductases, hydrolases, and other enzymes were employed in novel ways to prepare biocatalysis. Biocatalysts made from new enzymes provide cost-effective benefits in the pharmaceutical and agricultural industries.
10. At the moment, the firm emphasizes the use of green solvents instead of conventional solvents for chemical and environmental worker safety. The correct solvents have consistently boosted the environment's advantages, as well as the user's safety and responsiveness. At this moment, catalyst-free reactions and catalyst-free reactions in water and water are being replaced by laboratory synthesis and manufacture in the industry.
11. Ionic liquids have recently replaced organic solvents with significant volatility and intrinsic toxicity. Ionic liquids are organic salts that dissolve nonpolar and polar organic-inorganic solvents and have a low melting point, good thermal stability and are practically non-volatile under normal circumstances. Ionic liquids are sometimes characterized as "designer solvents" for similar reasons. Renewable energy sources such as solar, hydropower, wind, biomass, bio-refinery, geothermal, and ocean energy are critical resources for future sustainable advancement since they will replace carbon-based energy sources and reduce global warming emissions.
12. Pesticide poisoning has recently resulted in several farmer deaths. There is a list of very toxic pesticides that are still used in India even though they have been prohibited in many other nations. Monocrotophos and Oxydemeton-methyl are classified as Class-I pesticides by the World Health Organization, and even a little amount can be lethal. Pesticide poisoning kills at least 10,000 people in India each year, according to an official estimate.
13. Some of the chemicals still commonly used in agriculture have been linked to negative environmental and human health effects. Concerns are developing regarding how we farm for sustainable agriculture, what inputs we should use, and what technology we should utilize. Green chemistry will help agriculture flourish sustainably.

Future Perspectives of Green Chemistry

In numerous study disciplines, the future perspectives of green chemistry (GC) will be examined more thoroughly. Manufactured commodities and the environment should be evaluated jointly, with the understanding that the world needs a natural equilibrium. Any attempt to disrupt this balance will result in more severe consequences. As a result, we require greener techniques and ideas. Future GC Trends, which include oxidation, reagent, and catalysis, in hazardous issues such as heavy metals, have a substantial detrimental impact on human health and the environment, which may be mitigated with the use of safe compounds. Noncovalent derivatization, biometric multifunctional reagents, and supramolecular chemistry are all being researched to generate solid-state processes that do not require the use of solvents. Combinatorial GC is the chemistry of being capable to produce various chemical compounds rapidly on a small scale using reaction matrices, an increase of solvent-free reactions helps in the progress of product isolation, separation, and refining that will be less solvent and to maximize the benefits.

- Green nanochemistry
- Supramolecular chemistry
- Oxidation reagents and catalysts
- Biometric multifunctional reagents
- Combinatorial green chemistry
- Non-covalent derivatization method

GC is a trend in the pharmaceutical business to develop safer chemicals and methods. It helped the CS achieve sustainability by reducing the detrimental effects of chemicals on human health and the environment. The aim of chemists to create useful and low-cost products broadens the scope of GC.

- Source reduction
- Base metal catalysis
- Solar cells
- Waste prevention
- Include Sustainability early in the design process
- To generate an industrial procedure that prevents hazard problems
- Development of eco-friendly chemicals and materials
- Use of environmentally benign solvent systems
- Generating wealth from waste
- Minimization of hazardous products
- Analysis of the eco-toxicological and environmental effects of biomass processing.

2. Discussion

Green synthesis (GS) and green chemistry (GC) have a role in enhancing environmental quality, according to the literature assessment. The goal of both GS and GC is to limit the use of harmful chemicals that harm the environment and human health. In addition to benefiting the environment, the adoption of GS and GC is also beneficial to the bottom line. It is likely in the calculation of economic gains generated by the use of GC in industrial processes, such as the requirement for waste storage, management, and compensation payments for environmental harm. Improvement, achievement, and success are meaningless without constant development and advancement. GC is made for substances and procedures that are less hazardous. It helps to lessen the harmful impact of chemicals on the environment and to achieve chemical synthesis sustainability. The aim of chemists to create useful and inexpensive products broadened the scope of GC. GC produces not just environmental benefits, but also economic and social benefits. The "triple bottom line," which combines these three earnings, provides significant backing for expanding sustainable materials and practices. The GC is not a panacea for all environmental issues; rather, it is a fundamental approach to avoiding pollution, as it is preferable to prevent waste than to remediate it after it has been created [61]. The GS approaches are selective and effective, and they are frequently used in conjunction with microwave and sonochemical activation techniques. Greener solvents such as ionic liquids, water, and supercritical liquids can be used to replace toxic solvents and their equivalents. Solid-phase and solvent-free synthesis are increasingly gaining popularity. Green catalyst development and application are also difficult domains. Other topics covered include enantioselective techniques, chemical synthesis from biomass and wastes, natural compound extraction, green analytical methods, green biotechnology, and sustainability issues related to environmentally friendly chemistry [62]. The alternative approach for synthesizing ibuprofen is a typical example of GC concepts, and it has the potential to impact improved synthetic methods, not just from a cost standpoint, but also from a technical and scientific standpoint. Researchers predict that GC will alter the pharmaceutical business and medication manufacture in the future. GC has the potential to provide both environmental and economic advantages, and the firm is eager to apply the majority of its principles [63,64]. Although the scientific community has recognized the concept of GC, technical GC advancement requires education and investment to attain the correct attention.

