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THE PHILOSOPHY THAT MAKES CHEMISTRY GREEN

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ABSTRACT

The commercial approach of this world has led to the degradation of the environment. Though we have achieved economic success disposal of waste has become an acute problem in most industrialized nations. Green Chemistry has improved our chemical processes by working to reduce chemical wastes and restricting the use of hazardous chemicals. In this way, chemistry is now being applied to improve the manufacturing sector. Earlier chemistry followed traditional methods and primarily worked to minimize exposure to harmful chemicals. But with the advent of green chemistry, the main emphasis is on the improvement of technical design that utilizes hazard-free chemicals and protects the environment. So fundamentals and philosophy of green chemistry prevent the causation and spread of pollution and promote sustainability. Green chemistry has routed its development through different periods. Anastas and Warner proposed twelve principles that described green chemistry as a fundamental mechanism that provided means to face environmental challenges through sustainability.

Keywords: *Environment, Green Chemistry, Hazard-Free Chemicals, Sustainability, Twelve Principles.*

Introduction

The environment is composed of biotic and abiotic components. Biotics is the living components while abiotic are the non-living components. Both of these have unique roles and a balance between them makes our earth a healthy place to live. Abiotic consists of physical and chemical structures that design our habitat and even design our ecosystem's fate. For economic development industrialization is necessary and after the industrial revolution, there has been a continuous increase in the chemical components leading to pollution. This has harmed our ecosystem and contaminated every portion of our planet. Though our comforts are increasing somewhere purity is lost and we find toxic synthetic chemicals spreading everywhere and polluting our food chain. This is now a global trend and now it is a challenge for our chemists, engineers, and scientists to find such eco-friendly pathways for chemical reactions that reduce this pollution and also eliminate the use of hazardous chemical substances. Now for some time, we are facing the problem of global warming and climate change. Our existence is threatened and to reduce pollution we wish to practice those attributes that help to achieve ideal chemical reactions. For this our chemical processes should be safe, simple, selective, and energy efficient. They should also be high yielding and use recyclable raw materials and reagents. All these attributes are desired to be achieved for sustainable development and any environmental impact needs to be minimized. Green chemistry reduces health hazards by making chemical processes eco-friendly. In any chemical reaction, the raw material can be in the form of substrate, solvent, and reagent. These together produce products and wastes. Here wastes can be prevented by using recyclable solvents and reagents. Here in the concept of green chemistry, the wastes and health hazards are eliminated from the beginning by improving the design of the chemical process. Thus green chemistry promotes those industrial processes which achieve sustainable economic growth by minimizing environmental impacts.

Chemistry through Sustainability

Sustainability makes chemistry green and the aspects that make green chemistry sustainable are as follows:

- **Economic Parameter:** Green chemistry adopts simple and selective fundamental techniques and in economic terms, this makes the cost of green chemistry usually less.

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- **Use of Materials:** Green chemistry achieves sustainability by using recyclable materials.
- **Waste Production:** Green chemistry becomes sustainable by reducing and even eliminating waste production.

The Periods of Green Chemistry

The first period began in 1962 when Rachel Carson showed her concern for the environment in her Silent Spring. Later in 1970, President Nixon laid the foundation of the United States Environmental Protection Agency (USEPA). It commanded and controlled the execution of many environmental regulations. In 1985 the focus of the Organisation for Economic Cooperation and Development (OECD) countries was on three main issues- (1) To see the economic development together with the environment (2) Prevention and Control of Pollution (3) Information on environment and reviews on National level. Although regulatory features of US EPA continued but its actions were more inclined toward the prevention of pollution. Now confined to US EPA, an Office of Pollution Prevention and Toxics came up in 1988 which strengthened its commitment to the prevention of pollution. Later Pollution Prevention Act of 1990 was passed by US Congress. There were certain environmental issues that forced the US Congress to remark that the USA emitted a huge amount of pollution and it would be too expensive to be controlled. So environmental and economic concerns prompted the USA to endorse the policy of prevention of pollution.

During the second period ranging from 1993 to 1998 US EPA worked towards achieving the targets of the Pollution Prevention Act and broadly emphasized establishing cooperation and networking. Here networking included activities like organizing symposiums and collaborating officially with certain organizations like the National Science Foundation (NSF) and the Council of Chemical Research (CCR). Such cooperation guided by Pollution Prevention Act worked to achieve environmental and economic goals. Here the chemical philosophy included certain chemical concepts like Atom Economy and Catalysis that developed eco-friendly chemical processes achieving economic goals. Optimization of reaction conditions using recyclable raw material and achieving efficient reaction pathways prevented the spread of pollution. This philosophy framed the foundation of the Principles of Green Chemistry. Green Chemistry continued to receive political patronage and in 1995 US EPA under President Clinton started the Presidential Green Chemistry Challenge Awards. The US EPA along with the University of Carolina and certain industrial organizations formed a network that blended with green chemistry philosophy and further promoted the principles of green chemistry by establishing a charitable Green Chemistry Institute (GCI) in 1997. Prof. James Clark from the University of York used green chemistry as a keyword in his publication on the catalysis of Knoevenagel reaction using γ-aminopropyl silica. Prof. Clark's efforts towards establishing networking led the Royal Society of Chemistry (RSC) to start Green Chemistry Network (GCN) and a journal named Green Chemistry. Later in 1998 Anastas and Warner penned the twelve principles of green chemistry in a handbook that was more like the guidelines erupting from the projections of the 1990s. These accommodated the Pollution Prevention Act of 1990 and the US Clean Air Act with observed amendments that were intended to manage the quality of air.

