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Review Article

A Review on Evolution and Multidimensional Impacts of Green Chemistry

Rekha Rana[1], Deep Sharma[2], Varun Sharma[3]

Department of Pharmaceutical Sciences

[1,2]Associate Professor, [3]Assistant Professor DDM College of Pharmacy, UNA, Himachal Pradesh, India, Pin code- 177213

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Address for Correspondence: deeppharma86@gmail.com
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Abstract:
Green chemistry which is the latest and one of the most researched topics now days has been in demand since 1990's. Majority of research in green chemistry aims to reduce the energy consumption required for the production of desired product whether it may be any drug, dyes and other chemical compounds to minimize the environmental and occupational hazards inherent in industrial activities. Later, researchers discussed the importance of using twelve principles in the development of new methods and analytical techniques with the purpose of reducing their environmental impacts. Since the 1940s, social movements have revolutionized green chemistry and provided shifts in industrial positions and sustainable processes with advances in environmental impact and awareness of companies and population. One of the most active areas of Research and Development in Green Chemistry is the development of analytical methodologies, giving rise to the new concept of Green Analytical Chemistry. Green chemistry as the name indicates is a technology imbedded, environmental friendly and cost effective utilization of resources that minimize or even eliminate the production of harmful bi-products in the design and manufacturing of the product Here the impacts of green chemistry on environment, pharmaceutical analyzes, population and analyst are described. Every choice and analytical attitude has consequences both in the final product and in everything that surrounds it. This work shows a critical review of the history and evolution of green chemistry as well as its impact on pharmaceutical analysis, environment, population, analyst company and our future.
Keywords: Green chemistry, Multidimensional impacts, Green analytical chemistry

Introduction

Since the 1940s, environmental issues began to emerge in relation to the growth of industrial activities. In the face of environmental problems and concerns, companies have changed their position on conventional production and product development Habits through conferences, political agreements and advances research and ecological engineering adopting sustainable Processes to the present's the 1990s, Paul Anastas and John Warner postulated the 12Principles of Green Chemistry, still in use today, that rely on the Minimization or non-use of toxic solvents in chemical analyzes, as well as the non-generation of wastes from these Processes. These principles propose environmentally favorable actions from the planning of the product to its synthesis, processing, analysis and its destination after use. The main Objective is to minimize the environmental and occupational Hazards inherent in industrial activities [1].Later, Paul Anastas discussed the importance of using these 12Principles in the development of new methods and analytical techniques, with the purpose of reducing their environmental impacts. Thus, one of the most active areas of Research and Development in Green Chemistry is the development of analytical Methodologies. New methods and techniques that are able to reduce the use and generation of hazardous substances in all stages of chemical analysis are the main goals of the so-called Green Analytical Chemistry [2]. In this context, Galuszka Migaszewski and Namenski, in the year 2013, adapted the 12 principles of Green Chemistry, to better fit the Green Analytical Chemistry.

The impacts of green chemistry are multidimensional. Each analytical choice has consequences both in the final product and in everything that surrounds it, from the environment, population, analyst and even the company. Thus this work shows a critical review of the history and evolution of green chemistry as well as its impact on pharmaceutical analysis, environment, population, Analyst Company and our future.

History:

The growing process of industrialization was a milestone for the world Economic evolution. Despite the contribution to the increase in quality of life, the global government policies remained far for the environmental impact that the growth of industrial activities could cause in our planet. The rapid increase in population resulted in increased food production with excessive industrialization, which led to increased Pollution and resource depletion. In this way, natural resources began to be used as if there were no consequences on environmental problem[3]. Although the first concerns about the environment occurred since 1949 at United Nations Scientific Conference on the Conservation and Use of Resources (UNSCCUR) in the USA, environmental issues came into focus in 1968 from the Intergovernmental conference of experts on the Scientific Bases for Rational Use and Conservation of Biosphere Resources, known as the Biosphere Conference. In the 1960s the publication of the book “Silent Spring” stimulated a contemporary environmental movement. The historical book has raised awareness about ecological perception and has provided major government initiatives marked by concern about the risks associated with over exploitation of natural resources. Robert Downs, listed the book as “the book that changed America “And John Kenneth Galbraith cited it as one of the most important books in Western literature .The Stockholm conference occurred in Sweden in 1972, and it Was attended by representatives from a number of countries including members of the United Nations (UN) and nongovernmental organizations, where environmental law was also considered in the legal field. From this conference the world began to be alerted on the environmental damages that the depletion of the ecosystem could cause to humanity.