Green chemistry (GC) aims to improve farming profitability, community prosperity, and soil quality by lowering dependency and usage of nonrenewable resources, such as synthetic fertilizers and pesticides, while also minimizing negative impacts on water quality, wildlife, and security. Organic farming, natural farming, biological agriculture, ecological agriculture, and biodynamic agriculture are all alternatives to chemical farming. Bio-pesticides can be used in agriculture to manage pests, insects, and weeds, as well as to improve plant physiology and production. These bio-pesticides are environmentally friendly. As a result, for long-term sustainability, agricultural farming should change to green chemistry, industrialized processes, crop protection, and production, and the creation of green agrochemicals. As a result, sustainable agriculture and GC are revolutionary fields that are inextricably linked. Green chemists will need farmers to employ green technology for sustainable agriculture, as well as farmers' needs for safe and green agricultural inputs. Biocatalysts are being more widely used in the pharmaceutical, agricultural, and food sectors. These can also aid in minimizing waste and increasing product production. In the future, this will necessitate an increase in food supply to fulfill the demand. As a result, combining biochemical approaches with green strategies is critical for increasing crop output, reducing preharvest loss, and reducing postharvest loss from pest infestations. The agrochemical industries are expected to increase significantly in the future. The agrochemical industries have carried key growth in the future. The industry, regulatory bodies, government, and academia can build a joint work jointly and uses their ideas of GC practices. According to the findings, green synthesis processes can help increase environmental sustainability. It is proposed that enterprises use green synthesis technologies to carry out their industrial activities. Longer-term difficulties and potential in research, industrial uses, agriculture, and education are also discussed in this review.

3. Conclusion

Chemistry has created a plethora of helpful medication properties, and it not only produces the necessary product but also other dangerous and undesired waste. Synthesizing nonharmful goods is a difficult task for businesses. Green chemistry (GC) provides a significant platform for combating these hazardous chemicals. It provides a diverse and comprehensive study area for the creation of more capable reaction procedures to decrease waste and increase the highly desired product yield. However, GC alone will not be able to mitigate these effects. The principles of GC help to pave the way towards a greener future. Massive efforts are still being made to develop a superior technique that begins with pollution-free raw materials, produces no by-products, and does not require solvents for purification, isolation, or storage. The pharmaceutical industry has played an important role in increasing human life expectancy and quality of life, but these contributions must be achieved without harming the environment. The GC assisted the pharmaceutical industry in achieving its environmental objectives. As a result, it is the producer's responsibility to design and implement sustainable ways, such as reducing waste, increasing method effectiveness by utilizing fewer raw materials, recycling and reusing solvents, and producing cleaner, greener, and more energy-efficient methods. The GS and GC are both dedicated to reducing environmental issues. The application of GS and GC has a positive effect on the environment and human health. As a result, various firms must conduct GS and GC to carry out their trade activities. We have attempted to condense some of the most significant achievements in transitioning to greener pharmaceutical firms to enhance their performance in this study. Despite this, many difficulties and opportunities remain favorable. There are three main ways in which green chemistry and sustainable agriculture are linked. To begin, the green chemistry concept advises employing biobased resources or renewable feedstock or raw materials, such as agricultural waste items. Chemists should focus on creating bio-pesticides, bio-fertilizers, and bio-catalysts to transform agricultural inputs into high-value goods while also improving their production and safety. Second, by interacting with agriculture, green chemistry may be used in site cleanup. Farmers in traditional farming don't know how to handle a beneficial instrument, thus they leave some undesirable substances that contaminate the environment (soil, air, and water). Green catalyst is a safe way to remove particular pollutants from water, including pesticides. As a result, green chemists assist farms in addressing pollution, removing contaminants and undesired chemicals, and managing the use of reclaimed water. Finally, green chemistry produces novel green inputs for agriculture production and protection that are both sustainable and environmentally friendly.

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Conflict of interest
The author declares no conflict of interest.

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