



A Study On Role Of Green Chemistry For Pollution Control And Sustainable Development And Conservation Of Biodiversity

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Abstract

Biodiversity is critical for human well-being and activities because it offers a broad variety of ecosystem services; hence its preservation is urgently needed. At the moment, biodiversity is rapidly declining. After climate change, biodiversity loss is the second most significant global risk. The chemical industry plays a critical role in the development of environmentally friendly solutions such as bio based goods and solutions that need the use of biomass. Chemical industry represents a highly successful sector of manufacturing and a vital part of the economy in many industrialized and developing countries. The range of chemical industry is vast which makes an invaluable contribution to the quality of our lives. However, the manufacture of chemical products also leads to enormous quantities of environmentally harmful waste and the health of the environment is declining rapidly. Despite the great success and importance of chemistry to our society its public image has deteriorated. A major reason is that the industry is perceived as being polluting and causing significant environmental damage. “Green” chemistry is an effort of terminating or reducing the use and generation of hazardous chemicals in the design, manufacture and applications of chemical products. Green chemistry efficiently utilizes renewable raw materials, eliminates waste and avoids the use of toxic and/or hazardous reagents in the manufacture and applications of chemical products thereby it plays an important role for pollution control and sustainable development & conservation of environment and Biodiversity.

Key Words: Green Chemistry, Chemical Industry, Sustainable Development and Conservation of Biodiversity.

Introduction

Society has been very much benefitted from Chemical products synthesized. Chemical industry represents a highly successful sector of manufacturing and a vital part of the economy in many industrialized and developing countries. The range of chemical industry is vast which makes an invaluable contribution to the quality of our lives. However, the manufacture of chemical products also leads to enormous quantities of environmentally harmful waste and the health of the environment is declining rapidly [1].

Atmospheric air is polluted by exhaust gases from chemical industries which seriously affect Biodiversity. Lower life forms are more affected e.g. Lichens, Bryophytes, Fungi. On land, Plants are more prone than animals. It is also observed that due to air pollution some species declines but some expand to full fill space of declined species. Contamination of soil by anything is called Soil Pollution. It occurs when pollutants in the soil reduce soil quality and make it inhabitable to organisms such as insects. In recent decades, the use of inorganic fertilizers has increased dramatically. Chemical runoff from pesticides and fertilizers can degrade soil quality. Industrial development has been associated with both physical degradation and chemical contamination of soils. The industry is also responsible for dumping industrial chemicals and heavy metals (such as mercury) onto soil and thus polluting it. Soil pollution can lead to the lack of biodiversity in an ecosystem. The life of bird, insect, mammal and reptile species who live in the soil can get affected by pollution. The soil is an important habitat. When it rains, surface run-off carries contaminated soil into water sources causing water pollution. The contaminated water is thus unfit for both animal and human consumption. It will also affect aquatic life since the organisms that live in these water bodies will find their habitats inhabitable [2]. From all the described species of biodiversity, 6% belongs to fresh water. Effluent from Chemical Industry drastically affects the aquatic life and thus affecting the biodiversity. The pesticides are used to kill fungal or animal pests. As they are sprayed across the entire agricultural field affects lives of many species. Also, most of the pesticides after their use remains in the environment get transferred through food chain and causes many serious problems related to reproduction rates. Major problems in chemical production are handling of waste, the search for environmentally tolerable procedures, the preservation of resources, and the increase in the efficiency. Industry is increasingly realizing that environmental standards are a lifeline to profitability in the highly competitive global and community markets that exist today. The so-called 'triple bottom line', which seeks simultaneous economic, environmental and societal benefits, is seen as a realistic evolutionary goal in chemical manufacturing. This has led to the development of eco-friendly chemical processes to replace the current hazardous processes. Hence, the drive is towards so-called 'Green Chemistry' or 'Cleaner Technology'. Results and Discussion :- "Green" chemistry is an effort of terminating or reducing the use and generation of hazardous chemicals in the design, manufacture and applications of chemical products. The concept of green chemistry was formulated by Paul Anastas at the US Environmental Protection Agency (EPA) to address the environmental issues of both chemical products and the processes by which they are produced. The guiding principle is the design of environmentally benign products and processes, which is embedded in the 12 principles of Green chemistry, which in short can be narrowed down as: Green chemistry efficiently utilizes renewable raw materials, eliminates waste and avoids the use of toxic and/or hazardous reagents in the manufacture and applications of chemical products. Green chemistry eliminates waste at source, i.e. it is primarily pollution prevention than waste remediation [5].

