Alternative synthetic approaches for the industrial pollution control and prevention

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Abstract
Green methodologies are developed alternative methods to the existing methods so that toxic reagents, toxic byproducts and hazardous or toxic intermediates in a particular system (chemical) have been completely eliminated or minimized to maximum. Green methodology involves in the design and redesign of chemical synthesis and chemical products to prevent pollution e.g. using of thermal polyasparate (TPA) which is biodegradable and non-toxic in many industrial applications instead of non-biodegradable Polyacrylic Acid (PAC) to improve the performance characteristics of the reaction. Green methodologies are to be considered in the development of waste management systems by which the materials and energy may be recovered. Maximum pollution to environment is done by numerous chemical industries where chemical synthesis is conducted. Green methodology uses environment friendly approach to reduce or eliminate pollutants from the environment. Atmosphere and hydrosphere is the largest sink for pollutants believing that a dilution of pollution is the best solution to check it. Green methodology believes that prevention is better than cure to provide safer, habitable and maintainable environment. CO$_2$ gas is readily available as a recoverable byproduct from ammonia manufacture and natural gas units which can be used as resource for manufacturing the extruded polystyrene foam sheets. By removing CO$_2$ byproduct in the above process, it cannot contribute to the green house effect. Against these backdrops, this review presents some of the alternative synthetic approaches for the industrial pollution control and prevention.

Keywords: Green methodologies, toxic byproducts, thermal polyasparate, pollutants, green house effect.

Introduction
Atmosphere and hydrosphere (particularly oceans and seas) are the largest sink for the air pollutants and water pollutants believing that “Dilution is the solution to pollution”. By diluting the pollutants, the risk factors related to health may be reduced substantially for a particular species, but it may be hazardous to other species. Maximum pollution to the environment is contributed by numerous chemical industries and other chemical related industries where many chemicals and chemical synthesis are involved. The aim and objectives of this review is to follow the environmental friendly chemical synthesis through alternative methods. In this review, emphasis is also given to green chemistry and green technologies which have contributed to alternative pathways of synthesis to reduce or eliminate pollutants.

Industrial pollution and their impact
According to the Environmental Law, Section 2(b) and (c) of the Environment (Protection) Act, 1986 reads as an environmental pollution is the presence of any environmental pollutant, defined as any solid, liquid, or gaseous substance present in such concentration as may be, or may tend to be injurious to the environment. Environmental science says that the environmental pollution refers to severe degradation of environmental sustainability and lowest level of the carrying capacity to the earth.

Environmental sustainability refers to the maintenance and regeneration of fresh air, clean water, fertile soil and essential biotic resources, which in turn, depend on assigning serious disruption of ecological processes. The carrying capacity of the earth is defined as the maximum number of biota including humans to whom the earth could adequately provide all the basic amenities-food, water, air and shelter, particularly without decreasing the capacity of the earth to provide such amenities adequately in the future also.

Environmental pollution due to industries is very acute in India. Industries are the major source of air, soil, water and noise pollution. In 1884, the Government of India designated 20 categories of “polluting industries” for which the choice of location is also an important control mechanism (Balaram Pani, 2004). These 20 industries cover a broad range of chemical and metal manufacturers. They are distilleries, sugar, fertilizer, refinery, pulp and paper, basic drugs, pharmaceuticals, dyes, petrochemicals, pesticides, cement, iron and steel, leather, aluminium, caustic, zinc, copper, thermal power plant, mining and hydroelectric power industries. The major impacts of these industries are both global and regional environmental pollution like global warming, acid rain, soil erosion, deforestation, desertification, climate changes etc.
Maximum pollution to the environment (air, water and soil) is contributed by the above mentioned 20 categories of industries and to some extent contributed by other industries where many chemicals and chemical synthesis are involved. Many kinds of pollutants are emitted into the environment, each having its own way of impact. The adverse effects of the environmental pollutants can be broadly divided into acute and chronic effects on health of the living organism (Balaram Pani, 2007). The effects on different living organism and non-living substances are categorized in to four sections:
1. Physico-chemical effects
2. Biological effects
3. Pathogenic effects
4. Effect on materials

**Physico-chemical effects:** The pollutants have different physico-chemical effects in different environmental ecosystems.

- **In atmosphere:** Effects on temperature (Green House gases and ozone depletion), Climate changes (Local and Global), Visibility (Photochemical smog).
- **In hydrosphere:** Effects on colour, acidity and basic values, oxygen level etc.
- **In soil (Lithosphere):** Effects on soil, air, soil moisture, soil temperature, organic matter contents, porosity etc.

