WORLD JOURNAL OF PHARMACEUTICAL RESEARCH
Coden USA: WJPRAP Impact Factor 8.63
Volume 15, Issue 10, 162-170. Review Article ISSN 2277–7105

REVIEW PAPER ON: GREEN CHEMISTRY IN PHARMACEUTICAL INDUSTRY

[1]*Hingane Jayshri Sampat, [2]Hingane Sonali Bandu, [3]Shelke Shravani Vinayak, [4]Baravkar Tanishka Somnath, [5]Ladkat Samiksha Pandurang, [6]Navale Siddhi Sunil, [7]Ms. Anushka Hake, [8]Dr. Vikas Gadadhe

[1,2,3,4,5,6,7,8]Student of Shri Dhanaji Shelke College of Pharmacy, Wakhari, Pune.

Article Received on 14 April 2026,
Article Revised on 04 May 2026,
Article Published on 16 May 2026,

https://doi.org/10.5281/zenodo.20197396

***Corresponding Author**

Hingane Jayshri Sampat

Student of Shri Dhanaji Shelke College of Pharmacy, Wakhari, Pune.

How to cite this Article: [1]Hingane Jayshri Sampat, [2]Hingane Sonali Bandu, [3]Shelke Shravani Vinayak, [4]Baravkar Tanishka Somnath, [5]Ladkat Samiksha Pandurang, [6]Navale Siddhi Sunil, [7]Ms. Anushka Hake, [8]Dr. Vikas Gadadhe. (2026). Review Paper on: Green Chemistry In Pharmaceutical Industry. World Journal of Pharmaceutical Research, 15(10), 162–170.

ABSTRACT

Green chemistry is a cutting-edge method that focuses on creating chemical products and processes that minimize or completely do away with the production and use of dangerous materials. It is essential for advancing resource efficiency, human health, and environmental sustainability. The core ideas of green chemistry, such as waste avoidance, atom economy, the use of cleaner solvents, energy efficiency, and the creation of biodegradable goods, are highlighted in this review study. Additionally, it covers the use of green chemistry in the pharmaceutical sector, including environmentally friendly drug manufacturing, the decrease of hazardous byproducts, and the utilization of raw materials that are renewable. The study also highlights how crucial green chemistry is to reducing pollutants in the environment and promoting sustainable development. The pharmaceutical industry may drastically lessen its environmental impact while preserving productivity and creativity by implementing green chemistry techniques.

KEYWORD: Green synthesis, Biocatalysis, Eco manufacturing, Less toxicity.

INTRODUCTION

What is green chemistry in pharmaceutical industry?

In the pharmaceutical industry, "green chemistry" refers to the employment of eco-friendly concepts in the development, production, and administration of pharmaceuticals. It has its roots in the more general area of "green chemistry" and focuses on reducing the negative effects of chemical processes on the environment while preserving productivity, safety, and quality. This strategy is particularly crucial in the pharmaceutical industry since the manufacturing of drugs frequently entails intricate, multi-step syntheses that might employ dangerous materials and produce a lot of waste. The well-known 12 Principles of Green Chemistry, which prioritize waste avoidance, cleaner solvents, energy efficiency, and the utilization of renewable raw materials, serve as the fundamental guidelines for green chemistry. These guidelines are intended to increase overall sustainability, decrease emissions, and minimize the use of hazardous reagents in pharmaceutical manufacture. For instance, green techniques aim to optimize reactions such that the majority of the input materials are converted into the final product, decreasing waste, whereas standard medication synthesis may require enormous quantities of organic solvents and produce considerable by-products. The high degree of purity and accuracy needed in drug production is one of the major issues facing the pharmaceutical sector. Strict regulatory requirements must be met by medications in order to guarantee their efficacy and safety, which frequently results in extra processing stages and resource consumption. In order to solve this, green chemistry promotes cutting-edge methods like catalytic reactions, which boost productivity and lower the requirement for extra chemicals. Biocatalysis, which uses enzymes to drive chemical reactions, is becoming more and more popular. It offers extremely selective processes that run in mild settings, saving energy and minimizing hazardous byproducts. In the pharmaceutical sector, green chemistry is a revolutionary strategy that strikes a balance between environmental responsibility and innovation. It minimizes ecological effect while promoting the development of high-quality medications through waste reduction, increased efficiency, and the use of safer materials.

