12 PRINCIPLES OF GREEN CHEMISTRY

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Abstract:
It is also called sustainable chemistry, is a philosophy of chemical research and engineering that encourages the design of products and processes that minimize the use and generation of hazardous substances. Green chemistry is about reducing waste, material, hazard, risk, energy, and cost. In this we will discuss about twelve principles of green chemistry Prevent waste, Maximize atom economy, Design less hazardous chemical syntheses, Design safer chemicals and products, Use safer solvents and reaction conditions, Increase energy efficiency, Use renewable feedstocks, Avoid chemical derivatives, Use catalysts, not stoichiometric reagents, Design chemicals and products to degrade after use, Analyze in real time to prevent pollution, Minimize the potential for accidents

Key words: Sustainable chemistry, green chemistry, atom economy

Introduction: 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:

- 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

Green chemistry's 12 principles

1. **Prevention:**It is better to prevent waste than to treat or clean up waste after it has been created

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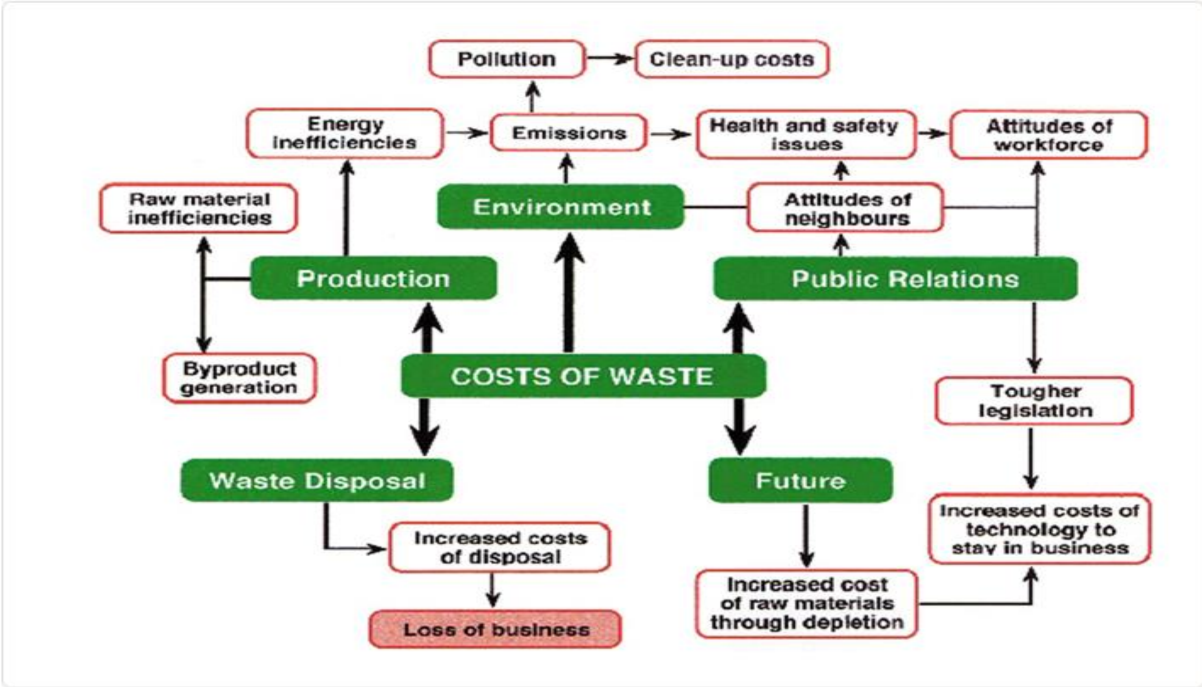

Fig 1: Prevention

2. **Atom Economy**

Synthetic methods should be designed to maximize incorporation of all materials used in the process into the final product.

