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Green Chemistry Is an Evolutionary Step in Organic Synthesis and Its Applications

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ABSTRACT
This article gives a general overview of how the 12 Green Chemistry principles and emerging trends can be applied. A word used to describe the development of chemical goods and procedures that lessen or do away with the use and manufacturing of dangerous compounds is "green" or "sustainable chemistry." They are only applied to substances and operations involving substances that don't harm the environment. It is founded on a set of twelve principles that can be used to generate or recreate molecules, materials, reactions, and processes that are less hazardous to both human health and the environment. Nearly all branches of chemistry, including organic, inorganic, biochemistry, polymer, toxicological, environmental, physical, technical, etc., are represented in the methods of green chemistry that have been established to date. The dual objectives of environmental protection and financial gain can be achieved by utilizing a number of popular green program trends, such as catalysis, biocatalysis, and the use of alternative renewable feedstock (biomass), reaction media (water, ionic liquids, and supercritical fluids), reaction conditions (microwave irradiation), and new synthetic pathways (photocatalytic reaction). This article provides examples of current trends that demonstrate how Green Chemistry lessens the environmental impact of chemical processes and technology.

KEYWORDS
Green Chemistry, Hazardous substances, Atom economy, Environmental Protection Agency (EPA), Prevention, Auxiliary, Safer solvents

1. INTRODUCTION
Movement and sustainable/green chemistry are concepts that are frequently used interchangeably. Green chemistry is the "design of chemical products and processes to limit or eliminate the usage and creation of hazardous compounds," according to the definition given.[1] Green chemistry aims to reimagine how chemicals are produced and used in our society such that they are intrinsically safer and more effective. This emphasis is consistent with broader sustainability.[2]

The idea of design is the most significant part of green chemistry. Design is a manifestation of human intention; it cannot happen by chance. It consists of novelty, organization, and methodical conception. To assist chemists in achieving the deliberate objective of sustainability, the Twelve Principles of Green Chemistry serve as "design rules." Careful planning of chemical synthesis and molecular design to minimize unfavourable effects is a hallmark of green chemistry. One can establish synergy through appropriate design rather than just trade-offs.

The goal of the Green Chemistry method is to establish molecular sustainability. It is hardly unexpected that it has been implemented across all industry sectors given this purpose. There are countless examples of successful uses of honourable, commercially viable technology in industries as diverse as agricultural, automotive, cosmetics, electronics, energy, home goods, and pharmaceuticals. [3]

The idea of "green chemistry" has had such a significant impact because it has impacted industry, education, the environment, and the general public in areas other than just the research laboratory. The area of "green chemistry" has shown how chemists may create viable, next-generation products and procedures that benefit both the environment and human health. Teaching programs, governmental funding, and the creation of Green Chemistry Research Centers have increased during the past 20 years in response to the scientific interest in the field. These days, a lot of colleges offer courses in green chemistry and engineering. Degrees in the subject are offered by some colleges. In several nations around the world, government support has also increased.[4]

This paper attempts to advance knowledge of the basic concepts and procedures of green chemistry and to illustrate how green chemistry lessens the environmental impact of chemical processes and technologies through examples and prevailing paradigms.

2. GREEN CHEMISTRY

Chlorophyll and money are both represented by the colour green. The battleground of environmental warriors has been going green for years, and going green is now a trend in product marketing. Applying the principles of green chemistry in all facets of chemical sciences, including fundamental and practical research, production, and teaching, becomes crucial for chemists. [5]

2.1 Definition of Green Chemistry

Green chemistry is described by the EPA as a type of chemistry that develops chemical processes and products that are safe for the environment, hence preventing the creation of pollution. After being used, chemical products should be broken down into components that are safe for the environment and should not be left in the environment. Savings due to effective synthesis without the need for "exotic" reagents, a decrease in the amount of energy needed, and the use of water instead of organic solvents are considerable even at the laboratory level, and on an industrial scale, savings in the millions are achievable.[6]

Green chemistry is an ethical, multidisciplinary approach to science that is founded on chemical, ecological, and social responsibilities. It promotes innovation and the promotion of novel research. It is not a distinct scientific field.[7] It seeks to strike and keep a balance between the use of natural resources, economic development, and environmental preservation as an active area of research.