The 1980s were marked by numerous world conferences on the environment. After an evaluation of the 10 years of the proposed actions at Stockholm Conference, the UN created the World Commission on Environment and Development in 1983 to produce report on world development and environment. This commission was established at a time of unprecedented pressure on the global environment and a growing recognition that much of the development was not sustainable [5]. The report known as the “Brundtland Report” reconciled environmental and social issues and was published in 1987 which for the first time defined the concept of sustainable developments development that meets the needs of the current generation without compromising the future generation. The report also emphasized the dangers of ozone depletion and the effects on global warming stating that scientists' ability to evaluate and propose solutions were lower than the speed of climate change [6].

In 1985, during a meeting of the Environment Ministers of the Countries of the Organization for Economic Co-operation and Development (OECD). Several decisions were made on three main themes: Economic Development and Environment, Pollution Prevention and Control and Environmental information and National Reviews, these decisions persisted until the year 1990.Interventions based on these main themes were central to issues Of chemical product risk reduction and pollution prevention and Control.The US Environmental Protection Agency (EPA) launched the "Alternative Synthetic Routes for Pollution Prevention programming 1991 that reported a new philosophy and policy on controlling the risks of toxic chemical products to prevent problems with These substances, emphasizing that the correct would be then on-production of these products in the first instance.

Since 1992, the inclusion of other topics as environmentally Friendly solvents and safer chemical compounds has been the Expansion and rename of this program, which since then officially adopted the name of green chemistry .The 1990s were marked by a worldwide consensus on environmental preservation. In Brazil there was a United Nations International Conference on Environment and Development in 1992 called ECO-92. The participation of heads of state resulted in the elaboration ration of a document entitled "Agenda 21", which had the commitment of countries to value sustainable development by moving environmental issues, economic policies and decision-making[7].Although the advances in the environment had been awakened worldwide, the environmental awareness of the companies was very insecure. The companies were submitted to controls established by the government when they were pressured by the media and civil society, taking this environmental dimension as a necessary evil, In order to transform the business sector, a program called "Responsible Care", was developed in 1984 in Canada and until the present day it is practiced in 68 economies around the world, improvements in the behavior of industries in relation to the environment, the health and safety of workers with this program: human activities began to be performed in pursuit of progress, replacing harmful activities with activities that emphasized quality of life and a safe environment such as: investments in infrastructure security improvements in energy efficiency, employee safety records, voluntary follow-up of process incident and reduction of hazardous emissions to air, earth and water [4]. Although environmental issues have had major impacts non-industrial and economic sectors. A survey of the European Chemical Industry Council (CEFIC) in 1994 showed that the population's views on the chemical industry were not favorable. In general, the population was mmore attentive to the pharmaceutical and Plastics sectors because of the benefits associated with their needs. Most interviewees did not believe that the chemical industries were concerned about the development of sustainable actions. Opinions generated dislikes about the transportation, safety and waste of these industries, making opinions more favorable to the oil, gas.The International Union of Pure and Applied Chemistry (IUPAC) together with ACS and GCI held four conferences on Green Chemistry between 1997 to 2011. The conferences included topics such as green products and processes to the environment, production energy, renewable sources of chemical waste in addition to adopting green policies and education in green chemistry. Although advances in chemistry and ecological engineering research have adopted sustainable processes over the years, continuing to invest in industrial techniques and policies will be extremely important in the process of implementing environmental improvement.

