B.Sc. Semester – II

Subject: - GE - 202: Green Chemistry

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1.1. Current status of chemistry and the Environment.

Environmental chemistry is the study of the chemical and biochemical phenomena that occur in nature. It involves the understanding of how the uncontaminated environment works, and which naturally occurring chemicals are present, in what concentrations and with what effects. Without this it would be impossible to study accurately the effects that humans exert on the environment through the release of chemical species.

At present, many environmental issues exist that have grown in size and complexity day by day, threatening the survival of mankind on earth. The various incidences of such environmental issues include London smog of 1952—killing about 4000 people, the Mediterranean sea turning into Dead Sea in the 1950s—unable to support aquatic life, death of a number of Japanese people because of eating fish from the Minamata Bay in the 1960s, historical monuments and statues in Greece and Italy getting damaged by the effect of rainwater, white marble of Taj Mahal in India 16 Introduction to Environmental Sciences becoming yellow by the action of sulphur dioxide fumes, leakage of methyl isocyanate (MIC) vapours at Bhopal in India in 1984, and the hazardous effects of nuclear weapons and radiations on the people of Hiroshima and Nagasaki. Pollution of river water in India, use of plutonium or other isotopic fuel-based breeder/nuclear reactors for energy production, use of dangerous artificial food additives, and ozone hole in the Antarctic and Arctic regions are some typical chemical issues that need to be resolved critically.

1.2. Evolution of the Environmental movement

✓ Public awareness

- ➢ After the scientific and industrial revolution in the recent past, there has been immense impact of man on his environment and balance of the ecosystem as a whole/the environment.
- ➢ Industrialization , urbanization, deforestation , use of insecticides, pesticides, improper use of fertilizers and chemicals in environment are some contributing factors which challenged the life of man, animals specially birds and other organisms.
- ➢ Human activities are causing many kinds of environmental pollutions for which public awareness is necessary.
- ➢ The Active co-operation of every one, at every level of social organizations is needed for issues concerning environment.

- Over exploitation of natural resources is a basic concern for everybody. Therefore, we should accept the family planning schemes this will not only reduce the population but also solve the problems of food and rehabilitation.
- There must be planning about the effects and control measures of environmental pollution. Govt. should initiate and help by awareness campaigns to save environment.
- There should be the integral part of our educational programs. Like, we should discourage to use fuel vehicles, until it is not necessary, over use of water, for cleaning and other purposes should be decreased. Rain water harvesting is another example for using the rain water instead flowing out.
- Any government at its own level cannot achieve the goals of sustainable development until the public has a participatory role in it.
- It is only possible only when public aware about the ecological and environmental issues. For example ban the littering of polythene cannot be successful until the public understands the environmental implications of the same.
- Public should understand about the fact that if we degrading our environment, we are harming ourselves.
- This is the duty of educated people to educate the others about the adverse effect on environment.
- Govt. alone cannot do anything until unless every citizen is aware of the environmental pollution & their effects.
- Everyone need to make aware and motivate each and every individual for environmental consciousness.

✓ **Dilution is the solution to pollution**

Dilution was the solution to pollution when populations were small. Everything people wanted to get rid of went into the water. These wastes were typically organic, such as human wastes and animal carcasses. They became food for animals, macroinvertebrates, bacteria, and fungi that broke down the waste. As small villages grew into towns and towns into cities, waterways were overwhelmed by the amount of disposed wastes, and many rivers became open sewers.

A larger problem developed during the Industrial Revolution. Chemicals used in industry were added to the mix in the rivers. Many of these substances could not be broken down naturally or biodegraded even in wastewater treatment plants. But because lower concentrations of cancer-causing pollutants, for instance, proved less harmful or had no effect in animal studies, the dilution of pollutants in large amounts of water was thought to be an effective method of disposal. Scientists, however, have recently discovered that many pollutants (pesticides, industrial chemicals, and pharmaceuticals) mimic hormones and can interfere with the reproduction of birds and fish at parts per million (ppm) to parts per billion (ppb). Dilution cannot render these pollutants harmless.

Nor does dilution work for chemicals that bioaccumulate. These persist through the food chain and increase in each organism. The U.S. Environmental Protection Agency (EPA) has banned twenty-two bioaccumulating chemicals (BCCs) in its Great Lakes Initiative (1995), including dichlorodiphenyl trichloroethane (DDT), polychlorinated biphenyls (PCBs), mercury, and dioxins. The Great Lakes Basin 2020 Action Plan of Environment Canada's Great Lakes Programs is working on the same problems. The International Joint Commission has designated forty-two areas of concern (AOCs) or pollution hot spots in the Great Lakes region. EPA regulations require industries using these chemicals to treat them at the source rather than releasing them into waters.