Principles of Green Chemistry: These principles provides a frame work for learning about the green Chemistry and designing or improving materials, products, processes and systems.

- Prevention : It is better to prevent waste than to treat or clean up waste after it has been created.
- Atom Economy: Synthetic methods should be designed to maximize the incorporation of all materials used in the process into the final product.
- Less Hazardous Chemical Synthesis: Wherever practicable, synthetic methods should be designed to use and generate substances that possess little or no toxicity to human health and the environment.
- Designing safer Chemicals: Chemical products should be designed to affect their desired function while minimizing their toxicity.
- Safer solvents and auxiliaries: The use of auxiliary substances (e.g., solvents, separation agents, etc.) should be made unnecessary wherever possible and innocuous when used.
- 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.
- Use of renewable feedstock: A raw material or feedstock should be renewable rather than depleting whenever technically and economically practicable.
- Avoid Derivatization: Unnecessary derivatization (use of blocking groups, protection/deprotection, temporary modification of physical/chemical processes) should be minimized or avoided if possible, because such steps require additional reagents and can generate waste.
- Catalytic Reagents: Catalytic reagents (as selective as possible) are superior to stoichiometric reagents.
- 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.
- Real-time analysis for Pollution Prevention: Analytical methodologies need to be further developed to allow for real-time, in-process monitoring and control prior to the formation of hazardous substances.
- Inherently Safer Chemistry for Accident Prevention: Substances and the form of a substance used in a chemical process should be chosen to minimize the potential for chemical accidents, including releases, explosions, and fires.

It is now generally accepted that the two most useful measures or “Green Metrics” of the environmental acceptability of chemical processes are the ‘E factor’ and the ‘atom efficiency’. One of the major goals of green chemistry is to demonstrate that adoption of the principles, by the industry, can create a competitive advantage.

E Factor: E factor is defined as the mass ratio of waste to the desired product. It takes the chemical yield into account and includes reagents, solvent loss, all process aids and in principle even fuel; excluding water. Higher E factor means more waste and consequently greater negative environmental impact; ideal E factor being zero. So, Chemical synthesis should be developed such that there is minimum E factor.

The concept of atom economy - Among the progenitors of Green Chemistry is Stanford Chemistry Professor Barry Trost, who first proposed the concept of ‘atom economy’ in 1973. The atom economy of a process is calculated by dividing the molecular mass of the desired product by the sum of the molecular masses of all substances produced in the stoichiometric equation .

Environment Laws in India:- The need for protection and conservation of environment and sustainable use of natural resources is reflected in the constitutional framework of India and also in the international commitments of India. The Constitution under Part IVA (Art 51A-Fundamental Duties) casts a duty on every citizen of India to protect and improve the natural environment including forests, lakes, rivers and wildlife, and to have compassion for living creatures. Further, the Constitution of India under Part IV (Art 48A-Directive Principles of State Policies) stipulates that the State shall endeavour to protect and improve the environment and to safeguard the forests and wildlife of the country. Several environment protection legislations existed even before Independence of India. However, the true thrust for putting in force a well-developed framework came only after the UN Conference on the Human Environment (Stockholm, 1972). After the Stockholm Conference, the National Council for Environmental Policy and Planning was set up in 1972 within the Department of Science and Technology to establish a regulatory body to look after the environment-related issues.

This Council later evolved into a full-fledged Ministry of Environment and Forests (MoEF). MoEF was established in 1985, which today is the apex administrative body in the country for regulating and ensuring environmental protection and lays down the legal and regulatory framework for the same. Since the 1970s, a number of environment legislations have been put in place. The MoEF and the pollution control boards ("CPCB", ie, Central Pollution Control Board and "SPCBs", ie, State Pollution Control Boards) together form the regulatory and administrative core of the sector.

Some of the important legislations for environment protection are as follows:

- The National Green Tribunal Act, 2010
- The Air (Prevention and Control of Pollution) Act, 1981
- The Water (Prevention and Control of Pollution) Act, 1974
- The Environment Protection Act, 1986

These important environment legislations have been briefly explained in the succeeding paragraphs

1.The National Green Tribunal Act, 2010: The National Green Tribunal Act, 2010 (No. 19 of 2010) (NGT Act) has been enacted with the objectives to provide for establishment of a National Green Tribunal (NGT) for the effective and expeditious disposal of cases relating to environment protection and conservation of forests and other natural resources including enforcement of any legal right relating to environment and giving relief and compensation for damages to persons and property and for matters connected there with or incidental there to.