2.2 Historical Context

The Environmental Protection Agency (EPA) first developed the term and idea of "green chemistry" at the start of the 1990s, about two decades ago.[8] The ideal pollution protection technique, according to this legislation, is a switch to chemicals that are naturally safer and more sustainable. Since then, green chemistry has experienced extensive adoption on a global scale, inspiring the creation of literally hundreds of programs and governmental efforts, with the initial major programs having their roots in the United States, the United Kingdom, and Italy.[9] These have been a major influence on sustainable design. The US Presidential Green Chemistry Challenge Awards were created in 1995, and the Green Chemistry Institute was launched in 1997.[10] and the release of the inaugural volume of the Royal Society of Chemistry's now-established Green Chemistry journal in 1999.[11] The 1998 release of Green Chemistry: Theory and Practice contributed to the development of a cogent vision for the growing green chemistry movement by explicitly articulating the 12 principles of green chemistry. The formulation of these concepts, though at first glance intuitive, assisted chemists and chemical engineers in comprehending how sustainability principles may be used in their research.

2.3 Trends in Green Chemistry [12]

Green Chemistry is a "program for the design, development, and implementation of chemical products and processes that decrease or eliminate the use or production of substances that are dangerous to human health and the environment." The fundamental objectives of the green program are accomplished by a number of prevailing trends:

a. studying catalytic and biocatalytic processes to produce highly selective, pure chemicals without producing hazardous byproducts;

b. looking for new, safe, and sustainable raw supplies, such as biomass;

c. creating chemicals that are less harmful and sustainable;

d. identifying and evaluating new non-toxic, renewable, and alternative reaction media, like water, ionic liquids, and supercritical fluids.

e. identifying and testing new circumstances for alternative reactions, such as those involving microwaves, ultrasounds, and light

f. investigation of alternative methods, such as photocatalytic processes, for the cleaning of polluted air and water to improve their quality.

Realizing the desired outcomes, "green chemistry transforms stable industrial practice creates, pollutes, then cleanses, and in the late 20th century becomes the heart and soul of industrial ecology."

A new generation of scientists and engineers is emerging that economically evaluates the methods and materials utilized in production and development in order to protect natural resources and the environment. Green chemistry is a Hippocratic oath for chemists.

The production and use of chemical goods and procedures that lessen or do away with the usage and production of hazardous compounds is known as "green chemistry," or chemistry that is ecologically safe, safe, and sustainable. Green chemistry aims to lessen and potentially eliminate the risk rather than limiting it by regulating exposure to dangerous chemicals, disputing the necessity of risk reduction through exposure control. It is unnecessary to worry about eliminating dangerous substances from the environment or limiting exposure to them if they are not utilized or manufactured. "Green chemistry is about decreasing waste, raw materials, hazards, energy, environmental impact, and cost."

2.4 Drivers for Green Chemistry Adoption

The creation of guidelines and measurements for the manufacture of sustainable chemicals has sped up the adoption and advancement of green chemistry. A few notable examples are atom economy,[13] environmental factor (E-factor),[14] the 12 principles of green chemistry, principles of sustainable chemistry,[15] and 12 additional principles of green chemistry. The 12 principles of green engineering, cradle-to-cradle design, natural capitalism, and design for the environment are just a few of the design and engineering measures that have been established.[16] These metrics all share the belief that chemistry should be created in a way that strives to optimize effectiveness while minimizing risks to human health and the environment at every step of a chemical's life cycle.

Researchers, business people, and politicians can now assess how far we've come in achieving sustainability goals thanks to the spread of metrics. The many stakeholders frequently rank green chemistry components in accordance with their respective requirements and select criteria accordingly. The variety of criteria can make it difficult to assess claims of greenness while also promoting the dissemination of green chemistry concepts. Complicating matters are recent press and marketing efforts that extoll promises of green jobs and the green economy, introducing a fresh wave of greenness claims that will need to be carefully investigated.

