Sustainable chemistry

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Outlines

- Introduction to Sustainable chemistry
- Environmental pollutants
- Key Principles of sustainable chemistry
- Green chemistry
- Solvents, solubility and green solvents
- Molten salts, Ionic liquids (ILs), and dee eutectic solvents
- Biocatalysis
- Renewable energy
- Biodegradable plastics
- Life cycle assessment

Environmental pollutants

- Environmental pollutants are harmful substances introduced into the natural environment that can cause adverse effects on ecosystems, human health, and the climate. These pollutants can originate from human activities (anthropogenic sources) or natural processes and can affect air, water, soil, and living organisms.
- There main environmental pollutants are:
- Air pollutants,
- Water pollutants,
- Soil pollutants,
- Chemical pollutants, and
- Noise and light pollution

Environmental pollutants

1. Air Pollutants:

- Particulate Matter (PM): Fine particles ($PM_{2.5}$ and PM_{10}) that originate from industrial emissions, vehicle exhaust, wildfires, and construction activities. They can cause respiratory and cardiovascular problems.
- Carbon Dioxide (CO_2): A greenhouse gas largely produced by the combustion of fossil fuels, contributing to global warming and climate change.
- Nitrogen Oxides (NO_x): Emitted from vehicles and power plants, they contribute to smog, acid rain, and respiratory illnesses.

Environmental pollutants

- Sulfur Dioxide (SO_2): Produced by burning coal and oil, it contributes to acid rain and respiratory issues.
- Volatile Organic Compounds (VOCs): Chemicals that evaporate into the air and contribute to smog formation. They are emitted from paints, solvents, and industrial processes.
- Methane (CH_4): An effective greenhouse gas released from agriculture, landfills, and natural gas extraction.

Environmental pollutants

2. Water Pollutants:

- Heavy Metals: Elements like Pb, Hg, Cd, and As that can accumulate in water sources through industrial waste, mining activities, and runoff, causing toxic effects on wildlife and humans.
- Pesticides and Herbicides: Chemicals used in agriculture that can run off into water bodies, harming aquatic ecosystems and potentially contaminating drinking water.
- Nutrient Pollution: Excess nitrogen and phosphorus from fertilizers and sewage can lead to algal blooms, depleting oxygen in water and causing dead zones (eutrophication).

Environmental pollutants

- Plastics and Microplastics: Non-biodegradable plastics that accumulate in oceans, rivers, and lakes, harming marine life and entering the food chain.
- Oil Spills: Accidental releases of petroleum into oceans and waterways, severely impacting marine ecosystems and wildlife.

3. Soil Pollutants:

- Pesticides and Insecticides: Chemicals used in agriculture that can persist in the soil, harming beneficial organisms, reducing soil fertility, and contaminating groundwater.

Environmental pollutants

- Industrial Waste: Improper disposal of industrial chemicals, mining tailings, and other hazardous substances can contaminate the soil and make it unsuitable for agriculture or human habitation.
- Heavy Metals: Pb, Hg, and As can also accumulate in soils from industrial emissions, mining activities, and sewage sludge, posing long-term risks to plants, animals, and humans.
- Waste Dumping: Illegal dumping of waste, including electronic waste (e-waste) and industrial by-products, can release toxins into the soil.

Environmental pollutants

4. Chemical Pollutants:

- Persistent Organic Pollutants (POPs): Toxic chemicals that persist in the environment and bioaccumulate through the food chain, such as polychlorinated biphenyls (PCBs) and dioxins. They can cause serious health effects, including cancer and endocrine disruption.
- Pharmaceuticals and Personal Care Products (PPCPs): Medications and chemicals from personal care products (e.g., soaps, lotions) that enter water systems and can affect aquatic life and potentially human health.

Environmental pollutants

- Endocrine Disruptors: Chemicals that interfere with the hormone systems of organisms, potentially leading to reproductive, developmental, and immune system issues. Examples include bisphenol A (BPA) and phthalates