The third projected as the latest period started from 1999 and further saw the development of green chemistry. In 1999 Prof. Clark in his inaugural editorial in the Green Chemistry journal mentioned about the handbook related to green chemistry that emerged in US EPA. Further, this Green Chemistry journal also contained an article about green chemistry. The majority of the articles that were published later referred to the term green chemistry and the authors published their own results but they did not elaborate on the philosophy of green chemistry that was nurtured inside US EPA. The US EPA continued with its networking efforts. These efforts resulted in a symposium-in-print on green chemistry initiated by a working party related to IUPAC Organic and Biomolecular Division that promoted eco-friendly synthetic pathways. Paul Anastas also published an article on green chemistry in Pure and Applied Chemistry in 2000 and it promoted the philosophy of green chemistry. Further in 2001, an international symposium was held in New Delhi (India) and a conference was held in Colorado (USA) on green chemistry. In 2001 and 2005 Nobel Prize in chemistry was awarded for chemistry that was greener oriented and this raised the importance of the future of green chemistry. There were several networks including journals, seminars, and conferences that promoted the concept of green chemistry internationally. There was a network of Mediterranean countries on green chemistry. In Japan, there was a network of Green and Sustainable chemistry. Green chemistry has now been associated with sustainable chemistry and several green products have been launched. But even now chemical business is more based on the petroleum industry. The Green Chemistry Institute (GCI) got associated with the American Chemical Society (ACS) in 2001. This ACS GCI promotes innovations and research that are based on green chemistry, engineering, and technology and adopts the philosophy of the basic principles of green chemistry. Now future processes and reaction pathways always uphold sustainability as a parameter of green chemistry.

The Pollution Prevention Act of 1990: *Evolution of a Philosophy*

Green chemistry originated from the Pollution Prevention Act. In 1990 America made the prevention of pollution its official policy. It requires the reduction of pollutants at the source where the quantity of any hazardous contaminant that enters any water body or environment is reduced before its disposal. Here the public health hazards caused due to spread of pollutants are also reduced. The contaminants can be reduced at the source by improving the adopted procedures and applied technology. Proper training and maintenance assume importance. Even the products can be reformulated and designs can be improved. Non-toxic raw materials can be utilized. This act assumes prevention and reduction of pollutants at source as the national policy of the USA. If prevention is not possible then safe recycling is necessary for the environment. Further, if both prevention and recycling are not possible then safe treatment of pollutants can be done that does not harm the environment. Disposal of pollutants should be the last resort and it should be environment friendly. The products should be made from eco-friendly raw materials obtained from renewable resources utilizing non-polluting solvents and reagents. The products and even the chemicals used should be designed in such a way that they are least harmful to the ecosystem and are suitable for undergoing reuse or recycling and if disposed they should be environmentally safe. So, all the chemicals used should preferably be less toxic to organisms and must be non-bio accumulative. The chemical process must be energy efficient and consume less water and release minimum waste. This philosophy of green chemistry aspires to reduce contaminants in the beginning and prevents the escalation of chemical hazards.

The Twelve Principles: *Go Green Guidelines*

- **Prevention of Waste:** We should prevent the creation of waste rather than cleaning it up after it has been created. Planning should be done before every step of the chemical reaction so that the wastage is minimized.
- **Economy of Atoms:** We should design and adapt those methods which convert all the reacting material into the final product.
- **Chemical Synthesis to be Less Hazardous:** Those synthetic reactions should be designed that evolve the least toxic substances. The safe synthetic approach will sustain the environment and do the least harm to human health.
- **Designing of Safe Chemicals:** We should design those chemical products that are acceptable and minimize the toxicity level.
- **Safe use of Solvents and Auxiliaries:** The unnecessary use of solvents and auxiliaries should be avoided as they often end up in waste. If used they should be correctly chosen fulfilling the safety norms.
- **Energy Efficient Designing:** Chemical processes should be designed and selected in such a way that there is the minimum environmental and economic impact of energy used. The process should avoid unnecessary steps of over-heating, cooling, high pressure, and vacuum and optimum conditions should be managed.
- **Renewable Feedstock to be Utilised:** Renewable plant-based feedstock should be used and petrochemical-based equivalent chemical resources should be avoided.
- **Reduce Derivative Formation:** Unnecessary formation of derivatives should be avoided as they result from extra steps and consume additional reagents and generate additional waste.
- **Preference for Catalysis:** Catalytic reagents are better than stoichiometric reagents and should be used selectively. Properly selected catalysts should be utilized and this reduces the reaction time and energy demand and less waste are generated.
- **Designing Chemicals for Degradation:** The designing of chemical products should be achieved in such a way that after their use they should break into harmless degradation products and should not accumulate in the environment.
- **Preventing Pollution through Real-time Analysis:** In any process, there should be real-time monitoring and control of the analytical procedures before the formation of hazardous substances.
- **Prevention of Accidents through Safe Chemistry:** In any chemical process those substances should be chosen that have the least potential for any type of chemical accident including fires and explosions. The safety measures will reduce the level of risks that are involved with any technique.

Conclusion

Green chemistry has multidimensional impacts. Networking has played an important role in propagating and generating the philosophy of green chemistry. Although chemistry fulfilled the materialistic demands of our society environmental concerns are being managed by adopting the philosophy of green chemistry. Consistent improvement in designing the energy-efficient reaction pathways has resulted in a reduction in the quantity of waste but continued dependence on petrochemical resources to meet the ever-rising demand still poses a challenge. The impacts of climate change are visible and to arrest these threatening changes the advocacy for green philosophy needs global attention. The disposal of waste is a big problem for every economically concerned country and by adopting the green guidelines sustainable economic growth can be achieved. Only green innovative ideas should be promoted to develop business start-ups to strengthen our commitment to saving the environment and securing a healthy future.

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