2.4.1 Economic Drivers

Businesses may now evaluate their processes and products in the context of the "triple bottom line," which integrates economic, environmental, and social aspects into decision-making. This is made possible by green chemistry tools and measurements.[17] Green chemistry offers criteria to assess new technology's effectiveness, environmental impact, and health effects. Green chemistry is unquestionably cost-effective when there are strong environmental and health protection regulations in place. Despite the financial obstacle to change, an increasing number of research and commercial studies show that green chemistry projects are profitable. The cost reductions brought about by these activities can be attributed to lower expenses for waste disposal, safety gear, regulatory compliance, reduced liability, and manufacturing security.[18]

2.4.2 Health and Safety Drivers

Politicians and public interest organizations have hailed green chemistry as a solution to chemical hazards in consumer products and the environment. These organizations believe that "benign by design" has the possibility of providing an alternative to the hazardous chemicals that are occasionally present in consumer goods. Green chemistry has been identified as a critical instrument for thoroughly resolving the current deficiencies in chemical regulation as both the federal and state governments in the United States contemplate chemical policy reform.[19] Advocacy groups want to prevent chemical-by-chemical regulation, which has unfortunate consequences such as the replacement of one hazardous chemical with another, by putting green chemistry and safe chemical design at the core of policy reform.

2.4.3 Research Drivers

Numerous achievements in research and development activities have been made using green chemical innovation. The number of new green technologies emerging has been rising together with the rate of patent applications. [20-21] Industry, which took advantage of the cost savings brought on by higher productivity and the reduction of hazardous waste, has played a significant role in the rise of green chemistry patents over the past 15 years. There is a clear demand for innovation throughout the supply chain as evidenced by the large number of chemical consumers and producers that have submitted green chemistry patents. Academic study has also been sparked by the widespread appeal of new cleaner technologies, and the body of literature detailing green chemistry has expanded at a similar rate.

To demonstrate how green chemistry can have an impact on technology development, it is applied to the concurrently developing field of nanotechnology.

3. 12 PRINCIPLES OF GREEN CHEMISTRY

Twelve principles of green chemistry were created by Paul Anastas and John Warner of EPA, and in their Green Chemistry Theory and Practice book, 1998, they described the practical application of each in detail.[1] These principles serve as a framework for the design of new chemical products and processes, and they apply to all facets of the process life-cycle, including the raw materials used, the effectiveness and safety of the transformation, the toxicity, and the biodegradability of the products and reagents used.

According to the concepts of "green chemistry," hazardous or dangerous compounds should be decreased or removed from the synthesis, manufacture, and application of chemical products. This will limit or eliminate the use of substances that are hazardous to both human health and the environment. These principles serve as a framework for the design of new chemical products and processes, and they apply to all facets of the process life-cycle, including the raw materials used, the effectiveness and safety of the transformation, the toxicity, and the biodegradability of the products and reagents used.

Figure 1: Green Chemistry

3.1 Prevention of waste

'It is better to prevent waste than to treat or clean up waste after it has been created.'

This principle simply states that chemical processes should be improved to produce the least amount of waste possible. An environmental factor, sometimes known as the "E factor," was developed to gauge how much waste a process generated. The E factor is calculated by effectively dividing the amount of garbage produced by a process by the mass of the item it produced, with a smaller E factor being preferable.[22] Drug production processes typically had infamously high E factors, however, this can be reduced with the use of other green chemistry techniques. Different methods are also used to evaluate waste measures, such as comparing the mass of the raw materials to that of the item.

3.2 Atom economy maximization

'Synthetic methods should be designed to maximize the incorporation of all materials used in the process into the final product.'

Atom economy is a percentage of the number of particles from the beginning of materials that are present in supportive items as a compound is being processed. Side products produced by undesirable reactions can lead to a reduced particle economy and eventually waste.[23] Atom economy is a better indicator of reaction efficiency from a variety of angles than the reaction's yield, which compares the amount of useful product produced to the amount you may have erroneously predicted from calculating. In this way, atom economy-expanding forms are favoured.

3.3 Less hazardous chemical synthesis

'Synthetic methods should be designed, whenever practicable, to use and generate substances that pose little or no toxicity to human health and the environment.'

In an ideal world, we would require artificial chemicals that we create for a variety of purposes in order for them not to pose a threat to human health. The goal is to avoid using dangerous chemicals in the beginning if more secure alternatives are going to be available because we also need to make the chemical combination as safe as possible under particular circumstances.[24] Furthermore, we must maintain a strategic distance from hazardous chemical wastes because their cleanup may be complicated.