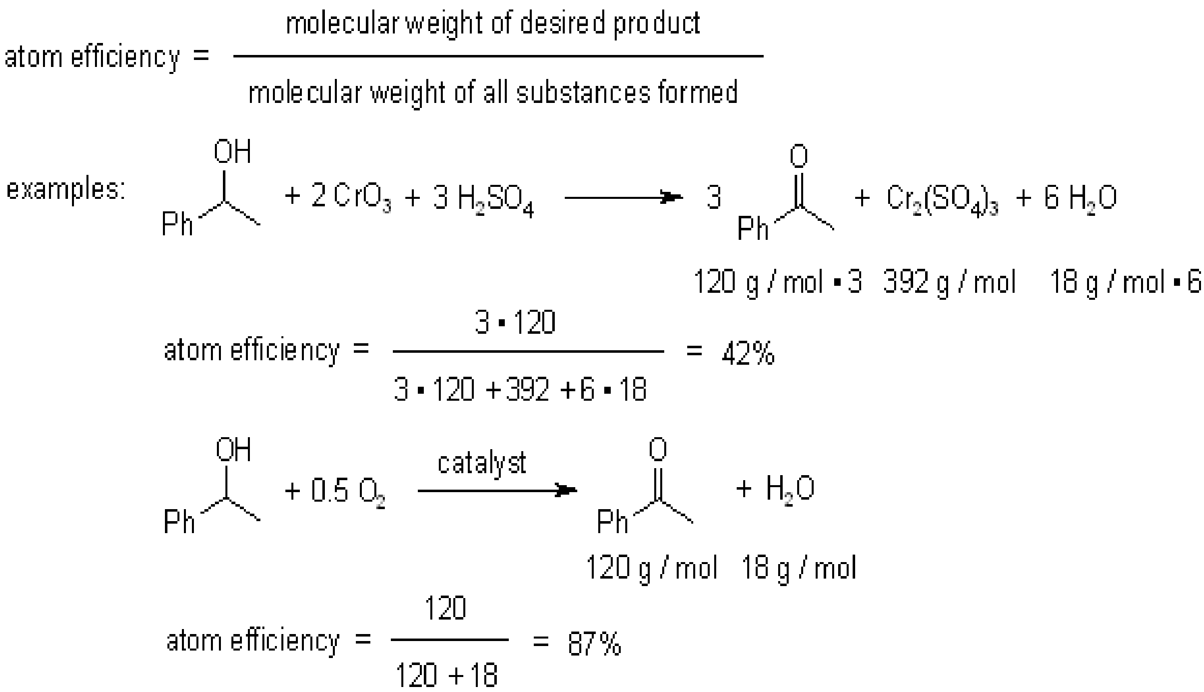

Fig 2: Atom economy

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3. **Less Hazardous Chemical Synthesis**
   Wherever practicable, synthetic methods should be designed to use and generate substances that possess little or no toxicity to human health and the environment