2.The Air (Prevention and Control of Pollution) Act, 1981: The Air (Prevention and Control of Pollution) Act, 1981 (the "Air Act") is an act to provide for the prevention, control and abatement of air pollution and for the establishment of Boards at the Central and State levels with a view to carrying out the aforesaid purposes.

3.The Water (Prevention and Control of Pollution) Act, 1974: The Water Prevention and Control of Pollution Act, 1974 (the "Water Act") has been enacted to provide for the prevention and control of water pollution and to maintain or restore wholesomeness of water in the country. It further provides for the establishment of Boards for the prevention and control of water pollution with a view to carry out the aforesaid purposes. The Water Act prohibits the discharge of pollutants into water bodies beyond a given standard, and lays down penalties for non-compliance.

4.The Environment Protection Act, 1986: The Environment Protection Act, 1986 (the "Environment Act") provides for the protection and improvement of environment. The Environment Protection Act establishes the framework for studying, planning and implementing longterm requirements of environmental safety and laying down a system of speedy and adequate response to situations threatening the environment. It is an umbrella legislation designed to provide a framework for the coordination of central and state authorities established under the Water Act, 1974 and the Air Act. The term "environment" is understood in a very wide term under s 2(a) of the Environment Act. It includes water, air and land as well as the interrelationship which exists between water, air and land, and human beings, other living creatures, plants, micro-organisms and property.

Molecular masses of substances produced: Simply, when all the raw chemicals/materials are completely converted into the desired product, there will be no waste generated that is no pollution and there is less effect on environment and biodiversity. Hence, chemical synthesis should be developed in such way that almost all the starting material is converted to product.

Few Important Examples of Green Chemistry: New and green synthesis of ibuprofen by BHC Company, green synthesis of Zoloft,integrated circuit production. Removing Arsenic and Chromate from pressure treated wood. New oxidants for bleaching paper and disinfecting water, getting the lead out of automobile paints, recyclable carpeting. Replacing VOC's and chlorinated solvents, biodegradable polymers from renewable resources (e.g. PLA), use of green solvent like supercritical CO₂, water, ionic liquids and ethyl lactate etc. for designing chemicals and Production of biodiesel by green reaction. Extraction of caffeine from coffee, dry cleaning of cloths using supercritical CO₂ instead of perchloroethylene, green synthesis of adipic acid (raw material for polymer) from glucose by e coli bacteria. Use of TiO₂ as a green catalyst in developing photovoltaic cells and in synthesis etc., use of biomass as renewable resource instead of petrochemicals, uses of catalytic reagents and enzymes in synthesis. Replacing conventional toxic pigment by synthetic azo pigment, use of biodegradable detergent, biopesticides instead of organohalogen pesticides in agriculture. Microwave and ultrasound assisted synthesis are also important examples of green chemistry.



Figure 1: TiO₂ as green catalyst

Global Environmental Issues:-

1.Climate Change like Global Warming: Climate change is a global modification of the climate over a long period of time. These changes can occur both regionally and globally. The main causes of it are the greenhouse gas (GHG) and its effects are global warming and air, water, land pollution. The atmospheric temperature of the world is going to increase day by day due to different human activities and modern civilization, Chemical industry and transportation are the largest contributors to the greenhouse effect, due to their expulsion of the CO₂, VOC's etc. VOC's are found in a wide variety of common products like paints, cleaning products, pesticides, glues, adhesive and fuels. Environmentally these are problematic because they react with oxides of nitrogen in the troposphere to form ozone, which is a large contributor to global warming. The first step to solve this issue is to educate those who are unaware of this global problem. Eliminating environmental effects and toxicity before they generate, rather than trying to clean up the hazard after they have been created, are the work for the future. Recent researches seem to indicate that CO₂ can be kept out of the atmosphere for many centuries if released into the sea, where phytoplankton when sinking in the seafloor takes the carbon with it. On the other hand, global warming can be addressed through behavioural change, emissions reductions and renewable forms of energy, community education and a new vision. This is because on the most part, CO₂ and other GHG's are humanly induced emissions and can be controlled. There are choices regarding sustainability open to the world but steps must be taken now. Global Warming and Climate Change are global challenges and the consequences are indeed dire as we have seen and experienced lately, all over the world. It behooves us all therefore, especially governments, to ensure stringent policies and compliance to well known safety principles that will curb these menace, lack of which is tantamount to the extinction of not just some species of animals and plants but also of the human race [10]. Industrial collaboration of green chemistry institutes / scientists, use of biodiesel to run vehicles and machines can reduce the production of GHG's. We can also reduce the GHG by making the products in a green way and using chemicals or products (green) which are non – hazardous to our health and environment. These facts can minimize the problem of global warming or climate change issues to some extent.

