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Sustainable Organic Composition: A Critical Analysis of Green Chemistry's Impact

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Abstract - Pollution in the environment and climate change are major challenges we face today. After years of steady growth, the need for human household appliances finally prompted the organic chemical-based sectors to ramp up output. That's why pollution is getting so bad: because of that. In order to encourage the chemical industry to be more environmentally sustainability, "green chemistry" was developed. In 20 years, organic chemistry will have changed significantly, thanks to the numerous researchers who have focused on it and the concepts of green chemistry. Up to this point, waste minimization, safer solvents, energy-efficient design, and the use of renewable feed stocks have all been taken into account in the context of organic compound synthesis. This paper provides a concise analysis of how green chemistry ideas have been applied to organic chemical production.

Keywords - Green Chemistry, Organic Substance, Synthesis and Process and Environmental Sustainability.

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BACKGROUND

Deterioration in the quality of the environment has reached an alarming level in recent years, which has a major impact on human survival [1]. It is generally agreed that environmental pollution occurs when the concentration of a pollutant in the environment is significantly higher than it should be, whether that concentration is the result of natural or human causes. In a nutshell, environmental pollution is a state of disequilibrium in the biosphere [2]. Industrial operations are mostly to blame for the steady worsening of environmental contamination such as soil, water, and air pollution. In addition, greenhouse gas emissions raise global temperatures, which has negative effects on the environment (known as global warming). If we want to maintain a sustainable environment, we need to give careful consideration to these issues. That's why it's not right for industrial processes to prioritise profit over environmental safety [3].

Prior to the industrial revolution, the chemical industry focused primarily on reaction yield and product purity [4] without giving much thought to sustainability concerns, energy consumption, or the efficacy of the chemical process. There may be no end in sight to environmental contamination, especially in emerging countries, despite the fact that national and international laws for chemical companies have been set [5]. Consequently, researchers are exerting themselves to advance the chemical industries in a "green" and environmentally friendly stage [6], since the governmental perspective does not appear to be effective enough to maintain environmental sustainability.

There had been a lot of work done to try to fix such environmental problems before to 1998, when Anastas and Warner presented the idea of green chemistry. The term "green chemistry" refers to the practise of adhering to a set of guidelines that, when applied to the development, production, and use of chemicals, drastically cuts back on or eliminates the creation of potentially harmful byproducts [7][8]. Green chemistry is based on the 12 principles depicted in Figure 1.

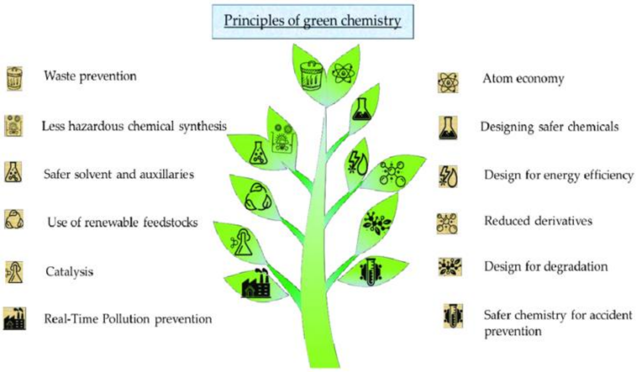

Figure 1: Principles of Green Chemistry[8]

REDUCING WASTE

Waste prevention is preferable to waste management, treatment, and elimination. The term **"waste"** refers to any unwanted consequence of an activity. Chemical processing generates waste that is poisonous, inert, and radioactive, which causes widespread public concern. Moreover, so long as chemical factories are in operation, these wastes will be perpetually produced [9]. There are two main types of garbage: liquid and solid.

Wastes are classified as liquid or solid depending on their physical state. Acid, base, metal ions (precious metals, alkali and base metals, and heavy metals), and organic pollutants (dyes, biomolecules, and so on) are common components of liquid waste. Meanwhile, common examples of solid trash include plastic, paper, metal, ceramic, and glass [10].

However, due to constraints on the length of the manuscript, we have focused on just four key principles: 1. waste prevention; 2. safer solvents; 3. design for maximum energy efficiency; and 4. utilisation of renewable feedstocks. The other concepts are only touched on briefly in the discussion of those four, though.Organic chemical synthesis and the use of "green chemistry" principles are also topics that will be covered in this overview.