The Whole Effluent Toxicity (WET) test is used to test the toxicity of effluent flowing into uncontaminated waters. The WET test is species-specific. The EPA has developed "Self-Implementing Alternate Dilution Water Guidance." This is included in any National Pollutant Discharge Elimination System (NPDES) permit issued by the EPA and would be used if a WET test shows the toxicity of water at the site for the species specified by the NPDES permit.

✓ **Pollution prevention**

Sustainable development is now accepted by governments, industry and the public as a necessary goal for achieving the desired combination of environmental, economic and societal objectives. This requires a new approach whereby the materials and energy input to a process are minimized and thus utilized at maximum efficiency. The dispersion of harmful chemicals in the environment must be minimized.

We must maximize the use of renewable resources and extend the durability and recyclability of products, and all of this must be achieved in a way that provides economic benefit to the producer and enables industry to meet the needs of society.

We can start by considering the options for waste management within a chemical process. From an environmental point of view it is more important to know how many atoms of the starting material are converted to useful products and how may to waste.

For prevention of pollution we must be apply 12 principle of green chemistry:

Pollution prevention option can be considered at every stage in the life cycle of a chemical product. In general we should be increasingly at the industrial ecology goals for green chemistry like:

- ✓ Adopt a life-cycle perspective regarding chemical products and processes.
- ✓ Realize that the activities of your suppliers and customers determine, in part, the greenness of your product.
- ✓ For non-dissipative products, consider recyclability
- ✓ For dissipative products (e.g. pharmaceuticals, crop-protection chemicals), consider the environmental impact of product delivery
- ✓ Perform green process design as well as green product design

✓ The role of Chemistry

Chemistry is having a difficult time. While society continues to demand larger quantities of increasingly sophisticated chemical products, it also regards the industries that manufacture these products with increasing degrees of suspicion and fear.

The range of chemical products in today's society is enormous and these products make an invaluable contribution to the quality of our lives. In medicine, the design and manufacture of pharmaceutical products has enabled us to cure diseases that have ravaged humankind throughout history. Crop protection and growth enhancement chemicals have enabled us to increase our food yields dramatically.

Chemistry has played, and continues to play, a fundamental role in almost every aspect of modern society, and, as the enormous populations in China, India and the emerging nations demand western levels of healthcare, food, shelter, transport and consumer goods, so the demands on the chemicals industries will grow. The successful development of the chemicals industries has almost had an inverse relationship with public perception. Since writing, over five years

The growth in the chemicals industries in the twentieth century was at the cost of producing millions of tons of waste, and if we extend the discussion to include health and safety issues then we must add the chemical disasters that have led to much unfavorable publicity and have hardened the views of many critics. The increasing levels of environmental awareness among the general public make it even more important that the chemicals industries 'clean up their act'. Public acceptability of environmental pressure groups adds to their influence and together they effectively force governments to use legislation to force industry into making improvements.

How much do we need to change? Although early work to 'green' the manufacture of chemicals was focused largely on reducing the environmental impact of chemical processes, a much wider view will be necessary in the new century. An exaggerated but illustrative view of twentieth century chemical manufacturing can be written as a recipe.

[1] Start with a petroleum-based feedstock.
[2] Dissolve it in a solvent.
[3] Add a reagent.
[4] React to form an intermediate chemical.
[5] Repeat (2)–(4) several times until the final product is obtained; discard all waste and spent reagent; recycle solvent where economically viable.
[6] Transport the product worldwide, often for long term storage.
[7] Release the product into the ecosystem without proper evaluation of its long-term effects.

The recipe for the twenty-first century will be very different:
[1] Design the molecule to have minimal impact on the environment (short residence time, biodegradable).
[2] Manufacture from a renewable feedstock (e.g. carbohydrate).
[3] Use a long-life catalyst.
[4] Use no solvent or a totally recyclable benign solvent.
[5] Use the smallest possible number of steps in the synthesis.
[6] Manufacture the product as required and as close as possible to where it is required.

The broader picture will apply not only to chemical manufacturing but also to transportation, legislation and, most critically, education. We must train the new generation of chemists to think of the environmental, social and economic factors in chemicals manufacturing.

1.3. Green Chemistry

✓ What is Green Chemistry

The term green chemistry was coined by Paul Anastas im 1991. However, it has been suggested that the concept was originated by Trevor Kletz in his 1978 paper where he proposed that chemist should seek alternative processes to those involving dangerous substances and conditions.

Green chemistry, also called sustainable chemistry, is an area of chemistry and chemical engineering focused on the designing of products and processes that minimize the use and generation of hazardous substances. Whereas environmental chemistry focuses on the effects of polluting chemicals on nature, green chemistry focuses on the environmental impact of chemistry, including technological approaches to preventing pollution and reducing consumption of nonrenewable resources.