Green chemistry in pharmaceutical industry: what is it ?

The activity of creating and producing medications utilizing sustainable and ecologically friendly chemical processes is known as "green chemistry" in the pharmaceutical sector. It originates from the field of "green chemistry," which aims to remove pollution at its source rather than after it is produced.

To put it simply, it refers to producing pharmaceuticals in a manner that uses safer chemicals and generates less trash. uses little energy and has little effect on the environment.

The 12 Principles of Green Chemistry serve as the foundation for this strategy. These guidelines motivate chemists to create procedures that minimize the use of hazardous compounds, increase productivity, and optimize raw material utilization (atom economy). Drug synthesis in the pharmaceutical business typically entails numerous intricate chemical interactions. Conventional techniques frequently produce a lot of byproducts and hazardous chemicals. This is enhanced by green chemistry via.

substituting safer solvents for hazardous ones, such as ethanol or water; increasing efficiency through the use of catalysts or enzymes (biocatalysis); decreasing the number of processes in medication manufacturing; and limiting waste and emissions In the pharmaceutical sector, "green chemistry" refers to the use of sustainable chemical principles at every stage of the process, from large-scale production to research, in order to produce medications in a safer, cleaner, and more effective manner.

Content

History and Evolution

Although the idea of "green chemistry" is relatively new, its origins can be found in the late 20th century, when people became more conscious of the risks industrial chemicals posed to the environment and human health. Prior to this, the pharmaceutical business frequently ignored environmental effects such the production of toxic waste, the use of hazardous solvents, and energy-intensive procedures in favor of improving product yield and efficacy. Growing worldwide concern over pollution and chemical safety during the 1960s and 1970s marked a significant turning point. Pharmaceutical companies and other businesses were forced to adopt safer methods as a result of incidents like the Bhopal Gas Tragedy, which brought attention to the serious risks involved in chemical manufacturing. Environmental protection regulations and regulatory agencies that started keeping an eye on industrial waste and pollutants were also introduced during this time. Paul Anastas and John Warner laid the formal groundwork for green chemistry in the 1990s. They presented the 12 Principles of Green Chemistry, which offered an organized method for creating chemical processes that are safe for the environment. These ideas pushed businesses to employ safer chemicals, reduce waste, and increase energy efficiency. Global environmental commitments and sustainability goals have sped up the development of green chemistry in pharmaceuticals in recent years. In order to stay competitive, businesses are investing in greener technologies, and regulatory bodies now promote eco-friendly production methods. The efficiency and sustainability of medication manufacture are being further improved by developments in digital tools, artificial intelligence, and process intensification. In the pharmaceutical sector today, green chemistry is a strategic requirement rather than an option. It has developed from a theoretical idea into a useful framework that directs the creation and production of contemporary drugs. Green chemistry continues to play a critical role in minimizing environmental impact while guaranteeing the manufacturing of safe and effective medications as the industry shifts toward more sustainable processes.

Principle of green chemistry in pharmaceutical industry

A scientific framework for creating chemical processes that are environmentally sustainable is provided by the concepts of green chemistry. These concepts are crucial to the pharmaceutical business since medication manufacturing frequently calls for numerous reaction steps, dangerous chemicals, and copious amounts of solvents. The methodical use of these concepts enhances productivity, safety, and cost-effectiveness while lessening the impact on the environment.

Need of Green Chemistry in Pharmaceutical Industry

The desire to lessen the effects of medicine manufacture on the environment and human health makes green chemistry crucial to the pharmaceutical business. Conventional pharmaceutical procedures can produce significant volumes of hazardous waste and use hazardous chemicals and solvents, which can pose a major risk to public health and the environment. By encouraging safer chemical reactions, effective raw material use, and the use of environmentally acceptable solvents, green chemistry helps to reduce this waste. Additionally, it promotes energy conservation by promoting reactions under moderate conditions and increases worker safety by lowering exposure to hazardous compounds. Additionally, by increasing process efficiency, it lowers total production costs and assists pharmaceutical businesses in adhering to stringent environmental requirements. Long-term industrial growth is further aided by the utilization of sustainable methods and renewable resources. To improve sustainability and lessen their environmental impact, numerous businesses, like Pfizer and AstraZeneca, have already embraced green chemical techniques. All things considered, safe, economical, and ecologically conscious pharmaceutical production depends on green chemistry.