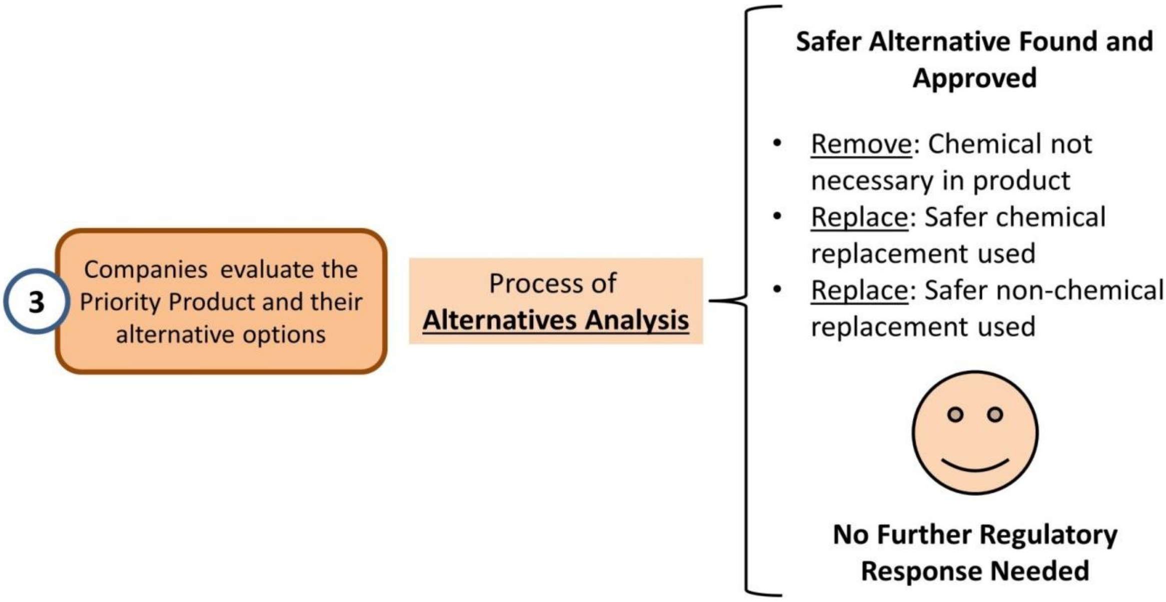

Fig 3: Less Hazardous Chemical Synthesis

4. **Designing Safer Chemicals**
   Chemical products should be designed to preserve efficacy of function while reducing toxicity.

Polyphenylsulfone is now widely used for the interior panels of aircraft and has been introduced into underground trains where it is also so important to use non-flammable materials.

Fig 4: Designing Safer Chemicals

5. **Safer Solvents and Auxiliaries**
   The use of auxiliary substances (e.g., solvents, separation agents, etc.) should be made unnecessary wherever possible and, innocuous when used.

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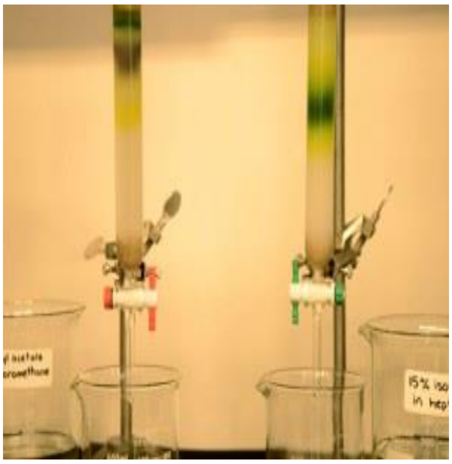

Column 1: 5% Ethyl acetate in DCM

Column 2: 15% Isopropanol in Heptane

Fig 5: Safer Solvents and Auxiliaries

6. **Design for Energy Efficiency**
   Energy requirements should be recognized for their environmental and economic impacts and should be minimized. Synthetic methods should be conducted at ambient temperature and pressure.

These tomatoes are growing in a greenhouse heated using waste steam from a nearby chemical plant making ammonia. Waste carbon dioxide from the plant is also used by injecting it into the greenhouse atmosphere to promote growth of the fruit.

Fig 6: Design for Energy Efficiency

This plant in Iceland is capable of producing 1300 tonnes of methanol a year from waste carbon dioxide from geothermal sources. Its capacity will shortly increase to 4000 tonnes a year and the next generation will increase that tenfold. The technology is such that plants could be built adjacent to other industrial emission sources such as in the manufacture of cement and steel.

Fig 7: Design for Energy Efficiency

7. **Use of Renewable Feed stocks**
   A raw material or feedstock should be renewable rather than depleting whenever technically and economically practicable