As chemical philosophy, green chemistry applies to organic chemistry, inorganic chemistry, biochemistry, analytical chemistry, bioengineering and even physical chemistry. While green chemistry seems to focus on industrial applications, it does apply to any chemistry choice. Click chemistry is often cited as a style of chemical synthesis that is consistent with the goals of green chemistry. The focus is on minimizing the hazard and maximizing the efficiency of any chemical choice. It is distinct from environmental chemistry which focus on chemical phenomena in the environment.

✓ Definition

The term green chemistry is defined as: the invention, design and application of chemical products and processes to reduce or to eliminate the use and generation of hazardous substances.

✓ Why is this new area of Chemistry getting to much attention

Green chemistry is the design of chemical products and processes that reduce or eliminate the use or generation of hazardous substances. Green chemistry applies across the life cycle of a chemical product, including its design, manufacture, use, and ultimate disposal. Green chemistry is also known as sustainable chemistry.

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

- Prevents pollution at the molecular level
- Is a philosophy that applies to all areas of chemistry, not a single discipline of chemistry
- Applies innovative scientific solutions to real-world environmental problems
- Results in source reduction because it prevents the generation of pollution
- Reduces the negative impacts of chemical products and processes on human health and the environment
- Lessens and sometimes eliminates hazard from existing products and processes
- Designs chemical products and processes to reduce their intrinsic hazards

✓ Why should chemist pursue the Goals of Green Chemistry

Green chemistry is spreading from academic labs into industry as a way to reduce costs, as well as environmental, health and safety risks. Applications of the 12 guiding principles are found on scales small and large, from choosing ingredients for reactions that minimize waste and risk to metrics that quantify waste and process efficiency. And principles of engineering and process design lead green chemists to track energy use during production, search for sustainable raw materials, and build biodegradable or recyclable products to prevent waste.

Further adoption of green chemistry could improve the public's perception of the field of chemistry as a whole. Proponents of green chemistry say the field combines environmental, health, and safety benefits with the traditional goals of economic gains in industrial chemistry and knowledge gains through academic research. Economics and knowledge, while important reasons to pursue chemistry, can conflict with the public's perception of chemistry as a toxic undertaking, particularly when safety, sustainability, and protection of the environment are on their minds. Promoting green chemistry research, and its adoption into industry, through federal policies and education might help the field of Chemistry Bridge the divide between its values and those of the public. Thus, the growth of green chemistry can lead to gains in other areas: profits, public perceptions, and protecting our planet.

✓ **Limitations / obstacles**

Given below are some of the key limitations to implementation & industrialization of green chemistry:

1. **Availability of green technologies**
2. **Scale-up and commercialization**
3. **Connecting green chemistry solution providers to industry**
4. **Understanding of basics of green principles**
5. **Green chemistry is costly, complex and not viable for SMEs?**
6. **Regulatory hurdles**

1. Availability of green technologies

The green chemistry tool box (set of platform technologies, based on the principles of green chemistry & engineering, alternative to conventional synthetic chemistry based processes/chemistries) is still quite empty. We still do not have viable green chemistry based solution for many chemistries/processes like nitration, sulphonation, Friedel-Craft, etc.

This is one limit, which academic & research institutes can make significant contribution in overcoming. Creating some fundamental invention/innovation in these areas is a very relevant problem which academic & research institutes can work on.

2. Scale-up and commercialization

There are many inventions/innovations that have already been developed by various academic and research institutes and these are potential solutions for some of the environmental challenges faced by the industry. However, for whatever reasons, these solutions have not been pursued after lab scale development. Scale-up and commercialization is a barrier because it calls for both academic/research institutes as well as industries to stretch themselves beyond their boundaries.

3. Connecting green chemistry solution providers to industry

There are many green chemistry solutions that are ready (with some start-up company, scientist/researcher, academic/research institutes, etc) and are proven. These are the most 'low hanging fruits'. One of the key barriers is the communication gap between the industry and such solution providers. This could be because the industry is in one part of the world and the solution provider is in other part of the world. This could also be due to insufficient marketing of the potential solution by the solution provider. This could also be due to industry not putting enough efforts to search and look around for solutions.

4. Understanding of basics of green principles

One of the barriers in implementation of green chemistry is that chemists & chemical engineers working on designing new products and processes have limited knowledge about the basic principles of green chemistry & engineering.

5. Green chemistry is costly, complex and not viable for SMEs?

Certain myths about green chemistry prevailing around us are also a barrier in implementation of green chemistry in the industry. Myths like green chemistry is good theory but practically not feasible, green chemistry is difficult & complex, it is not viable for small & medium size organizations, it requires huge resources, etc.

6. Regulatory hurdles

This is a big barrier for the pharmaceutical and other industries where any change in process (when a green chemistry based process is replacing a conventional process) has to go through validation trials, change in documentations and filings as well as series of approvals from internal regulatory affairs team, customers and, finally, from external regulatory agencies. Besides the time invested for tedious process of making these changes in Drug Master File (DMF) filings, this also involves significant cost/financial resources.