Applications of Green Chemistry in Pharmaceutical Industry

- Utilizing Eco-Friendly Solvents
- Enzyme-based reactions, or biocatalysis
- Catalytic Mechanisms
- Chemistry in Continuous Flow
- Optimization of Atom Economy
- Synthesis that uses less energy
- Utilizing Renewable Raw Materials
- Decrease in Derivatives
- Green Methods of Analysis
- Recycling and Waste Reduction

Examples of green chemistry in pharmaceutical industry

➢ **Pfizer (Sildenafil Production)**

created a more environmentally friendly method of producing sildenafil (Viagra) by using less dangerous solvents and increasing yield, which greatly reduced waste production.

- **Merck & Co. (Manufacturing of Sitagliptin)**

increased efficiency, decreased waste, and enhanced environmental safety by substituting an enzyme-based (biocatalytic) process for a conventional metal-catalyzed one.

- **Green Solvent Selection by AstraZeneca**

used greener reaction conditions and solvent selection guidelines to reduce the usage of hazardous solvents and increase the sustainability of drug manufacturing.

- **GlaxoSmithKline (Optimization of Process)**

To improve process efficiency and lessen the impact on the environment, green chemistry metrics and solvent selection tools were introduced.

- **Johnson & Johnson (Initiatives for Waste Reduction)**

adopted green manufacturing practices to increase pharmaceutical processes' energy efficiency and decrease hazardous waste.

- **Continuous Manufacturing, or Novartis**

used continuous flow technology to increase medicine production's scalability, cut waste, and improve safety.

Advantages of green chemistry in pharmaceutical industry

- less of an impact on the environment
- Safer procedures and goods
- An increase in energy efficiency
- Reduction of waste
- Utilizing sustainable resources
- Improved adherence to regulations
- Improved sustainability
- Innovation in the manufacture of drugs
- decreased chance of mishaps
- reduces pollutants in the environment
- safer for both employees and patients
- Reduction of waste

FUTURE SCOPE

- **Greener production of drugs**

In order to reduce waste and increase yields, new synthetic approaches will increasingly adhere to concepts like atom economy and catalytic efficiency. For cleaner, more scalable manufacturing, continuous flow chemistry will take the place of conventional batch methods.

- **The development of biotechnology and biocatalysis**

The application of microbes and enzymes (biocatalysis) will grow, enabling extremely selective reactions in mild environments. This is a significant field of biotechnology that will lessen dependency on hazardous substances.

- **Solvent-free procedures and sustainable solvents**

In order to reduce hazardous waste, future production will use recyclable, bio-based, or water-based solvents, as well as solvent-free reactions.

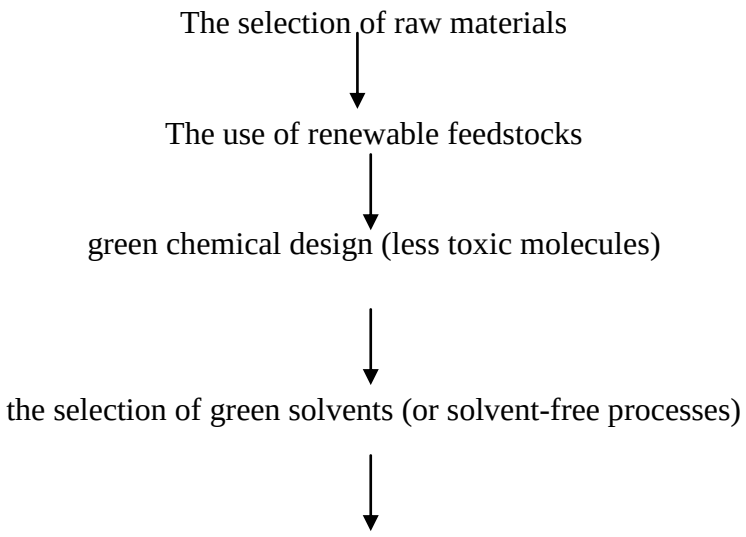
- **AI and digital technology integration**