3.4 Designing Safer Chemicals

'Chemical products should be designed to achieve their desired function while minimizing their toxicity.'

Near the previous principle, this one connects. Scientists must devise plans to create substances that fulfil their needs, whether clinical, industrial, or otherwise, while also posing minimal human poisoning risks. Knowledge of how chemical mixtures behave in our bodies and on the earth is necessary for the design of more secure chemical or synthetic targets.[25] There are times when a certain level of poisonousness toward people or animals may be unavoidable, but alternatives should be sought out.

3.5 Safer solvents and auxiliary substances

'Unnecessary use of auxiliary substances (e.g solvents, separation agent, etc) should be avoided whenever possible and made innocuous when used.'

Many chemical processes call for the use of solvents or other substances to speed the reaction. They may pose a variety of risks, such as combustibility and volatility. While solvents may not always be avoided in operations, they are typically chosen to reduce the energy needed for the reaction, to have negligible harmfulness, and to be reused if at all possible.[26]

3.6 Design for energy efficiency

'Energy requirements of chemical processes should be recognized for their environmental and economic impacts and should be minimized. If possible, synthetic methods should be conducted at ambient temperature and pressure.'

Green chemistry disapproves of energy-intensive procedures. Where a chemical is conceived, it is wiser to keep the vitality, or energy, needed to create it, to a minimum through reactions carried out at an appropriate temperature and a specific pressure. [27] The reaction's design must take into account the fact that solvent removal or other means of removing contaminating influences might increase the amount of energy required and, consequently, the process's natural (environmental) impacts.

3.7 Use of renewable feedstock

'Whenever technically and economically practicable, raw material or feedstock should be renewable rather than depleting it.'

The focus of this recommendation is mostly on petrochemicals, which are materials made from crude oil. These are used as starting materials in the context of the chemical reaction, however, they are non-renewable and have a finite shelf life. [28] By using renewable feedstocks, such as artificial mixtures created from natural resources, procedures can be made more rational.

3.8 Reduction of derivatization reactions

'Unnecessary derivatization (use of blocking groups, protection/deprotection, and temporary modification of physical/chemical processes) should be minimized or avoided if possible because such steps require additional reagents and can generate waste.'

In compound synthesis, securing bunches are commonly used because they can prevent some aspects of an atom's structure from changing during a chemical reaction while allowing necessary modifications to be made to other sections of the structure. However, these methods also increase the amount of trash a technique generates and need more reagents. [29] The use of enzymes has been researched as an option in some operations. Enzymes can be used to target certain components of an atom's structure without the need for the use of ensuring groups or other derivatives because of their extreme specificity.

3.9 Catalysis

Catalytic reagents (as selective as possible) are superior to stoichiometric reagents.

The use of catalysts can facilitate processes with higher atom economies. Because catalysts themselves are not used up by the specific chemical process, they can be reused repeatedly and don't contribute to waste. [29] They can take into account the use of reactions that wouldn't occur in normal circumstances, but which also result in reduced waste.

3.10 Design for degradation

'Chemical products should be designed so that at the end of their function they break down into innocuous degradation products and do not persist in the environment.'

Chemical goods should ideally be designed so that, after serving their purpose, they split into harmless compounds and have beneficial effects on the environment. Items that don't separate, accumulate, and survive in the earth are known as "tireless organic contaminants." These substances are typically halogenated chemicals, with DDT being the most well-known example.[30] Wherever possible, synthetic molecules that are more easily separated by water, UV light, or biodegradation should be used in place of these synthetic substances.

3.11 Real-time analysis to prevent pollution

'Analytical methodologies need to be further developed to allow for real-time, in-process monitoring and control, prior to the formation of hazardous substances.'

Keeping an eye on a complex reaction while it takes place might assist in preventing the introduction of harmful and contaminating compounds due to accidents or unexpected reactions. By keeping an eye out for warning indications, the response might have been stopped or controlled before such an incident occurred.[31]

3.12 Safer chemicals to prevent accidents

'Substances and the form of substances used in a chemical process should be chosen so as to minimize the potential of chemical accidents, including releases, explosions and fires.'