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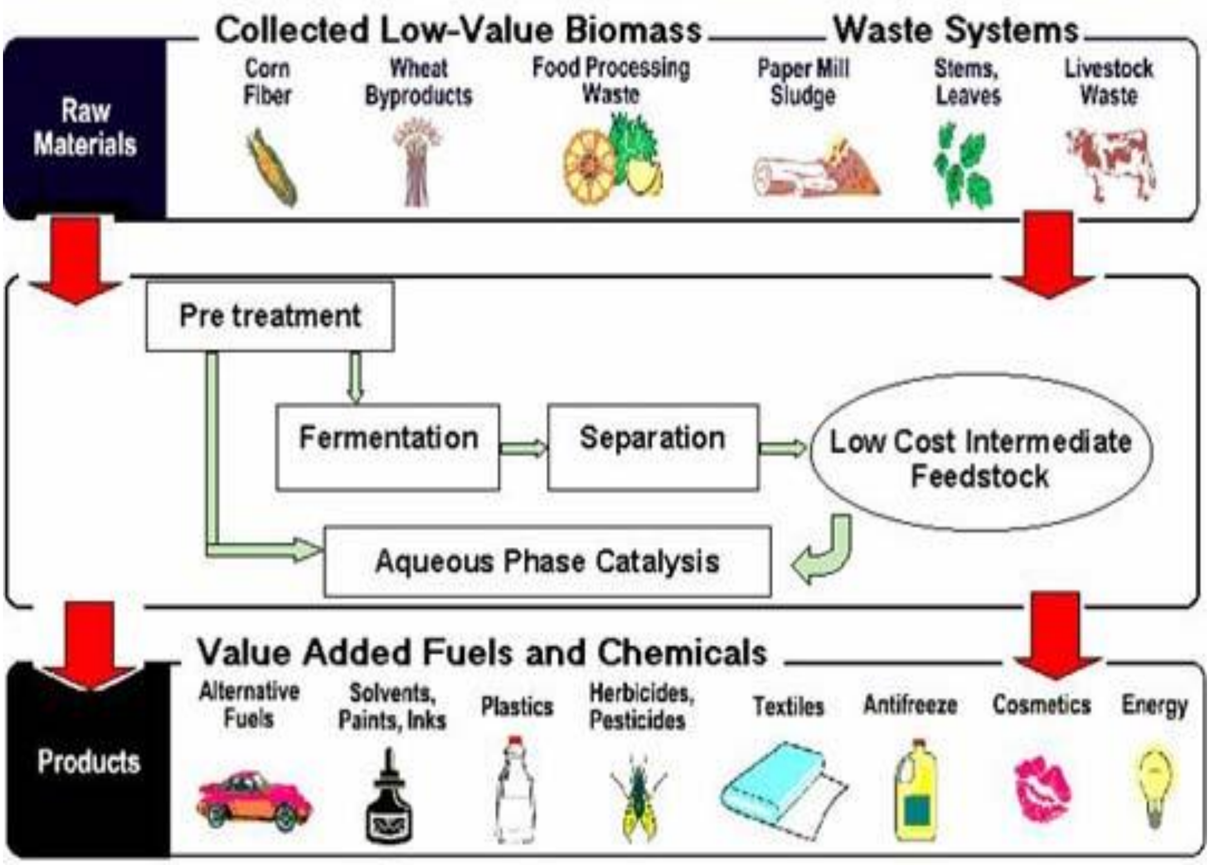

Fig 8: Use of Renewable Feed stocks

Ingeo polymer for plastics production

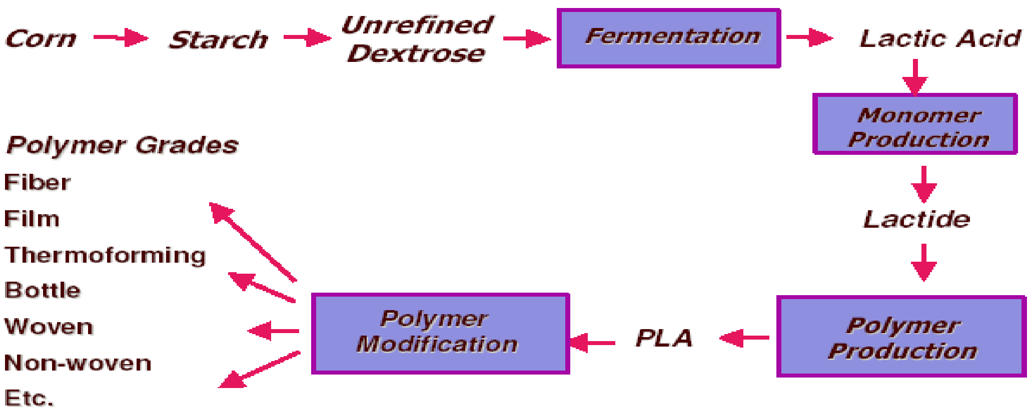

Fig 9: Use of Renewable Feed stocks

8. **ReduceDerivatives**
   Unnecessary derivatization (use of blocking groups, protection/deprotection, temporary modification of physical/chemical processes) should be minimized or avoided if possible, because such steps require additional reagents and can generate waste.