Green Chemistry:

Cathcart in1990, who presented a discussion on the growth of the Irish chemical industry, probably used the term “Green Chemistry for the first time in a paper title in the year1990. However, only in 1996, the first publication by Anastas and Williamson approached Green Chemistry with the philosophy adopted today [8]

The main concept of Green Chemistry is the use of chemical skills and knowledge to reduce or eliminate the use or generation Of hazardous substances during the planning, manufacturing and application of chemicals in order to minimize threats to the health of operators and the environment. Thus, the concern to eliminate or minimize the generation of toxic waste has become greater than treating the waste already generated. In 1998, Paul Anastas and John Warner published the first manual of Green Chemistry, in which they proposed 12 principles for the theme, which have been described in Table 1.

Table 1: 12 Principles of Green Chemistry proposed by Anastas and Warner.

Number	Principle	Description of principle
1	Prevention	It concerns the prevention of waste generation. It is better to avoid generating waste than to treat it after its generation
2	Atomic economy	Synthetic methods should be planned so that the final product incorporates as much of the reagents used during the process as possible. Thus, waste generation will be minimized
3	Safer chemical synthesis	Synthetic methods should be designed to use and generate substances with low or no occupational and environmental toxicity. Thus, replacement of toxic solvents with low or no toxicity solvents is highly recommended
4	Safer chemicals design	Great importance should be given to the toxicity of the designed chemicals. They should obviously fulfill their functions, but should also present the lowest possible toxicity
5	Use of safer solvents and auxiliaries	The use of solvents and other reagents should be avoided where possible. When it is not possible, these substances should be innocuous
7	Use of renewable raw materials	Whenever it is economically and technically feasible, renewable raw materials should be used instead of non-renewable
8	Reduction of derivatives	Unnecessary derivatization processes should be avoided or minimized, as they require the additional use of reagents and, therefore, generate waste
9	Catalysis	The use of catalytic reagents (as selective as possible) is better than the use of stoichiometric reagents
10	Degradation products design	Chemicals should be designed so that at the end of their function they decompose into harmless degradation products and do not persist in the environment
11	Real-time analysis for pollution prevention	Analytical methods should be monitored in real time to avoid the formation of hazardous substances
12	Accidents prevention	Both the substances and the way they are used in a chemical process should be chosen considering the minimization of potential accidents, such as leaks, explosions and fires, aiming at greater occupational and environmental safety

In1998, Paul Anastas and John Warner published the first manual of Green Chemistry, in which they proposed 12 principles for the theme. In summary, the 12 principles of Green Chemistry are based on The minimization or non-use of toxic solvents in the chemical processes and analyzes, as well as on the non-generation of residues resulting from these processes. For this, the atomic and energy economies occupy prominent places, as well as the use of renewable and innocuous raw materials. In addition, the acceleration of chemical reactions through catalysis can help, for example, in energy savings and less waste generation. One of the principles is also concerned with the conscious development of chemicals, so that after their useful life they must decompose and become degrade gradation products harmless to the environment, also avoiding bioaccumulation. Thus, it is observed that these principles are concerned with the planning of the product, through its synthesis, processing, analysis and its destination after the use. The main objective is to minimize the environmental and occupational risks inherent in industrial activities[8].

At the same time, it is possible to predict some of the economic benefits generated by the adoption of Green Chemistry in industrial chemical processes, such as the lesser need for investment sin effluent storage and treatment, as well as the payment of indemnities for environmental damages. This is an important aspect, since it is clear that if Green Chemistry does not bring economic benefits to the market, it will not be viable. However, if the market ignores the needs of the environment, it will not prosper. To illustrate, we can mention the worst environmental disaster ever recorded in Brazil in 2015, after the collapse of the waste dam of Samarco mining company in the city of Mariana, state of MinasGerais. In this tragedy (Mariana Catastrophe), according to the Brazilian magazine Exam 2017 more than 34 million cubic meters of mud were flowed on down in the Rio Doce, the "sweet river", damaging the life of communities for six hundred kilometers, affecting water supplies and threatening the livelihoods before spilling into the Atlantic Ocean.