A measure of risk is always present when working with synthetic substances. However, the threat can be reduced if risks are properly managed. Unmistakably, this rule interacts with some of the other regulations that address hazardous materials or chemicals. Wherever possible, processes should be designed to limit dangers and should be eliminated from the introduction of hazards where the ultimate result is unthinkable. [32] By doing away with the procedure or substituting safer alternatives, the highest level of safety control is accomplished (Figure 2).

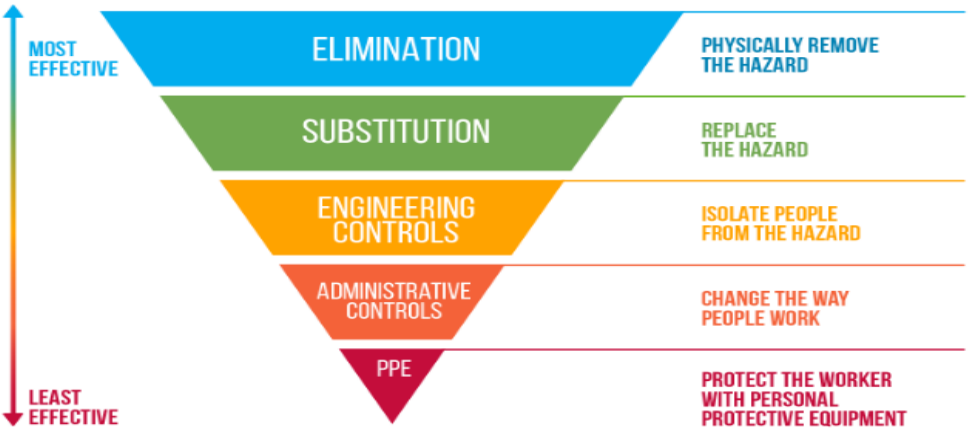

Figure 2: Hierarchy of security control

Table 1: Overview of 12 Principles of Green Chemistry

Sr. No.	Principles	Description of Principles
1	Prevention of waste	It is better to prevent waste than to treat or clean up waste after it has been created.
2	Atom economy maximization	Synthetic methods should be designed to maximize the incorporation of all materials used in the process into the final product.
3	Less hazardous chemical synthesis	Synthetic methods should be designed, whenever practicable, to use and generate substances that pose little or no toxicity to human health and the environment.
4	Designing safer chemicals	Chemical products should be designed to achieve their desired function while minimizing their toxicity.

5	Safer solvents and auxiliary substances	Unnecessary use of auxiliary substances (e.g. solvents, separation agents, etc) should be avoided whenever possible and made innocuous when used.
6	Design for energy efficiency	Energy requirements of chemical processes should be recognized for their environmental and economic impacts and should be minimized. If possible, synthetic methods should be conducted at ambient temperature and pressure.
7	Use of renewable feedstock	Whenever technically and economically practicable, raw material or feedstock should be renewable rather than depleting it.
8	Reduction of derivatization reactions	Unnecessary derivatization (use of blocking groups, protection/deprotection, and temporary modification of physical/chemical processes) should be minimized or avoided if possible because such steps require additional reagents and can generate waste.
9	Catalysis	Catalytic reagents (as selective as possible) are superior to stoichiometric reagents.
10	Design for degradation	Chemical products should be designed so that at the end of their function they break down into innocuous degradation products and do not persist in the environment.
11	Real-time analysis to prevent pollution	Analytical methodologies need to be further developed to allow for real-time, in-process monitoring and control, prior to the formation of hazardous substances.
12	Safer chemicals to prevent accidents	Substances and the form of substances used in a chemical process should be chosen so as to minimize the potential of chemical accidents, including releases, explosions, and fires.

4. IMPACT OF GREEN CHEMISTRY

4.1 Pharmaceutical analysis

The chemical and pharmaceutical businesses, as well as laboratories, must now think about green chemistry in addition to their analyses. Aspects of ecologically sound thinking include the method that is used, the reagents, the accessories, the people qualifications, and the time spent assessing the quality of a product.