If possible, all of the ingredients that go into the chemical process should be part of the final product. Effective mass yield, product efficiency, carbon efficiency, atom economy, reaction mass efficiency, ecoscale, environmental factor, and biologictool plots [11] are all quantitative indicators used in green chemistry that can be used to design a chemical process with waste reduction in mind. According to the literature [12], effective mass yield is the ratio of the mass of the final product to the total mass of all inert ingredients (water, dilute alcohol, NaCl, etc.) utilised in the chemical reaction. However, this metric fails to indicate the toxicity level of the chemical process, and it is highly subjective when used to define "non-benign" substance. However, product efficiency measures how close the actual mass of the product comes to the theoretical total atomic mass of the product.

The level of carbon efficiency describes how well carbon atoms are used in the final product. Although it serves well in the pharmaceutical sector, it has no practical application in inorganic sectors such as metal oxide, inorganic paint, inorganic polymer, and advanced materials manufacture. The atom economy formula was developed by Barry Trost in 1995 and is dependent on the relative amounts of the reactants and the final product. Although homogenous catalyst and used solvents are not included in the atom economy calculation since they are not considered reactants in the chemical process, atom economy is nevertheless widely recognised as a good metric for organic and inorganic processes. Atomic economy is only taken into account theoretically via the handwriting response equation [13], thus it should be treated as such.

In contrast, the atom economy, chemical yield, and reaction stoichiometry are all taken into account while calculating reaction mass efficiency. Similar to the carbon efficiency parameter, reaction mass efficiency is a theoretical calculation that demonstrates the "sreenness" of the reaction but not the actual process because it does not take into account the consumption of solvents or energy. Ecoscale was first proposed by Van Aken et al. [14] in 2006, as a way to measure environmental impact. The ecoscale provides a score between 0 and 100 that takes into account price, safety, technical setup, energy, and purification factors, just like the effective mass yield parameter. To calculate it, start with a perfect reaction (where "Compound A undergoes a reaction with Compound B to give the desired Compound C in 100% yield at room temperature with minimal risk for the operator and minimal impact on the environment") and deduct points for less-than-perfect conditions. However, in practise, this optimum state is rarely reached in the chemistry involved.

In the realm of quantitative measures for green chemistry, the environmental factor (E-factor) has proven to be one of the most adaptable tools available. In 2007, [15] Roger A. Sheldon proposed the E-factor formula, which defines waste as the percentage of total output that is not useful. The E-factor is comprehensive enough to determine whether or not a chemical process is safe for the environment by taking into account the amounts of solvent and catalyst used. Refining oil yields between 106 and 108 tonnes per year, while bulk chemicals yield between 104 and 106 tonnes, and fine chemicals and pharmaceutical processes yield between 102 and 104 tonnes, and the latter two yield between 10 and 103 tonnes. At the same time, the waste generated by the oil refining, bulk chemical, fine chemical, and pharmaceutical processes accounts for 105-107, 104-105, 10-104, and 102-105 tonnes, respectively.

According to these numbers, the E-factor for oil refining is between 0.1 and 0.5, for bulk chemicals between 1 and 5, for fine chemicals between 5 and 25, and for pharmaceutical processes anywhere from 25 to 100. Thus, as of right now, the oil refining industry is the cleanest chemical industry and the pharmaceutical industry is the dirtiest.

Lie et al. [16] recently introduced a new quantitative metric for green chemistry called the biologic tool plot. This parameter provides a simple way to represent a chemical pathway given information about the reactants, products, and intermediates involved, as well as the yields at each stage of the reaction. A biologic tool score is calculated by plotting the percentage of heteroatoms in the materials against their molar masses. If the score for the biologic tool is close to 1, the chemical approach is the more sensible option. The design and evaluation of a complete chemical process relies heavily on this parameter. The formulas for these "green chemistry metrics" are displayed below.

To create a "greener" synthesis strategy for biodiesel manufacturing, we have previously worked to perfect the esterification reaction of fatty acid with ethanol. Table 1 displays the process's green quantitative metrics. Results showed that under the reflux conditions, sulfuric acid outperformed KSF montmorillonite in terms of yield percentage and reaction mass efficiency. However, the KSF montmorillonite gave a 17-times lower E-factor than the sulfuric acid process, proving that the KSF montmorillonite-catalyzed reaction is superior to be applied as an alternative green technique [17].