However, two years after the Mariana Catastrophe, Samarcothe mining company is still trying to evade its responsibilities by Co-opting the state. Thus, it is possible to understand the extent of environmental financial and reputational damage that a tragedy of this level can cause[10].The efforts that emerged in the 1990s regarding the manufacture of chemicals with the minimum possible use of toxic reagentand solvents also raised a factor used to assess how green an industrial process is. This factor, named “Effector” (efficiency factor), was proposed by Roger Sheldon [7]. Its calculation is based on the division of the mass of the waste generated (kg) by the mass of the finished product (kg). The meaning of “waste” in this context is everything that was formed during the process, with the exception of the final product. Thus all processes must aim for the lowest possible E factor.

It is possible to observe that the higher the production of the segment, the smaller the E factor. The oil refinery for example, which produces from 1 to 100000000 tons per year, presents an E factor of 0.1, while the pharmaceutical industry, which produces from 10 to 1000 tons per year, presents an E factor of 25-100. Thus, through the calculation of E factor, it can be noted that large scale manufacturing processes, although perceived to be worse for the environment compared to small-scale operations. The low performance of the pharmaceutical Industry in this regard, which also occurs in the fine chemical industry comes from the fact that its industrial plants were designed to employ classical stoichiometric reactions, which generate large amounts of inorganic salts as waste. In relation to the toxicity of solvents, there are several guides in this regard, carried out by many institutions and companies. However, Prat and coworkers, in a paper published in 2014, made an interesting comparison of several of these guides and elaborated actable with the compilation of them, in which they divided the solvents into six categories: "recommended", "recommended "problematic "or "hazardous" and "highly hazardous" [11]. Most solvents are highly volatile, easily causing air pollution; In addition, many of them are flammable and toxic. Thus wherever possible organic solvents should be replaced with water. However, this is often not possible, since most organic compounds are not soluble in this solvent. Another alternative to organic solvents is the use of supercritical Co., which is non-toxic and does not contribute to climate change, since it is a byproduct of other processes. Ionic liquids are also a good choice, since they suffer very little evaporation and therefore are not lost to the atmosphere.

Green Analytical Chemistry:

In 1999, Paul Anastas published a paper in which he discussed the importance of using the 12 principles of Green Chemistry, postulated by him and john Warner in the previous year (1998) in the development of new methods and analytical techniques, in order to reduce their environmental impacts. One of the most active areas of research and development in Green Chemistry is the development of analytical methodologies. New methods and techniques that are able to reduce and eliminate the use and generation of hazardous substances in all stages of chemical analysis are the main targets of the so called Green Analytical Chemistry. Galuszka, Migaszewski and Namenski, in 2013, adapted the 12 Principles of Green Chemistry, to better fit the Green Analytical Chemistry [12]. Thus the 12 principles of Green Analytical Chemistry are suggested by Galuszka. Migaszewski indamines (2013) are based mainly on the elimination or minimization of the use of chemical substance, on the minimization of the consumption of electricity, on the correct handling of the generated analytical residues and on the greater safety of the operators. Green chemistry's roots in the of 1990 to stop creating pollution in the first place became America's official policy In 1990 with the Pollution Prevention Act. The law defines source reduction as a practice that:

- Reduces the amount of any hazardous substance, pollutant, or Contaminants entering any waste stream or otherwise released into the environment (including fugitive emissions) prior to recycling, treatment, or Disposal.
- Reduces the hazards to public health and the environment associated with the release of such substances, pollutants, or contaminants.
- The term "source reduction" includes:
- Modifications to equipment or technology.
- Modifications to process or procedures.
- reformulation or redesign of products
- Green chemistry aims to design and produce cost-competitive chemical products and processes that attain the highest level of the pollution prevention hierarchy by reducing pollution at its Source.
- For those who are creating and using green chemistry, the hierarchy looks like this: Source reduction and prevention of chemical hazards.
- Designing chemical products to be less hazardous to human health and the environment.
- Making chemical products from feedstocks, reagents, and solvents that are less hazardous to human health and the environment.
- Designing synthesis and other processes with reduced or even nonchemical waste and designing synthesis and other processes that use less energy or less water. Using feedstock's derived from annually renewable resources or from abundant waste.
- Designing chemical products for reuse or recycling.
- Reusing or recycling chemicals.
- Treating chemicals to render them less hazardous before disposal.
- Disposing of untreated chemicals safely and only if other options are not feasible.
- Chemicals that are less hazardous to human health and the environment are less toxic to organisms, less damaging to ecosystems, not persistent or bioaccumulation in organisms or the environment.
- Inherently safer to handle and use because they are not flammable or explosive.

The Congress hereby declares it to be the national policy of the United States that pollution should be prevented or Reduced at the source whenever feasible.

A. In Research:

Many conferences, research, other academic activities, awards, production, adoption by industry and researcher and many more are being held as green chemistry is a social movement for change; education has a greater role to teach properly about the concept and practice of Green chemistry. The research laboratory is organizing in a well-equipped way to prevent from chemical exposure, adoption of safer technologies, use of greener feedstock practices are increasing. Mostly to the developed nation they are adapting very fast. The recently established institution is adopting recent technologies matched with the green chemistry principle. More advanced research is still to be adopted in the core areas like in renewable feedstock and other Bio-based transformation, design for degradability and structural design. The generated waste should be handled and treated safely to dispose properly. Some renewable feedstock's like eg. Co, are utilizing in various purposes. The polymer that is derived from carbohydrate Feedstock's like corn and soya are seen in automobile and food packing to convert the glucose to a biodegradable polymer, the use of microbial fermentation is increasing. Mostly the use of less toxic solvents or solvent-free synthesis is being more focused. Some large company has categorized ice solvent based on their toxicity and labeled as Green, Yellow and Red. The use of water as a reaction solvent is focusing more and many reactions are done in water with using a proper catalyst, using Phase transfer catalyst and optimized reaction conditions. Even the water sensitive reactions like Grignard reaction can also run in an aqueous medium using various metal like zinc and indium. The use of ionic liquid also increases due to its negligible vapor pressure and their enhanced polar system attracts researcher to perform diverse reactions. The fundamental pillar of GC remained as catalyst development which decreases reaction time, temperature, solvents, reagents, better yields, nontoxic and many more. A lot of researchers are involved in developing a proper catalyst. As greater than 98% of organic chemicals are from petroleum products. So to make sustainable chemistry we need to search renewable sources and many progress, research is going on like utilizing carbohydrate as a feedstock for various chemical syntheses and other polymer chemistry. Some commercially available chemicals like chitin derived from natural shells from crabs and other sea life, which can be further converted to Chitosan, a valuable biopolymer used in various kinds of application in synthesis. The use of genetically modified E. coli to convert glucose to catechol and recombinant saccharomyces yeast can convert both the xylose and glucose to ethanol. The proper analytical detection methods always remained a central role for detecting, monitoring and measuring environmental contaminants. For this many advanced analytical instruments are developed and developing. If we are success to apply the analytical method in real time monitoring especially in feedstock utilization, then we will be able to detect the progress in updated time and control further action if not going well, generating more hazardous chemicals etc. Designing a safer chemical always remains a focused point and many pharmaceutical companies have already got success on it and many researches are going on to develop a safer option. Success in the solvent, pesticide, surfactants, polymer, and dyes are some better example.