High-performance liquid chromatography is the technique of choice for identifying active medicinal components as well as researching contaminants and degradation products (HPLC). The majority of these techniques employ acetonitrile and/or methanol as organic solvents. Many people additionally choose buffering options. This cannot be contested. However, the majority of them either do not employ buffer solutions in the mobile phase or have never even tried to use an additional organic solvent in addition to the acetonitrile/methanol mixture. Buffer solutions take some time to prepare in addition to having a short shelf life that necessitates a fresh preparation and therefore a longer dispensing time. Its use necessitates a thorough cleaning of the chromatographic system as a whole as well as the column.[33]

4.2 Environment

Prior to being released back into the environment, the residues from chemical-pharmaceutical analyses must be pre-treated. The cost of this process varies depending on how toxic and dangerous the solvent is, though.

For instance, when acetonitrile is burned, trash is produced which leads to acid rain. Even when a method is used to reduce the solvent's toxicity, it still has an adverse effect on us (World Health Organization, 1993). Cars, structures, historical sites, vegetation, rivers, lakes, and other things are all harmed by acid rain.

4.3 Population

Various aspects and fronts of the population are affected by the current chemistry. The selection of analytical techniques and reagents by analysts or chemical pharmaceutical operators has an impact on patients who regularly obtain their medications from pharmacies or health facilities. An expensive process results in an expensive product being sold. An expensive process with more components that are not always required creates a more expensive end result. An expensive process with extras and multiple processes (which aren't necessarily required) results in an even more expensive product on the market.[34]

4.4 Analyst

The physical-chemical analyst interacts with pharmaceutical analyses on a daily basis. He is the first person the entire analytic chain has an impact on. The body absorbs toxic solvents like acetonitrile fast, and its metabolism produces cyanide that hinders breathing (World Health Organization, 1997). Methanol is another illustration, which is also gorgeous according to pharmacological analysis. In addition to excreting more slowly than ethanol, the byproducts of its metabolism produce formic acid, formaldehyde, and other compounds that cause extreme intoxication. [35] The analyst may experience mental distress as a result of performing time-consuming and impractical analytical procedures that call for particular accessories, involve multiple steps, or expose all parties to harmful solvents and chemicals.

4.5 Company

Since turning off the light until selecting the reagent to be used in evaluating a pharmaceutical, since the interaction with the collaborator until the provision of training for a team, chemical-pharmaceutical companies must increasingly consider the principles of green chemistry and/or green analytical chemistry.

Green chemistry must be viewed as a sustainable concept that extends from better earth to better people, businesses, and social interactions. A business that cherishes this cutting-edge, modern approach will undoubtedly be successful. There won't be any employees there; only partners. There won't be a chief in it; only leaders. It will be sustainable, green, and clean throughout the entire supply chain, not just the final product. [36] Thus, the business expands on its own.

5. ADVANTAGES OF GREEN CHEMISTRY

a. Cleaner air: less airborne emission of dangerous substances.
b. Cleaner water: less dangerous chemical leakage into the water.
c. Less use of harmful compounds will increase worker safety in the chemical industry.
d. The effects of environmental toxins on plants and animals are less severe.
e. Chemical reactions with higher yields that require less feedstock to produce the same quantity of output.
f. Lower likelihood of smog generation, ozone depletion, and global warming.
g. Less chemical ecosystem disruption.
h. cleaner manufacturing techniques.

6. DISADVANTAGES OF GREEN CHEMISTRY

Designing chemical products and processes that minimize or fully do away with the usage or production of toxic and dangerous compounds is the fundamental objective of green chemistry.

The largest obstacle to achieving this objective a lack of green chemistry is reflected in time, expenses, and a lack of knowledge. More specifically, it takes a lot of time to transition from an outdated, conventional product or process to a new, "green" product or process. Additionally, designing or redesigning a new product or process is frequently challenging and quite expensive, and there is a lack of consensus regarding what is safe.

There are no known alternatives to employing chemical raw materials or alternative technologies for green processes, which contributes to the absence of green chemistry along with the high implementation costs and information gaps. Human resources and talents are also in short supply.

The supply chain does not divide the risks associated with converting to green products and processes, and there are insufficient funds for further study.