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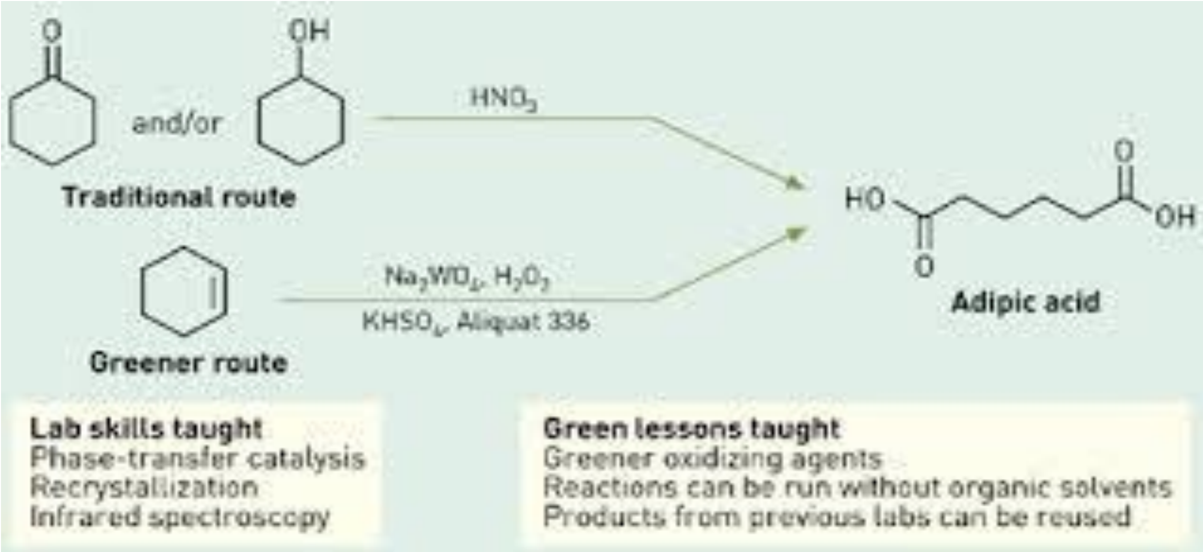

Fig 10: ReduceDerivatives

9. **Catalysis**
   Catalytic reagents (as selective as possible) are superior to stoichiometric reagents

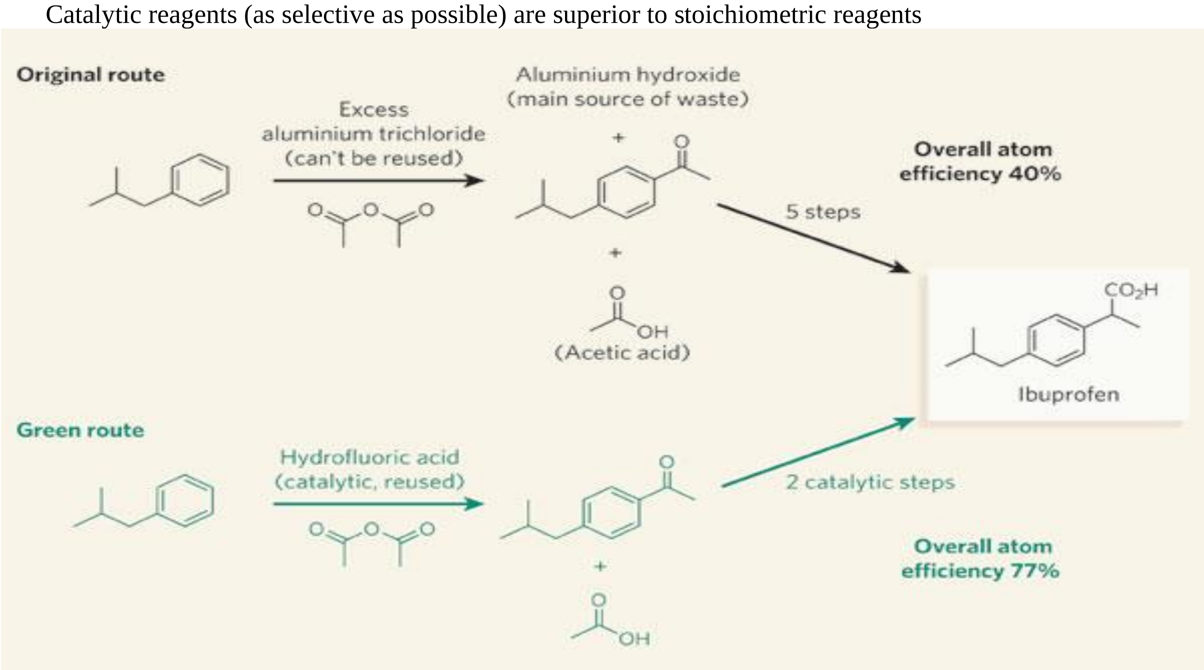

Fig 11: **Catalysis**

10. **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.

