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Need of green chemistry in present era

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ABSTRACT

The twenty-first century is marked by rapid industrialisation, advancement in technology, urbanisation, and population growth; all these have significantly increased the demand for chemical products and industrial processes. Nevertheless, conventional chemical practices have also resulted in strict environmental degradation, depletion of natural resources, climate change, and adverse health effects due to the generation of toxic wastes and hazardous substances. In this perspective, green chemistry has emerged as a sustainable and novel approach aimed at minimising or eliminating the use and generation of harmful chemicals. Green chemistry focuses on the plan of safer chemicals, energy-efficient processes, renewable feed stocks, and waste prevention strategies. This research paper highlights the growing necessity of green chemistry in the present scenario and discusses its principles, applications, environmental significance, industrial relevance, economic benefits, and role in sustainable development. The study further emphasises the significance of adopting eco-friendly technologies in sectors like pharmaceuticals, agriculture, polymers, energy production, as well as manufacturing industries. Green chemistry not only contributes to prevention of pollution and conservation of resources but also promotes economic growth by encouraging innovation and the development of green technologies. The article also reflects the role of education, government policies, and scientific research in promoting sustainable chemical practices. The result suggest that the adoption of green chemistry is vital for achieving environmental sustainability, protecting public health, and ensuring a balanced coexistence between industrial development and ecological safeguarding.

Key Words - Green chemistry, renewable resources, pollution prevention, eco-friendly technology, environmental sustainability, green technology, sustainable development.

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INTRODUCTION

In the present era, the global community faces unprecedented environmental challenges due to industrialisation, population growth, and resource depletion. Especially the chemical manufacturing processes, have significantly contributed to environmental pollution, climate change, and ecological imbalance. Conventional chemical industries often rely on hazardous substances, non-renewable resources, and energy-intensive processes that generate large quantities of toxic waste. Such practices threaten both environmental and human health.

In response to these growing concerns, the concept of green chemistry has gained global importance. Green chemistry, also known as sustainable chemistry, refers to the design and development of chemical products and processes that reduce or eliminate the use and generation of hazardous substances. The term was formally introduced by Paul Anastas and John Warner in the 1990s and

has since become a guiding principle for sustainable industrial development.

Green chemistry emphasises pollution prevention rather than pollution control. Instead of treating waste after it is generated, green chemistry focuses on designing processes that evade waste generation altogether. It promotes the use of renewable raw materials, safer solvents, biodegradable products, and energy-efficient technologies. The adoption of green chemistry principles helps reduce environmental damage while simultaneously improving economic efficiency and industrial productivity.

In the present era, where climate change, resource depletion, and environmental degradation pose serious threats to global sustainability, green chemistry has become a necessity rather than an option. Governments, industries, educational institutions, and environmental organizations worldwide are increasingly recognizing the importance of sustainable chemical practices for ensuring a healthier future.

Concept and Definition of Green Chemistry

Green chemistry can be defined as: "The design of chemical products and processes that reduce or eliminate the use and generation of hazardous substances." It involves the application of scientific principles to minimise environmental impact throughout the lifecycle of chemical products, from raw material extraction to disposal.

The primary objectives of green chemistry include:

- Prevention of waste generation
- Reduction of toxicity
- Efficient utilisation of resources
- Energy Conservation
- Use of renewable feed stocks
- Development of biodegradable products
- Enhancement of process safety

Green chemistry differs from environmental chemistry. Environmental chemistry studies the effects of pollutants on nature, whereas green chemistry aims to reduction of pollution at its source.

Twelve Principles of Green Chemistry

The foundation of green chemistry is based on twelve principles formulated by Paul Anastas and John Warner. These principles provide guidelines for designing sustainable chemical processes.

i. Prevention of Waste

It is better to prevent waste formation than to treat or clean it after generation.

ii. Atom Economy

Chemical reactions should maximize the incorporation of all materials into the final product.

iii. Less Hazardous Chemical Syntheses

Chemical methods should minimize toxicity to humans and the environment.

iv. Designing Safer Chemicals

Products should perform their intended function with minimal toxicity.

v. Safer Solvents and Auxiliaries

The use of hazardous solvents and auxiliary substances should be minimized.

vi. Energy Efficiency

Energy requirements should be minimized, preferably using ambient temperature and pressure.

vii. Use of Renewable Feedstocks

Raw materials should be renewable whenever technically and economically feasible.

viii. Reduction of Derivatives

Unnecessary derivatization should be avoided because it generates additional waste.

ix. Catalysis

Catalytic reagents are superior to stoichiometric reagents because they increase efficiency and reduce waste.

x. Design for Degradation

Chemical products should break down into harmless substances after use.

xi. Real-Time Analysis for Pollution Prevention

Analytical methods should allow monitoring and control during chemical processes.

xii. Inherently Safer Chemistry

Chemical processes should minimize the risk of accidents, explosions, and toxic releases.

Need of Green Chemistry in Present Era

i. Environmental Protection

One of the major reasons for the growing need for green chemistry is environmental conservation. Conventional chemical industries release toxic gases, wastewater, and hazardous residues into the environment. These pollutants contaminate air, water, and soil, adversely affecting biodiversity and human health.