Ionic liquids are viewed as the green chemistry of the future. There is no doubt that they are helpful in chemical synthesis, but it is becoming more and more controversial whether they live up to expectations. Ionic liquids do not appear to be very green when the 12 principles that identify green compounds are applied. According to others, it is impossible to anticipate that ionic liquids will find widespread application within the next ten years given the state of scientific development. Ionic liquids are known to be slightly volatile due to their low vapour pressure, but this is just one of several factors that contribute to a substance's true green colour. For instance, liquids based on ions, imidazoles, and fluoro-anion are likely to be toxic yet cannot evaporate into the environment. The issue is that the majority of ionic liquids are water soluble and can quickly enter the biosphere via this route. [37]

7. FUTURE CHALLENGES [38]

Due to the scientists working in academia, business, and research facilities all over the world, Green Chemistry has made significant progress to this point. The big problems the field still needs to solve are, however, preceded by the achievements made thus far. Below are a few significant difficulties.

7.1 Twelve Principles of a Cohesive System

The Twelve Principles of Green Chemistry were intended to be an integrated, coherent system of design rather than twelve separate objectives, and their design framework has served as a model for numerous advancements in the area. One can only hope to create a process that is truly sustainable by putting all of the concepts into practice. Systemic sustainable design is conceivable and can support revolutionary innovation rather than incremental improvement by looking for the components of the principles that mutually reinforce one another.

7.2 Multi-functional catalysts

The past 20 years have seen a considerable advancement in catalysis. However, even today, the majority of catalysts are made to only affect one particular transformation, and little is understood about multi-functional catalysts, which are described as those that allow a single catalytic system to affect a number of different transformations. Chemistry would advance to a new level if it were possible to perform a full synthesis in one pot or use the same catalyst for multiple separate reactions with greater material and energy economy.

7.3 Mastering weak forces for synthesis and properties

Future developments in chemistry are projected to place a greater emphasis on non-covalent and weak-force interactions. There are considerable benefits to imparting characteristics by weak forces and directing synthetic pathways in the same way while reducing the quantity of bond breaking and bond building. These include lowering the amount of energy used, minimizing waste, and improving efficiencies. The capacity to control weak forces in the same manner that chemistry has controlled covalent forces has a tremendous deal of potential to aid in achieving molecular sustainability.

7.4 Integrative Systems Thinking

Reductionism has served as the foundation for much of the conventional method of scientific inquiry. The items of modern life, such as communication, transportation, and medicine, are now possible because of this method's depth of understanding and discovery. It has also had a great deal of unwanted and unanticipated repercussions, which have a negative effect on both people and the environment. By using a systems perspective, Green Chemistry is able to pursue substantial advancements without producing unexpected outcomes. Innovations that actually transform society can be produced by fusing reductive and integrative thinking.

8. LOOKING FORWARD [39]

Globally, scientists and engineers are being influenced by green chemistry and green engineering. More than 25 countries now have educational and/or research projects as part of the expanding global community. Practitioners have been able to cooperate thanks to new technical journals, numerous international conferences, and the development of social networking sites for green chemistry. Many of these partnerships focus on informing scientists of the potential advantages of green chemistry. Sustainability ideas must be included in all aspects of education if green chemistry is to have an impact on how materials are manufactured.

8.1. Educational Efforts

Open-access strategies for curriculum dissemination, which make extensive use of the Web's resources, are promoting educational programs in green chemistry. This is crucial for the international adoption of green chemistry curricula. The curricular materials found on the Beyond Benign Foundation, American Chemical Society Green Chemistry Institute, and Greener Education Materials Web sites have all been created and refined in classroom settings. Despite the fact that the majority of the resources are focused on chemistry teaching, campus-wide sustainability initiatives are enabling new multidisciplinary programmes. More individuals can be excited and involved about the potential for green chemistry to address society's urgent resource concerns through interdisciplinary collaborations and learning opportunities.

8.2 Concluding Comments

Iteration is a key component in green chemistry. There is always space for improvement, but using the different measurements and green chemistry concepts can assist in finding superior goods. There are only greener alternatives, which means there are no green chemicals. The majority of scientists and academics find this idea of continuous development to be natural and appealing, but politicians, businessmen, and consumers, who frequently seek out clear-cut solutions, may find it confusing. It is crucial for scientists and engineers to engage the public in order to avoid incorrect legislation, subpar investments, and greenwashing initiatives. The applications and effects of new technologies must be explained.

By encouraging researchers to think about problems that are both application- and implication-driven, green chemistry takes the first step. This comprehensive approach to technology development should lead to interdisciplinary relationships that promote improved public outreach. Because the success of any new technology ultimately rests with the public, we must seize this chance to involve all public stakeholders.