5. Noise and Light Pollution:

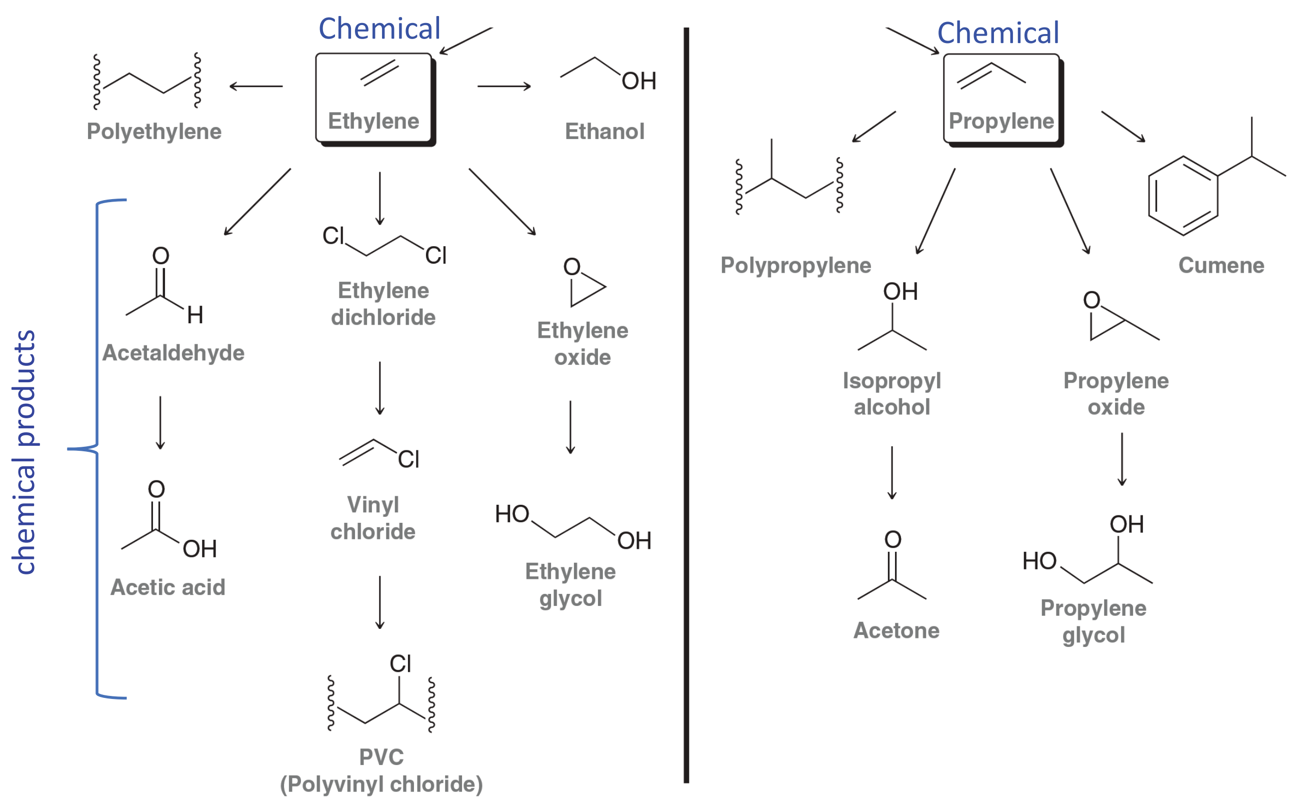
- Noise Pollution: Excessive noise from industries, transportation, and urban areas can disturb wildlife, leading to changes in animal behavior and stress in humans.
- Light Pollution: Artificial lighting from cities and industrial areas disrupts natural cycles (e.g., bird migration, sleep patterns in humans) and interferes with ecosystems.

Sustainable chemistry

- Sustainable chemistry; refers to the design, development, and application of chemical/chemical products (e.g. next Figure) and processes that reduce or eliminate the use and generation of hazardous substances.
- The goal of sustainable chemistry is to minimize the environmental and human health impacts of chemical production, use, and disposal, while improving efficiency and resource utilization.
- In essence, sustainable chemistry seeks to construct a more responsible and long-term approach to chemical innovation, production, and consumption to support a healthier planet and society.

Sustainable chemistry

Chemicals/chemical products



Sustainable chemistry

Some examples of sustainable chemistry applications are:

1. Green solvents:

- Using safer solvents, such as water, supercritical carbon dioxide, or ionic liquids, instead of volatile organic solvents that contribute to air pollution.

2. Biodegradable plastics:

- Replacing conventional plastics with biodegradable alternatives made from renewable resources like corn starch or cellulose.

Sustainable chemistry

3. Renewable energy: Using chemical processes to develop more efficient and sustainable ways of producing and storing renewable energy, such as solar cells or batteries.
4. Biocatalysis: Employing enzymes or microorganisms to catalyze chemical reactions.
5. Life cycle assessment: Evaluating the environmental impact of a product throughout its entire lifespan.

Objectives of sustainable chemistry

- Reduce Environmental impact: Minimize pollution, waste, and hazardous by-products, and reduce the overall environmental footprint of chemical processes.
- Conserve resources; Maximize the use of renewable resources and optimize the use of energy and raw materials.
- Economic Feasibility: Promote cost-effective and efficient processes that provide economic benefits to industries while reducing environmental costs.
- Safety and Health: Reduce risks to human health by designing safer chemicals and processes that lower the risk of accidents and exposure to toxic materials.

Key principles of sustainable chemistry

- Sustainable chemistry is guided by 12 key principles of green chemistry outlined by Paul Anastas and John Warner in 1998.
- These principles aim to minimize the environmental footprint and promote safer, more efficient chemical processes:
- Prevention: It is better to prevent waste than to treat or clean up waste after it is created.
- Atom Economy: Synthetic methods should maximize the incorporation of all materials used in the process into the final product, minimizing waste.

Sustainable chemistry

- Less Hazardous Chemical Syntheses: Chemical processes should be designed to use and generate substances with little or no toxicity to humans and the environment.
- Designing safer chemicals: Chemical products should be designed to perform their intended function while minimizing toxicity.
- Safer solvents and auxiliaries: The use of auxiliary substances (e.g., solvents, separation agents) should be made unnecessary or harmless when used.

Sustainable chemistry

- Energy efficiency: Energy requirements should be minimized, and processes should be conducted at ambient temperature and pressure when possible.
- Use of renewable feedstocks: Whenever possible, raw materials should come from renewable sources rather than depleting finite resources.
- Reduce derivatives: Unnecessary derivatization (e.g., using blocking or protecting groups) should be avoided to reduce the generation of waste.
- Catalysis: Catalytic reagents (which are as selective as possible) are superior to stoichiometric reagents.

Sustainable chemistry

- Design for degradation: Chemical products should be designed so that they break down into non-toxic substances after use, preventing environmental accumulation.
- Real-time pollution prevention: Monitoring and controlling chemical processes in real-time can prevent the formation of hazardous substances.
- Safer chemistry for accident prevention: Chemical processes should be designed to minimize the risk of accidents, such as explosions or releases of toxic substances.

Green chemistry

- The entire world is in the cancerous command of rapidly increasing environmental pollution in its various sides like water pollution, air pollution, soil pollution, and so on.
- This problem is further supported by global warming and energy crisis.
- Environmental pollution makes life miserable on the Earth planet,
- This is all because of use of gray chemistry to fulfill different demands of materials with diverse applications, such as metallurgy, synthesis of pharmaceuticals and other chemicals, use of