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GREEN CHEMISTRY AND GLOBAL ENVIRONMENTAL ISSUES

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ABSTRACT:

During the last decades some tragic episodes of contamination or illness have been attributed to the usage of some chemical products. This has driven some people to the assumption that "chemicals" are bad and harmful, while "natural" things are good and healthy. This fear towards "Chemicals" has been named chemophobia. This chemophobia forced people, researchers, scientists and different governments all over the world about clean, environmentally benign and non hazardous Chemistry. Green chemistry is a new philosophical approach for developing more effective chemical production and it is efficient, economical and environmentally friendly. It refers to reducing the damage done to the environment around us, it includes anything from reducing waste to even disposing of waste in the correct manner. To save our environment through green chemistry is to make use of renewable feedstock, biodegradable catalysts in experiments rather than using stoichiometric reagents. To manage our global environmental problems like curbing global warming, creating the clean energy future, protecting our health by preventing pollution, loss of biodiversity, natural resource depletion and environmental issues with agriculture we must need to drastically change the application of traditional scientific methodologies or technological culture.

Keywords: Environmental issues, global warming, Green Chemistry, human health, pollution prevention, renewable resource

I. INTRODUCTION

Green Chemistry is Sustainable or environmentally benign and practice of chemical science and design of chemical products and processes in a manner that is safe & non polluting that consumes minimum amount of materials and energy while producing little or no waste material & utilizing renewable resources. Green chemistry incorporates a new approach to the synthesis, processing and application of chemical substances in such a manner as to reduce threats to health and the environment. This new approach is also known as: Environmentally benign chemistry, clean chemistry, Atom economy and Benign-by-design chemistry (Anastas and Warner, 1998; Wardencki et al., 2005). The origin of green chemistry is Environmental chemistry, which is the scientific study of chemical and biochemical phenomena that occur in natural places and it is the chemistry of air, water, earth and life i.e. atmosphere, hydrosphere, geosphere and biosphere. We must include a fifth sphere i.e.

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anthrosphere consisting of the things humans make and do. The beginning of green chemistry is frequently considered as a response to the need to reduce the damage of the environment by man-made materials and the processes used to produce them. A quick view of green chemistry issues in the past decade demonstrates many methodologies that protect human health and the environment in an economically beneficial manner. A brief history of green chemistry and future challenges are also mentioned below.

II. FACTS BEHIND GREEN CHEMISTRY

World food crisis during World War I and II forced people throughout the world to increase agricultural production. Green revolution takes place to increase agricultural production worldwide. The *Green Revolution* refers to a series of research, development and technology transfer initiatives, occurring between the 1930s and the late 1960s that increased industrialized agricultural production worldwide, especially in the developing world, beginning most markedly in the late 1960s. The initiatives, led by Norman Borlaug, the "Father of the Green Revolution," who won the Nobel Peace Prize in 1970, credited with saving over a billion of people from famine, involved the development of high-yielding varieties of cereal grains, expansion of irrigation infrastructure, modernization of management techniques, distribution of hybridized seeds, synthetic fertilizers, and pesticides to farmers (Kumar Prashant, 2017). During the period of green revolution huge amounts of chemicals have been used to increase the agricultural production and this episode of contamination or illness have been attributed to the usage of some chemical products. This has driven some people to the assumption that “chemicals” are bad and harmful. This fear towards “Chemicals” has been named chemophobia. This chemophobia forced people, researchers, scientists and different governments all over the world about clean, environmentally benign and non hazardous Chemistry. Apart from the above facts some previous issue like Minamata disease in Japan caused by release of methylmercury in industrial water in 1956, and then Rachel Carson (1962) set the agenda for protection of the environment with her ‘Silent Spring’ where she has mentioned the effects of DDT on birds and ecosystem. Acclaimed as the catalyst of the modern environmental movement, the book condemns the overuse of pesticides. From then on, gradually, politics got involved, resulting in the foundation of the US Environmental Protection Agency (US EPA) in 1970 by President Nixon (Linthorst J. A., 2010). By the latter half of the 1980s, the worldwide chemical industry knew that it had to clean up its act: its environmental reputation was dismal. Still fresh in the public mind was the 1984 disaster at Bhopal, India, toxic gas leak at a Union Carbide pesticide plant. Also fresh were memories of the 1978 Love Canal incident in Niagara Falls, New York (Sanderson K., 2011). Chemical companies struggled to deal with increasingly stringent environmental regulations, was an industry-wide move towards what is often called ‘green chemistry’ — a term introduced in 1991 by Paul Anastas, then a 28-year-old staff chemist with the EPA. The goal of green chemistry was never just clean-up, explains Anastas, in his conception, green chemistry is about redesigning chemical processes from the ground up. It’s about making industrial chemistry safer, cleaner and more energy