9. APPLICATIONS OF GREEN CHEMISTRY

9.1 Green Dry Cleaning of Clothes

Perchloroethylene (PERC) is frequently employed as a dry-cleaning solvent. It is now established that PERC is a possible carcinogen and that it contaminates groundwater. Liquid CO2 and a surfactant were used in Joseph De Simons, Timothy Romark, and James McClain's Micell technology, which replaced PERC in the dry cleaning of clothing. This method is now being used to develop dry-cleaning machines. A metal cleaning solution developed by Micell Technology uses CO2 and a surfactant, doing away with the requirement for halogenated solvents.[40]

9.2 Versatile Bleaching Agents

It is well known that wood is used to make paper (which contains about 70 percent polysaccharides and about 30 percent lignin). The lignin must be entirely eliminated to produce paper of high quality. First, lignin is eliminated by soaking small pieces of wood that have been chipped in a solution of sodium hydroxide (NaOH) and sodium sulphide (Na2S). About 80 to 90 percent of the lignin is broken down during this process. Through a reaction with chlorine gas, the residual lignin was almost completely eliminated (Cl2). Chlorine is used to completely eliminate the lignin, resulting in high-quality white paper, but it also has negative environmental effects. Additionally, chlorine combines with lignin's aromatic rings to create dioxins including 2,3,4-tetrachloropdioxin and chlorinated furans. These substances cause various health issues and have the potential to cause cancer. H2O2 can degrade lignin in less time and at a lower temperature thanks to the catalytic action of TAML activators. These bleaching agents are used in washing, which uses less water overall.[41]

9.3 Green Solution to Turn Turbid Water Clear

Tamarind seed kernel powder, which is typically dumped as agricultural waste, works well to clarify wastewater from both municipal and industrial sources. At the moment, such water is treated using Al-salt. It has been discovered that alum causes diseases like Alzheimer's by increasing harmful ions in treated water. In contrast, kernel powder is non-toxic, biodegradable, and economical. Tamarind seed kernel powder, a mixture of the powder and starch, starch, and alum, were used as the four flocculants in the study. We made flocculants using slurries by combining a precise amount of clay with water.

The outcome demonstrates that a combination of the powder and suspended particles was more porous, allowing water to easily seep out and compress, resulting in a larger amount of clear water.[42]

9.4 Computer chips

enormous amounts of energy, water, and chemicals. Use supercritical CO2 in one of the chip processing processes. Reduce the amount of raw resources required to make chips.

9.5 Polymers

Plastics or synthetic polymers are used often. The US produces more than 60 million pounds of polymers annually. Biomass, a sustainable resource, is being looked at to produce polymers in order to reduce petroleum consumption. The polylactic acid (PLA) produced by the fermentation of corn at Nature Works is a naturally occurring lactic acid that is biodegradable. The simple conversion of PLA back into LA is another way to recycle it.

9.6 Pesticides

During World War II, dichlorodiphenyl trichloroethane (DDT) was one of the most widely used insecticides. serious harm was done. 1973 saw a ban in the United States. Organophosphates, which break down quickly in the environment but are significantly more harmful to animals, should take their place. Utilize substances that solely kill the intended organisms. For instance, a pesticide activates the body's natural defenses against pathogens or pests by mimicking a hormone only produced by moulting insects.

10. CONCLUSION

The idea of "green chemistry" is founded on twelve principles, which speak of lowering or removing hazardous or dangerous compounds from the synthesis, manufacture, and application of chemical products and thereby the use of substances that are detrimental to human health and the environment. It is impossible to build a green chemistry process that satisfies the requirements of all twelve principles at once, but it makes an effort to do so during specific stages of synthesis.

Green chemistry pursues a number of prominent directions to achieve its objectives of environmental preservation and economic benefit. A few of them are biocatalysis, catalysis, the use of different sustainable raw materials (such as biomass), alternative reaction mediums (such as water, ionic liquids, and supercritical fluids), different reaction conditions (such as microwave activation), and novel photocatalytic processes.

The application of the idea of "green chemistry," which introduces the idea of chemical safety, entails proper legal backing through the legislative control of certain processes and activities, which are necessary for the execution of such an idea.

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