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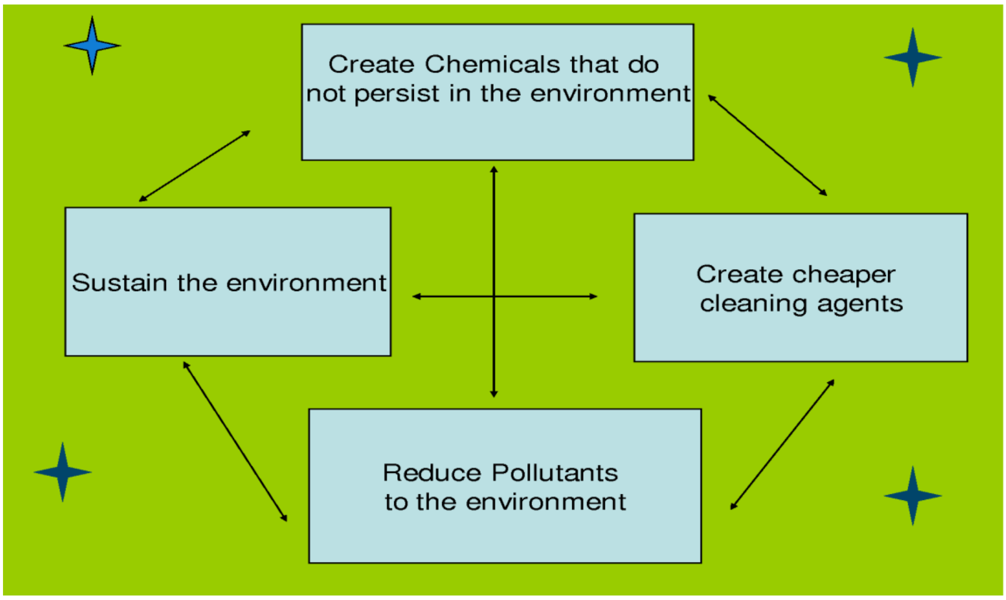

Fig 12: Design for Degradation

11. **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

12. **Inherently Safer Chemistry for Accident Prevention**
Substances and the form of a substance used in a chemical process should be chosen to minimize the potential for chemical accidents, including releases, explosions, and fires.

Exactly 30 years ago, in a factory in Bhopal, water entered the tank E-610, which held 42 tons of Methyl Isocyanate (MIC). MIC is a highly toxic compound with a very low boiling point and can only be stored in stainless steel or glass containers. On reaction with water, MIC violently releases toxic gases, which is what happened in the Union Carbide plant in Bhopal. It instantly started producing the toxic gases, which killed more than 2500 people, leading to the worst-ever chemical disaster ever.