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efficient throughout the product's life cycle, from synthesis to clean-up to disposal. "It's more effective, it's more efficient, it's more elegant, it's simply better chemistry," says Anastas.

I. IMPLEMENTATION OF 12 PRINCIPLES OF GREEN CHEMISTRY INTO PRACTICE

A. Prevention instead of remediation

It is better to prevent waste than to treat or clean up waste after it has been formed. Example - Synthesis of ethylene oxide (EO) using O_2 (e factor 0.3 kg) rather than synthesis of EO by Cl_2 (e factor 5 kg).

B. Atom Economy

Synthetic methods should be designed to maximize the incorporation of all materials used in the process into the final product. An example is direct high yield synthesis of dimethyl carbonate (DMC), a modern green reagent from CO_2 & methanol.

C. Less Hazardous Synthesis

Whenever practicable, synthetic methodologies should be designed to use and generate substances that possess little or no toxicity to human health and the environment. Synthesis of Adipic acid by oxidation of cyclohexene with 30 % hydrogen peroxide is an example, the process is less damaging to the environment (Sato K. et al., 1998).

D. Designing safer chemicals

Chemical products should be designed to effect their desired function while minimizing toxicity. Example - New less toxic organic based pesticides (Spinosad).

E. Safer solvents and auxiliaries

The use of auxiliary substances should be made unnecessary wherever possible and innocuous when used. Use of supercritical fluid instead organic solvent in extraction and chromatographic separation & use of ionic liquids in synthesis are the example.

F. 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. Example - Enzymatic conversion of sugarcane lignocellulosic biomass as a platform for the production of ethanol, enzyme and nanocellulose.

G. Use of renewable feedstocks

A raw material or feedstock should be renewable rather than depleting whenever technically and economically practicable. Example - Production of surfactants (bio-based or oleo).

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H. Reduce derivatives

Unnecessary derivatization should be minimized or avoided if possible, because such a step requires additional reagents and can generate waste. An example is industrial synthesis of penicillin Vs semi-synthetic penicillin by using pen-acylase enzyme and water.

I. Catalysis

Catalytic reagents (as selective as possible) are superior to stoichiometric reagents. An example is efficient Au (III) catalysed synthesis of β – enaminones from 1,3 – dicarbonyl compounds and amines (Acardi A. et al., 2003).

J. 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. An example is synthesis of biodegradable polymers from renewable resources (sugar based polyester byenzyme catalyzed polycondensation).

K. 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. An example is use of a real-time, in-line sensor for waste water monitoring.

L. Inherently safer chemistry for accident prevention

Substances and the form of substances used in a chemical process should be chosen to minimize the potential for chemical accidents, including releases, explosions, and fires. One of the examples is Dimethyl carbonate (DMC) is an environmentally friendly substitute for Dimethyl sulfates and Methyl halides in methylation reactions of organic compounds (Tundo P. et al., 2000).

I. 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 CO_2, 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 CO_2 instead of perchloroethylene, green synthesis of adipic acid (raw material for polymer) from glucose by e coli bacteria. Use of TiO_2 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

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of organohalogen pesticides in agriculture. Microwave and ultrasound assisted synthesis are also important examples of green chemistry (Ahluwalia and Kidwai, 2004).

Figure 1: TiO_2 as green catalyst

II. GLOBAL ENVIRONMENTAL ISSUES

A. 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 CO_2, 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 (Oristian James, 2015). 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, CO_2 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

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tantamount to the extinction of not just some species of animals and plants but also of the human race (Matawal & Maton, 2013) . 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.

B. 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 (Singh S K, 2016). 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.

C. 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 CO_2 and CH_4 etc. The GHG's overheat the earth and destroy the climate conditions. It is understood that this will cause more extreme weather, the

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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 (Chu and Majumdar, 2012).