2.Protecting Our Health by Preventing Pollution: Preventing pollution or 'source reduction' is any practice that prevents or reduces pollution at the source. That means using raw materials, energy, water, land and other resources more efficiently thereby reducing or eliminating the generation of waste pollutants. Pollution prevention process also reduces the quantity and toxicity of waste generated. By minimizing the use and production of hazardous materials we can prevent those substances from entering the air, water, soil and food chain. This process is an essential tool for decreasing public health risks and for assuring healthy people and healthy communities (EPA, 1995). Environmental pollution is a worldwide problem and its potential to influence the health of the human population is great. Pollution reaches its most serious proportions in the densely settled urban-industrial centers of the more developed countries. The air we breathe is an essential ingredient for our wellbeing and a healthy life. Unfortunately polluted air is common throughout the world, especially in developed countries. The main pollutants found in the air we breathe include, particulate matter, PAH's, heavy metals, ozone and oxides of carbon, nitrogen, sulfur etc. The water we drink is essential for our healthy life. WHO states that one sixth of the world's population does not have access to safe water. Polluted water consists of industrial discharged effluents sewage water, rain water pollution and polluted by agriculture or households cause damage to human health or the environment. Improper management of solid waste is one of the main causes of environmental pollution. Land pollution is one of the major forms of environmental catastrophe our world is facing today [11].

We are polluting our nature (water, air, soil) by our different activities like industrial and automobile exhaust and by using different chemicals like VOC's, solvents, fertilizers and pesticides etc. The contaminated water we are drinking and polluted air we are breathing and the polluted land we are using for producing crops what we are eating, all these facts making our health in problem. Application of green chemistry in different fields and industry can reduce all kinds of pollution of our nature and a healthy environment can give us a healthy life.

3.Creating the Clean Energy Future: Energy that we are using now is mostly coming from power stations that use coal and petroleum oil. The power stations burn fossil fuels to make our electricity and in that process a LOT of GHG's are made, including CO₂ and CH₄ etc. The GHG's overheat the earth and destroy the climate conditions. It is understood that this will cause more extreme weather, the spread of diseases and threaten the habitat of all living things. Diesel or petroleum oil we are using to run machines in different industries and to run vehicles that also produce a large amount of GHG's. Coal, oil and gases are non-renewable sources of energy because we can use the amount that is available in our planet only. We have already found ways to tap into the energy of the sun, wind, waves and water, amongst other things. These sources of energy produce negligible amounts of GHG once operating. They are also renewable which means they can be used over and over again (Green Cross, Australia). Access to clean, affordable and reliable energy has been a cornerstone of the world's increasing prosperity and economic growth since the beginning of the industrial revolution. Our use of energy in the twenty-first century must also be sustainable. Solar and water-based energy generation and engineering of microbes to produce biofuels are a few examples of the alternatives. These alternative opportunities and pathways could lead to a prosperous, sustainable and secure energy future for the world. Solar, wind and water are examples of clean energy sources we have started to use.

4.Environmental Issues with Agriculture: Agriculture accounts for the major share of human use of land. Crop and livestock production have a profound effect on the wider environment. They are the main source of water pollution by nitrates, phosphates and pesticides. They are also the major anthropogenic source of the GHG's methane and nitrous oxide, and contribute on a massive scale to other types of air and water pollution. The extent and methods of agriculture, forestry and fishing are the leading causes of loss of the world's biodiversity. Agriculture also affects the basis for its own future through land degradation, salinization, the over extraction of water and the reduction of genetic diversity in crops and livestock. (FAO, UN). Pollution of groundwater by agricultural chemicals and wastes is a major issue in almost all developed countries and, increasingly, in many developing countries. Pollution from fertilizers occurs when these are applied more heavily than crops can absorb. Excess nitrogen and phosphates can leach into ground-water or runoff into waterways. Agriculture is also a source of air pollution. It is the dominant anthropogenic source of ammonia and is a major source of GHG emissions. It releases large quantities of carbon dioxide through the burning of biomass, mainly in areas of deforestation and grassland. There is good evidence that delaying and reducing the rates of fertilizer application can reduce overall costs and pollution without hurting yield.