**Biological effects:** The higher concentration of pollutants in the environment can lead to many disturbances in the biological ecosystem. It may be
(i) Shifting or elimination of flora and fauna.
(ii) Increase of diversity of species.
(iii) Change of ecosystem from autotrophic to heterotrophic.
(iv) Decrease the metabolic process of many plants.

**Pathogenic effects:** The polluted conditions of environment give rise to pathogenic, non-pathogenic microorganism and viruses. These pathogenic organism and viruses spread many deadly diseases. These diseases may be classified as water borne, air borne and infectious diseases.

**Effects on materials:** Ozone degrades the fabric and rubs them. Sulphur-di-oxide (SO₂) corrosion of steel, copper, zinc and other metals.

**Remediation**

There are numerous attempts that have been made by utilizing a variety of methodologies and techniques to prevent pollution. Science and advanced technologies have also contributed to alternative pathways of synthesis to reduce or eliminate pollutants. Remediation is a process of removing chemical contaminants or pollutants from the affected areas by applying different methods and techniques to protect human health and the ecosystem. It is based on the theory that “Pollution control at the source (Fig. 1).

Disodium iminodiacetate (DSIDA) is a key intermediate in the production of Monsanto’s Roundup(r) herbicide by using the well-known Strecker process (requiring ammonia, formaldehyde, hydrogen cyanide and hydrochloric acid) (Office of pollution prevention and toxics, 1996). Monsanto has developed and implemented an alternative DSIDA process that relies on the copper catalyzed dehydrogenation of diethanolamine (DEA).

The chemistry that prevents problems and solves current pollution is known as green chemistry. The basic theory or principle of green chemistry is:
- Prevention is better than cure
- Zero waste technology
- Pollution control at the source

Green chemistry is a particular type of pollution prevention (Anastas and Farris, 1994; Anastas and Williamson, 1996; Collins, 1997). Green chemistry is an approach that provides a fundamental methodology for changing intrinsic nature of a chemical product or process so that it is inherently of less risk to human health and the environment. These objectives are achieved through applying the green methodologies. One of the most important green methodologies is ‘Bioremediation’. Bioremediation is a process of clearing chemical contaminants from a polluted area by biological methods. Generally, the bioremediation technology is applied to remove the volatile, semi-volatile, solvents, organic pollutants, organic solvents and pesticides from the polluted areas namely:
(i) Water hyacinths-absorbs heavy metals from polluted water.
(ii) Horseradish roots-removing phenols from effluents carrying out of chemical industries.

Polymers are a very important class of compounds that have broad application and a wide array of properties that can be exploited.
The work of Gross et al. (1994) utilizes biosynthetic methods to make the polysaccharide based polymers, a technique that can often be employed as a substitute for carrying out the same transforming using more hazardous substances. Similarly, using biotechnological techniques to manipulate the shikimic acid pathway (responsible for making many of the aromatic compounds in nature), compounds such as hydroquinone, catechol, and adipic acid, all of which are important large volume chemicals can be synthesized (Draths and Frost, 1990a, b; 1991). Monsanto Company has developed a method of synthesizing poly-urethanes and their isocyanate precursors that totally eliminates the use of phosgene (McGhee and Riley, 1993).

Biocatalysts are used in many organic syntheses to save the environment from toxic pollutants. Bioremediation has involved four basic methods, such as:

1. **Bioaugmentation**: It is a process on which the microorganisms are added to degrade the toxins.
2. **Biostimulation**: In this process, oxygen and nutrients are supplied to enhance the growth of indigenous microorganisms.
3. **Biosparging**: In this process, injection wells are used to deliver oxygen in to the saturated aqua to promote biological degradation of contaminants.
4. **Bioventing**: In which wells are used to deliver oxygen to the unsaturated zone to promote biological degradation of contaminants.

The rate and efficiency of bioremediation are greatly influenced by the degradability and the presence of toxin elements. The order of effectiveness of bioremediation of chemicals is:

Degradable and non-toxic > degradable and toxic > non-degradable and nontoxic > non-degradable and toxic.

**Conclusion**

This alternative pathway used to get the same final product by reducing or eliminating toxic starting materials, byproducts and wastes. Green chemistry is the use of chemical principles and methodologies for source reduction, the most effective form of pollution prevention and it satisfies the principle of zero waste technology. Green chemistry involves the design and redesign of chemical synthesis and chemical products to prevent pollution. This developed alternative chemical synthesis may be applied to every field of service to solve the environmental pollution problems. The theory “Prevention is better than Cure” is always considered as better “Environmental Ethics” than “Dilution is best solution to Pollution”.

**References**