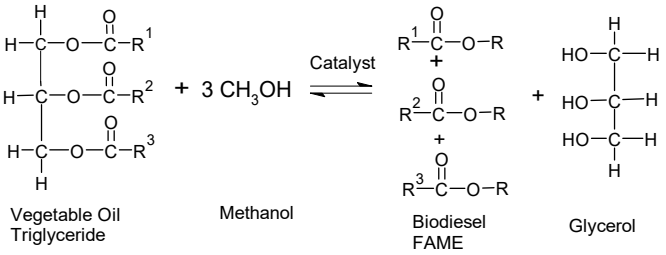

Figure 2: Synthesis of biodiesel from vegetable oil

Instead of using natural resources which produce GHG's we can use renewable resources for a clean energy future like solar energy by the help of TiO_2 as a green photocatalyst to produce solar cells, use of biodiesel to run our machines and vehicles. These can become an alternative of our conventional more polluting thermal power plant.

D. 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

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and grassland. There is good evidence that delaying and reducing the rates of fertilizer application can reduce overall costs and pollution without hurting yield (Tilman et. al., 2002). Agriculture can either sustain or degrade the environment has documented agriculture's main negative effects on land and fresh water, as well as the importance of agricultural landscapes in providing products for human sustenance, supporting biodiversity and maintaining ecosystem services. Negative impacts such as conversion of forests, grassland and other habitats for agricultural use, degradation of soil quality, pollution of soil and surface water through excessive or inappropriate use of pesticides and fertilizers, significant loss of crop and livestock genetic diversity through the spread of industrial monocultures, reducing resilience in the face of climate and other changes. Many agricultural activities can have environmental impacts on air, water and soil (Rohila A. K. et al., 2017). Social, economic, and environmental sustainability are closely intertwined and necessary components for a truly sustainable agriculture. For example, farmers faced with poverty are often forced to mine natural resources like soil fertility to make ends meet, even though environmental degradation may hurt their livelihoods in the long run. Only by creating policies that integrate social, environmental, and economic interests can societies promote more sustainable agricultural systems (Bordt S et al., 2011). To increase our agricultural production we are using many fertilizers, herbicides and pesticides etc. and with that we are polluting our environment and we are eating agricultural products and water which contains many toxic ingredients. Green chemistry can help us to avoid using such halogenated chemicals and can produce chemicals like bio based pesticides, herbicides etc. what we need to increase our agricultural products, which will not cause any environmental problem and to our health.

E. 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 (Daily G C et al., 1997). 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 (Millenium 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.

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Organisms depend on it for the air to breathe, the food to eat, and the water to drink. Thus we must conserve biodiversity. Biodiversity conservation is about saving life on earth in all its form and keeping natural ecosystems functioning and healthy. This incorporates the preservation, maintenance, sustainable use, recovery and enhancement of the components of biological diversity (Rawat and Agarwal, 2015). If there is a biodiversity crisis our health and livelihoods are at risk too. Management of the biosphere for sustainable benefit is necessary to meet the needs of future generations. Human activities like water disposal, dams, use of pesticides, poaching, discharge of effluents and climate like global warming, ozone depletion, acid rain etc. are the cause of altering ecosystems. Due to excess utilization of natural resources loss of biodiversity also occurs. So there is a need for conservation and protection of the environment. Green Chemistry alone can't solve the problem of biodiversity crisis but by preventing environmental pollution (air, water, soil and by implementation of green chemistry principle into practice like use of photocatalytic wastewater treatment, use of green solvent, bio-based fuel, fertilizer, pesticides etc. can play a vital role in this case also.

F. 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 (Nichols M. R., 2019). The main causes of natural resource depletion are global overpopulation, poor framing (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 (Subramanian K R, 2018). 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

The challenges in resource and environmental sustainability require more efficient and benign scientific technologies for chemical processes and manufacture of products. Green chemistry addresses such challenges by opening a wide and multifaceted research scope thus

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allowing the invention of novel reactions, as well as the design of new synthetic schemes that are inherently, environmentally, and ecologically benign. Therefore, combining the principles of the sustainability concept as broadly promoted by the green chemistry principles with established cost and performance standards will be the continual endeavour for economies for the chemical industry. It is, therefore, essential to direct research and development efforts towards a goal that will constitute a powerful tool for fostering sustainable innovation. 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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