B. In Education:

Education is always a milestone to change society. To be a better chemist and work on ethics, better education always plays a crucial role. So the GC now vibrates the academic institutions, professors, researchers, and students. Many GC concepts are incorporated into the curriculum to improve student's better understanding. Many rules and regulation by the Government are tightening to adapt to the GC principal in an academic Research lab and man leadership programs are being held by *Royal chemical Society, American chemical society, German and lap on chemical society* which played great role to make it better and understandable. The GC initiatives include literature, textbooks, some important case studies, experiments at the laboratory, related and other student organization, faculty training, school teacher training, other resource tools, seminar and symposia related to it, and other professional workshops. Now the undergraduate, graduate, Ph.D. program in GC are established.

C. In other parts:

Above discussed are about the role of education and research in green Chemistry. Here other many factors are related to tackling with the GC principle to practice. As we know the basic of GC is, we should be able to change the perspective and thinking that will force us to adopt GC principle throughout the life. In regard to the community, chemical society, Journals, books, symposia, other award recognition, governmental and Non-governmental institutions role are much important. With the aim to promote green chemistry research, education, and outreach in the mid-1990 the OCI (green chemistry institute) begin an opened many chapters in different nations. It is working to promote awareness and many programs as described above. The other network like GC network in the UK, Japan and Italy serves in a similar way and also involves in industrial as well as in an educational journal. To focus Pace reviewed research and other advancements in the field of GC, the Royal Society of Chemistry launched Green chemistry journal and other similar journals are increasing in number. Many green chemistry conferences are held in different countries regularly.

Further Challenge:

Although the GC concept is widely accepted and vibrate researchers, students, faculty, university, industry, policymakers and in general society but many obstacles are also on it.For this, we can view challenges in a below-categorized way:

Challenge in Research:

Describing each challenge in this category is not possible as we know a lot of challenges are in this field but some of the major challenges in research are-

- Schooling researcher in a better way with recent advancement and rapidly adapting green products and services.
- Utilizing energy rather than the materials in transformation.
- Optimization in all sectors with solvents, catalysts, and others. Also development of a toolbox for various synthetic approaches that are benign to environment, health and promote the atom economy harmful additive free design of polymer and plastics and developing other biodegradable product instead of plastics.
- Designing for reuse and recycle for all substances,
- Can be reused but due to the negligence of the researcher, they are just Throwing it.
- The development of non-material intensive and no combustion energy Source.
- Adapting to modern safety technologies and using greener reagents, Solvents throughout the world research laboratory.
- Selective reaction with reactive functionality without using protecting groups.
  Not having enough availability options regarding to agents, solvents, Instruments and many more to adapt to green chemistry,

Challenge in implementation:

- Whatever the principle we develop, the implementation is a core thing to signify the principle to practice. Although, we developed many greener technologies, chemicals and many greener alternatives doesn’t guarantee that it will be adapted rapidly and completely. For this, we need to do many things some of the challenges under this category are pointed
- Adaptable regulation and flexibility, reduced or incentives in tax who use cleaner technologies and green reagents. Research program and collaborative work among the Industries, academic institutions, research institutes and government for technology transfer. Also extension of patent time for optimization of cleaner process.

Challenge in Education:

- Education is the core to change all. The future leader in the industry or any Institution moved there after their education. So giving proper education to the student in an academic institution is core. Some of the needed point and challenges are recognition of the toxicity, hazards with relation to the physical and chemical properties via molecular structure in a systematic way.
- Adapting recent technologies, practically utilizing green chemistry principle in the laboratory during the experiment and providing detailed concept about it. Thinking and further practice of atom economy approach. Providing a better understanding of toxicity and molecular hazards.
- Applying GC topic in institutional as well professional certification exam.
- Repeated seminar, symposia, discussion, awards about GC within the Institution and exposure to the greater stage to numerous students and introducing benefits of adopting green chemistry based on above GC principle many country, industry, institution and the individual persons are carrying out their action, activities, policies and overall direction to shift to the greener concept from use, reuse to the process and finalization.

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