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Combating air pollution through green chemistry methods

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Abstract
Chemistry plays an essential role in our lives, with its applications having a global impact across various fields. It is integral, especially in areas like medicine, where we heavily rely on chemical applications. However, many reactions taught in pharmaceutical and medicinal chemistry labs today pose environmental hazards, necessitating modifications. In response to the Pollution Control Act, a newer branch called Green Chemistry has emerged, representing a vital component for our sustainable future. Numerous industries and academic researchers recognize the importance of adopting green chemistry practices. Green chemistry, also known as sustainable chemistry, is an approach that focuses on designing products and processes that minimize the use and generation of hazardous substances. It aims to reduce the environmental impact of chemical processes and products throughout their life cycle.

Keywords: Simultaneously, chemistry, redesigning, materials

Introduction

Chemistry's widespread applications are undeniable and crucial for various purposes globally. However, our focus should shift towards green chemistry, also known as sustainable chemistry, aiming to minimize or eliminate environmental harm. This encompasses efforts ranging from waste reduction to proper waste disposal. All chemical waste must be disposed of responsibly to prevent harm to the environment and living organisms. This article provides a concise overview of the implementation of various green chemistry principles and their applications in both basic and applied research [1-2].

Green chemistry comprises two primary components. Firstly, it tackles the issue of efficiently utilizing raw materials while simultaneously minimizing waste generation. Secondly, it addresses health, safety, and environmental concerns associated with the manufacturing, use, and disposal or reuse of chemicals. Green chemistry introduces a novel approach to the synthesis, processing, and application of chemical substances, aiming to mitigate threats to health and the environment. This approach is also known as environmentally benign or clean chemistry. Coined by Paul T. Anastas in 1991, the term "Green Chemistry" aims to design chemicals and processes that are less harmful to human health and the environment, not merely by cleanup but by inventing new, non-polluting chemical processes [2-4].

The 12 Principles of Green Chemistry

The 12 Principles of Green Chemistry, formulated by Paul T. Anastas and John C. Warner, serve as a set of guiding principles for designing environmentally friendly and sustainable chemical processes [2]. These principles aim to minimize the environmental impact of chemical manufacturing and promote the development of greener alternatives. Here are the 12 Principles of Green Chemistry:

1. Prevention

Emphasizes the importance of waste prevention over cleanup after its formation. Redesigning chemical transformations to minimize hazardous waste generation is a key step in pollution prevention.

2. Atom Economy

Promotes the efficient use of all atoms in a chemical process, minimizing waste generation and choosing transformations that incorporate most starting materials into the final product.

3. Less Hazardous Chemical Synthesis

Aims to reduce the hazard of chemicals used in product synthesis. Focuses on using less toxic reagents and designing synthetic methodologies that generate substances with minimal toxicity.

4. Designing Safer Chemicals

Advocates for the design of safe and non-toxic products. Particularly crucial in pharmaceuticals, where the design of chiral molecules can have life-altering consequences.

5. Safer Solvents

Promotes the use of environmentally benign solvents, with an emphasis on water as an ideal, inexpensive, and non-toxic solvent.

6. Design for Energy Efficiency

Focuses on creating products and materials in an energy-efficient manner, contributing to global efforts in renewable energy and energy conservation.

7. Use of Renewable Feedstocks

Encourages a shift away from petroleum dependency to make products from renewable materials. Examples include biodiesel and bio-based plastics.

8. Reduce Derivatives

Urges the avoidance of unnecessary derivatization, as additional reagents for protection/deprotection steps generate more waste.

9. Catalysis

Encourages the use of catalysts to reduce energy requirements and increase reaction efficiency, with an emphasis on green catalysts, such as enzymes.

10. Design for Degradation
Aims to design products that do not persist in the environment and degrade into simple, non-toxic substances.

11. Pollution Prevention
Emphasizes using materials, processes, or practices that reduce or eliminate pollution or wastes at the source.

12. Safer Chemistry for Accident Prevention
Focuses on using materials and chemicals that ensure safety for workers and surrounding communities, avoiding highly reactive and potentially hazardous chemicals.

These principles can motivate chemistry at all levels: research, reduction to practice, education and public perception. The first principle describes the basic idea of green chemistry in protecting the environment from pollution. The remaining principles are focused on such issues as atom economy, toxicity, solvent and other media using consumption of energy, application of raw materials from renewable sources and degradation of chemical products to simple, nontoxic substances that are friendly for the environment [5-6].

Ways to Overcome Air Pollution
Overcoming air pollution is a complex challenge that requires a combination of regulatory measures, technological innovations, and individual actions. Here are various ways to address and overcome air pollution:

1. Transition to Clean Energy.
2. Enhance Vehicle Efficiency.
3. Strict Emission Standards.
4. Waste Management.
5. Afforestation and Green Spaces.
6. Regulate Industrial Processes.
7. Education and Awareness.
8. Incentivize Green Technologies.
9. International Cooperation.

Air Pollution Control Measures through Green Chemistry
Activated carbon stands out as a widely utilized method for controlling air pollution. This form of control employs pollution filters containing carbon to diminish the release of pollutants into the air. During operation, these filters absorb pollutants, contributing to the purification of the air and the elimination of potential toxins. Another effective air pollution control method is bio-filtration, utilizing microorganisms, including bacteria and fungi, to break down pollutants. Industries implementing bio-filtration systems include those in food and waste management, pharmaceuticals, and wastewater facilities. Despite its effectiveness, bio-filtration requires substantial space for operation, making it impractical for many industries [7].
Fuel modification represents another technique to reduce air pollution. Substituting low sulfur fuel for high sulfur fuel in electric utilities is an example, acknowledging the higher cost of low sulfur fuel. Alternatively, electric utilities can opt for natural gas as a fuel source. Fuel switching, guided by meteorological conditions or air pollution forecasts, has been employed to prevent air pollution issues in various regions. In some cases, industries utilize low-ash oil or natural gas for specific processes, such as drying at asphalt plants, to decrease particulate matter. The introduction of alternative fuels like compressed natural gas, propane, ethanol, and oxygenated fuels for automobiles has contributed to the reduction of air pollutants. While nuclear power plants are relatively pollution-free compared to coal-fired counterparts, they remain controversial due to concerns about their overall environmental impact [8].
Improving dispersion is an approach based on the principle that diluting air contaminants before they reach the ground can lower population exposure concentrations. However, the United States Environmental Protection Agency (US EPA) discourages the use of this approach in industrial settings. Instead, emissions from industrial plants undergo treatment in control devices before being released into the atmosphere. These devices remove, destroy, or transform pollutants, ensuring a cleaner discharge into the ambient air [9-10].

Conclusion
Air pollution poses serious threats to both the environment and societal well-being. Efforts to combat air pollution involve policy reforms, technological innovations, and the adoption of sustainable chemistry principles. Sustainable chemistry, as a novel philosophical approach, can significantly contribute to sustainable development by designing processes that start from non-polluting materials. The future of the chemical industry lies in the production of safer products and processes driven by innovative ideas from fundamental research. Combining green chemistry principles with these strategies can contribute to a more sustainable and environmentally friendly approach to chemical processes, ultimately helping to overcome air pollution.

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