5.Loss of Biodiversity: Biological diversity appears to be in trouble, despite numerous initiatives at the global, national, regional and local level to halt its loss. The convention on biological diversity (CBD) defines biodiversity as "the variability among living organisms from all sources, including terrestrial, marine and other aquatic ecosystems. Biodiverse ecosystems provide multiple goods and services, such as climate regulation, carbon sequestration, pollination, seed dispersal, food control and recreation values [14].

Nevertheless, biodiverse ecosystems -important “livelihood assets” upon which human well-being is overtly dependent through a range of ecosystem services. The main drivers of decline in biodiversity are habitat change, invasive alien species, and overexploitation of species, pollution and increasingly climate change. The impacts of these five key drivers have been increasing over the years despite global and national commitments to reduce biodiversity loss (Millennium Ecosystem Assessment, 2005). Over the last century, humans have come to dominate the planet. Ecosystems are being rapidly altered and the planet is undergoing a massive loss of biodiversity. Biodiversity is the variety of different forms of life on earth, including the different plants, animals, micro-organisms, the genes they contain and the ecosystem they form. It refers to genetic variation, ecosystem variation, species variation (number of species) within an area, biome or planet. Biodiversity is the life support system. The biodiversity plays a significance role in human’s lives. This was well understood 20 years ago. Different countries signed an international agreement called the Convention on Biological Diversity (CBD). The agreement was aimed at protecting biodiversity, using natural resources in a sustainable way and ensuring fair sharing of the benefits of nature. This agreement did not stop the loss of biodiversity. Year 2010 data/evidence showed that the loss of plant/animal species was increasing fast all over the world. When this problem became known, countries decided that specific targets for biodiversity conservation were required until the year 2020, and thus this observation prompted a set of new targets for 2020 (the AICHI target). The primary goal of AICHI was to control biodiversity loss and conserve it. Countries should set specific goals. Parallel to this, a new international body was formed known as the Intergovernmental Science Policy Platform on Biodiversity and Ecosystem Services (IPBES). IPBES evaluates scientific information and advises the government on policy. IPBES evaluates biodiversity and ecosystem services at various levels, including regional, global, and thematic evaluations. Bradley .J. Cardinale et al. (2012) state that we must monitor how we develop and use land, as well as any changes that might endanger ecosystems and biodiversity. The authors also claim that there is a big gap between science and policy right now. It indicates that there is still a policy gap that needs to be filled because we are still ignorant of biodiversity and scientific knowledge. Further research study is required to reduce the gap between scientific and policy gap [17].

6.Natural Resource Depletion: As the human population increases and economies develop, we’re using more natural resources, materials the earth provides that enable economic gain. These substances include minerals, forests, water, fertile soil and more. In many cases, we’re using these resources faster than nature can replenish them [15]. The main causes of natural resource depletion are global overpopulation, poor farming (excess use of chemicals for cultivation), deforestation and human civilization which lead to soil erosion and over consumption of natural resources. Effects of the above come to our nature like water shortage, fossil fuel depletion, extinction of species, loss of forest cover and depletion of minerals etc. The above problems can be solved by controlling deforestation, reducing natural resource (oil, mineral & material) consumption, more exploration and use of renewable energy resources, protecting wetlands & coastal ecosystems and creating awareness among the people throughout the world. Our main natural resource is fossil fuel which is depleting day by day due to the growing need for energy in human civilization. The most obvious solution to the issue of overconsumption of natural resources is to slow down the rate of resource depletion. Less consumption naturally has negative effects on our economic growth so instead, we must look to curb consumption rates while allowing for new industries such as biorefinery, renewable energy and other recycling technologies to flourish and deflect some of the economic burden [16]. Use of renewable energy resources like photovoltaic solar energy cells, hydrogen fuel cells, wind energy and hydro energy and use of bio fuel in a green way can solve the problem to much extent.

Conclusion :- Green chemistry will be one of the most important fields in the future. Scientists, Biologist, engineers and industrialists should work together to promote the development of this field. There is no doubt that the development and implementation of green chemistry will contribute greatly to pollution prevention and thus will play an important role in Conservation of Environment and Biodiversity. However from the above discussion it is very clear that Green Chemistry alone cannot solve the pressing environmental concerns and impacts to our modern era because it's a very small, young and new branch of study comparing to our old environment, but doing more research, study and collaboration with industry we can minimize the toxic effect of chemicals and industry to our environment and aware people around the world about using hazardous things and chemicals and how green chemistry can give us a safe environment. By implementing the twelve principles of green chemistry into practice will eventually help to pave the way to a world where the grass is greener.

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