Green chemistry helps reduce pollution by:

- Minimizing toxic waste
- Reducing greenhouse gas emissions
- Promoting biodegradable products
- Encouraging sustainable industrial practices

ii. Conservation of Natural Resources

Many industrial processes rely heavily on non-renewable fossil fuels and mineral resources. Excessive consumption of these resources threatens future availability.

Green chemistry encourages:

- Use of renewable raw materials
- Recycling and reuse of materials
- Sustainable resource management
- Development of bio-based chemicals

This approach supports long-term resource sustainability.

iii. Reduction of Climate Change

Industrial chemical processes contribute significantly to global warming through the emission of greenhouse gases such as carbon dioxide and methane.

Green chemistry promotes:

- Energy-efficient technologies
- Renewable energy integration
- Low-carbon manufacturing processes
- Reduction in fossil fuel dependence

These measures help mitigate climate change and environmental degradation.

iv. Human Health and Safety

Hazardous chemicals used in industries can cause severe health problems including cancer, respiratory diseases, neurological disorders, and skin diseases.

Green chemistry improves safety by:

- Reducing exposure to toxic substances
- Developing safer chemicals
- Preventing industrial accidents
- Promoting non-toxic alternatives

v. Economic Benefits

Green chemistry is economically advantageous because it reduces:

- Raw material costs
- Energy consumption
- Waste treatment expenses
- Environmental cleanup costs

Additionally, green technologies create new industries, employment opportunities, and markets for sustainable products.

vi. Sustainable Development

Sustainable development aims to meet present needs without compromising the ability of future generations to meet their own needs.

Green chemistry contributes to sustainable development through:

- Eco-friendly industrialization
- Resource conservation
- Pollution prevention
- Promotion of circular economy models

Applications of Green Chemistry

i. Pharmaceutical Industry

Green chemistry is widely used in pharmaceutical manufacturing to reduce hazardous solvents and waste generation.

Examples include:

- Solvent-free synthesis
- Catalytic reactions
- Microwave-assisted synthesis

These methods improve efficiency and reduce environmental impact.

ii. Agriculture

Green chemistry promotes sustainable agriculture through:

- Biofertilizers
- Biopesticides

- Controlled-release fertilizers
- Eco-friendly agrochemicals

These alternatives reduce soil and water contamination.

iii. Polymer Industry

Biodegradable plastics and bio-based polymers are important achievements of green chemistry.

Examples:

- Polylactic acid (PLA)
- Biopolyethylene
- Starch-based plastics

These materials reduce plastic pollution.

iv. Energy Sector

Green chemistry contributes to clean energy development through:

- Biofuels
- Hydrogen fuel technology
- Solar cell materials
- Green batteries

Such technologies reduce dependence on fossil fuels.

v. Water Treatment

Environmentally friendly chemicals are used in water purification and wastewater treatment to reduce contamination and improve public health.

Role of Education and Research

Educational institutions play a vital role in promoting green chemistry awareness. Universities and schools should incorporate sustainable chemistry concepts into curricula to encourage environmentally responsible scientific practices.

Research institutions must focus on:

- Development of eco-friendly technologies
- Alternative renewable materials
- Green catalytic systems
- Sustainable industrial processes

Scientific innovation is essential for the widespread implementation of green chemistry.

Government Policies and Global Initiatives

Governments worldwide are implementing environmental regulations and promoting sustainable industrial practices. International organizations such as the United Nations and environmental agencies support green chemistry initiatives to achieve sustainable development goals (SDGs).

Important measures include:

- Environmental legislation
- Incentives for green industries
- Research funding
- Public awareness campaigns
- Industrial sustainability standards

India has also initiated several environmental programs encouraging renewable energy, waste management, and sustainable industrial development.

Challenges in Implementing Green Chemistry

Despite its numerous advantages, several challenges hinder the widespread adoption of green chemistry:

- High initial investment costs
- Lack of awareness and technical expertise
- Resistance to industrial change
- Limited availability of green alternatives
- Inadequate policy implementation

Addressing these challenges requires collaboration among scientists, industries, policymakers, and educators.

Future Prospects of Green Chemistry

The future of green chemistry is highly promising due to increasing global awareness regarding environmental sustainability.

Future developments may include:

- Advanced biodegradable materials
- Carbon-neutral manufacturing
- Green nanotechnology
- Artificial intelligence in sustainable chemistry
- Renewable chemical feedstocks
- Circular economy-based industries

Green chemistry is expected to become an integral component of industrial and scientific progress in the coming decades.

CONCLUSION

The present era is in need of urgent and effective solutions to environmental degradation, climate change, resource depletion, and public health

concerns. Green chemistry is the probable and scientifically sound and economically viable pathway toward sustainable development. By minimising hazardous substances, conserving resources, and promoting eco-friendly technologies, green chemistry helps establish a balance between industrial growth and environmental preservation.

The adoption of green chemistry principles is essential for achieving a cleaner, healthier, and more sustainable future. Governments, industries, researchers, and educational institutions must work collaboratively to accelerate the transition toward greener technologies and responsible chemical practices. In the long run, green chemistry will not only protect the environment but also improve quality of life and ensure the well-being of future generations.

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