Fig 13: Inherently Safer Chemistry for Accident Prevention

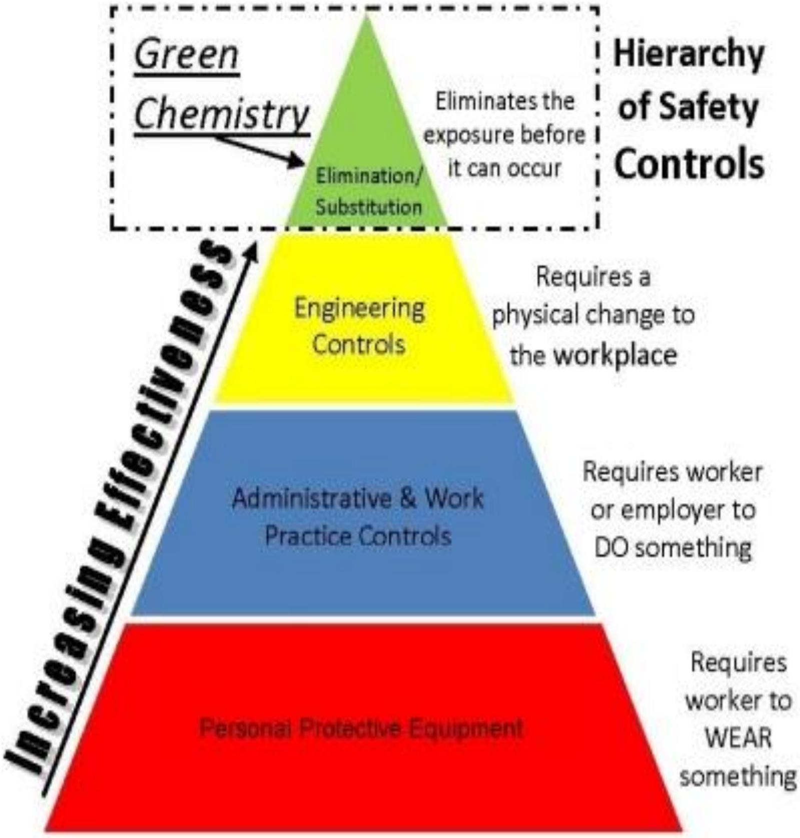

Fig 14: flow chart of green chemistry

Examples of Green Chemistry:

1. Computer Chips: Many chemicals, and much water and energy are needed to manufacture computer chips. A 2003 study estimated a ratio of 630:1 in terms of chemicals and fossil fuels required to make one computer chip – i.e. it takes 630 times the weight of the chip in source materials to make one chip (in comparison, the ratio for manufacturing a vehicle is 2:1).

Advances in Green Chemistry include:

- A new process that uses supercritical carbon dioxide in one of the steps of chip preparation, significantly reducing the chemicals, energy and water needed in the production process.
- Innovation using chicken feathers to make computer chips. The protein, keratin, in the feathers is used to make a fibre form that is both light and tough enough to withstand mechanical and thermal stresses. The result is a feather-based printed circuit board that works at twice the speed of traditional circuit boards. While this technology is still in the works for commercial purposes, the research has led to other uses of feathers as source material, including for biofuel.

2. Medicine: Pharmaceutical research, besides investigating new medical solutions, also focuses on ways to reduce harmful side-effects and processes that produce less toxic waste. Some Green Chemistry successes include:

- New biocatalysts – using an enzymatic process originally developed for the treatment of type 2 diabetes but holding promise for other drugs as well – which reduce waste, improve yield and safety, and eliminate the necessity for a metal catalyst.
- A new synthesis using an engineered enzyme and low-cost feedstock for a well-known high cholesterol medicine was optimised to be more cost-effective, as well as to greatly reduce hazard and waste.

3. Biodegradable Plastics: Many companies are developing plastics made from renewable, biodegradable sources. Successes include:

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- New food containers made from a method where microorganisms convert corn starch into a resin that is just as strong as the rigid petroleum-based plastic used for containers such as water bottles and yogurt pots.
- Fully biodegradable bags made of a compostable polyester film with cassava starch and calcium carbonate. The bags are tear-resistant, puncture-resistant, waterproof, printable and elastic; as well as able to disintegrate into water, CO_2, and biomass in industrial composting systems.

4. Paint: Oil-based paints containing synthetic resin made from dicarboxylic acid (known as alkyd paints), give off organic compounds. These volatile compounds evaporate from the paint as it dries and have environmental impacts. Improvements in this area include:

- Replacing fossil-fuel-derived paint resins and solvents with a mixture of soya oil and sugar cuts hazardous volatiles by half. These bio-based oils are used to replace petroleum-based solvents, creating safer paints with less toxic waste.
- Water-based acrylic alkyd paints with low volatile organic compounds that can be made from recycled soda bottle plastic, acrylics, and soybean oil. In 2010, enough of these paints were manufactured to eliminate more than 362 874 kg of volatile organic compounds.

Conclusion: Green chemistry not a solution to all environmental problems but the most fundamental approach in preventing pollution

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