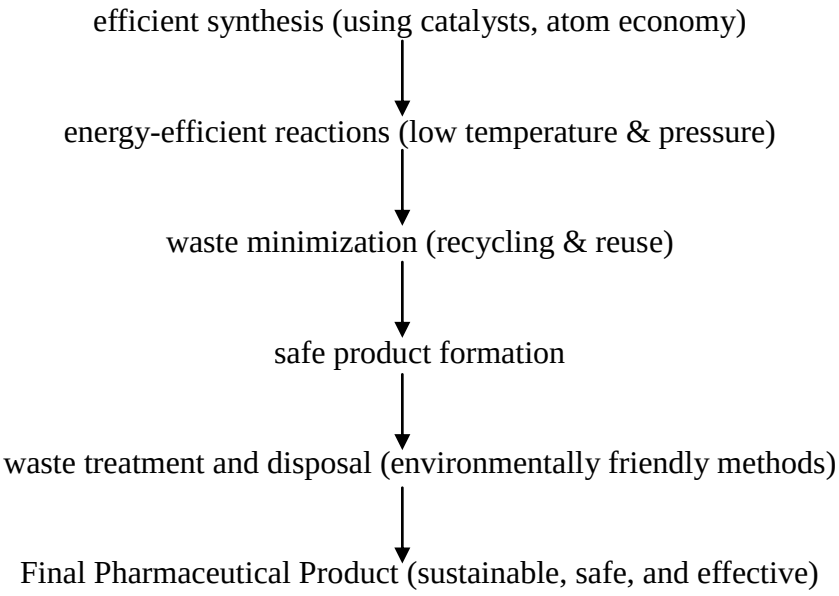
Reducing trial-and-error in drug development, optimizing reactions, and designing more environmentally friendly synthesis routes are all made possible by artificial intelligence and machine learning.

- **Sustainable feedstocks**

Drug manufacture will become more sustainable as more plant-based and bio-renewable raw materials take the place of inputs sourced from petroleum.

Pharmaceutical industry flow chart for green chemistry





CONCLUSION

- Green chemistry is a sustainable method that lessens the influence of pharmaceutical manufacturing on the environment. It guarantees high-quality medications with little waste by utilizing concepts like atom economy, safe solvents, and energy-efficient procedures.
- It contributes to cost savings, increased efficiency, and improved safety. Its implementation is being accelerated by growing legislation and sustainability objectives.
- For the pharmaceutical sector to be secure, sustainable, and environmentally friendly, green chemistry is crucial.
- In order to make the pharmaceutical industry more environmentally conscious and sustainable, green chemistry is essential. It guarantees effective resource use and little waste production by implementing concepts like atom economy. It minimizes the environmental persistence of pharmaceuticals, supports lifecycle-based drug design, and lowers production costs and environmental contamination.

REFERENCE

Foundational and extensively cited literature provides significant support for the topic of green chemistry in the pharmaceutical sector. Paul T. Anastas and John C. Warner first methodically presented the idea in their 1998 book Green Chemistry: Theory and Practice, which lists the 12 core tenets of green chemistry. Roger A. Sheldon's work "The E Factor: Fifteen years on" (2007), which focused on industrial waste reduction, further advanced our understanding of process efficiency and waste minimization. James H. Clark (1999) offered

early insights into prospects and obstacles in this sector, emphasizing its industrial importance. Research by K. M. Koenig et al. in Accounts of Chemical Research offers a concentrated discussion on the application of green chemistry in drug development in the context of pharmaceutical applications. Organizations like the U.S. Environmental Protection Agency and the American Chemical Society, through its Green Chemistry Institute Pharmaceutical Roundtable, have also made a substantial contribution by providing case studies, policy frameworks, and guidance for practical implementation. Furthermore, Martyn Poliakoff et al. (2002) gave a thorough summary of the development and influence of green chemistry over time, while David J. C. Constable et al. (2007) indicated important study topics required for expanding it in industry. When taken as a whole, these sources provide a solid theoretical and practical basis for comprehending and developing green chemistry in the pharmaceutical industry.