When it is not possible to prevent waste entirely, the next best step is the waste remediation stage, which aims to reduce environmental damage as much as possible [18]. Methods for cleaning up liquid waste, such as coagulation and precipitation, adsorption, bioremediation, and photocatalysis, are not new [9]. Pollutants are coagulated and precipitated when their liquid form is converted to a solid or semi-solid form, either by a physical process (centrifugation) or a chemical process (precipitated as their insoluble materials). Adsorption is the practise of using solid materials to trap contaminants within their pores and on their surface [18]. Bioremediation is the use of microorganisms and/or enzymes in a chemical process to degrade pollutants [19]. And yet, photocatalysis is described as a chemical degradation process that employs a catalyst material while being illuminated by light [20]. Conversely, incineration is frequently used in solid waste treatment, followed by landfill application [9].

For instance, phenol (C_6H_5OH) is used in the manufacturing of herbicides, detergents, polycarbonate, bakelite, and nylon, all of which are polymer materials.

$$\text{Effective mass yield (\%)} = \frac{\text{mass of products x 100\%}}{\text{mass of non-benign reagents}} \quad \text{...... (1)}$$

$$\text{Product efficiency} = \frac{\text{real mass of the desired product x 100\%}}{\text{theoretical total atomic mass of the desired product}} \quad \text{.....(2)}$$

$$\text{Carbon efficiency (\%)} = \frac{\text{amount of carbon in product x 100\%}}{\text{total carbon present in reactants}} \quad \text{....... (3)}$$

$$\text{Atom economy} = \frac{\text{m.w. of desired product x 100\%}}{\Sigma\ \text{(m.w. of used reactant)}} \quad \text{..... (4)}$$

$$\text{Reaction mass efficiency} = \frac{\text{molecular weight of the product x yield}}{\text{m.w. reactant A + (m.w. reactant B x molar ratio reactant B/A)}} \quad \text{.... (5)}$$

$$\text{E-factor} = \frac{\text{total waste}}{\text{product}} \quad \text{.....(6)}$$

However, the Agency for Environmental Protection lists phenol as one of 129 harmful pollutants [19], despite the fact that demand for phenol is constantly on the rise due to its indispensable nature. This motivates the creation and improvement of many phenolic wastewater treatment options. Adsorption studies of phenol have been conducted on a wide variety of het-erogeneous materials with the goal of attaining the highest possible maximum adsorption capacity (mg phenol/g adsorbent). Unfortunately, desorption of phenol isn't always simple, leaving behind a potentially dangerous solid. Bioremediation of phenol is gaining popularity as an alternative method of phenol degradation due to enzymatic metabolism by bacteria; nevertheless, the bacteria need precise and stable environmental condition, such as pH 7.4 at 310 K [21]. This constraint means the chemical process cannot be easily scaled up for widespread commercial use.

In contrast, photocatalytic phenol degradation to CO_2 and H_2O can be accomplished in the presence of metal oxide catalyst material [22]. Because it requires just lightweight and reusable catalyst ingredients, this treatment is both easy and effective. Prior to this, we have used red amaranth natural pigments to make P25 TiO2 nanoparticles more photocatalytic toward phenol under visible light. Sensitized P25 TiO_2 showed exceptional photodegradation activity of 22% for phenol under visible light [20], while bare P25-TiO_2 showed no photo-degradation activity at all. From these results, it is clear that a smart material for the photodegradation of phenol to water and carbon dioxide can be created by combining the right organic molecules with the right inorganic elements.

HEALTHIER SOLUTIONS

To paraphrase:*"Chemical products should be designed to optimise their function while reducing their hazardous effect."*A solvent is the primary liquid compound needed to make a solution by dissolving the chemicals. Even in a straightforward chemical procedure, a substantial amount of solvent may be needed during the reaction medium and/or purification step [23]. Solvents like benzene, carbon tetrachloride, formaldehyde, etc. are highly flammable, toxic, and environmentally damaging, but they are not necessary for a chemical reaction to take place [24]. Evaporation of volatile solvents like carbon tetrachloride creates hazardous air pollution and poses a significant health risk to humans [23]. Formaldehyde and other high polarity solvents are undesirable because they can accumulate in aquatic environments, posing a threat to human health [25]. This motivates a number of ongoing solvent substitution initiatives aimed at improving environmental sustainability. The ideal conditions for chemical processes [26] include those in which no solvent is required, such as the grinding method or the sol-gel reaction.Due to its carcinogenic properties, benzene has recently been replaced by toluene, and carbon tetra-chloride has been replaced by chloroform or dichloromethane because of its effect on the ozone layer [27]. Byrne et al. coined the term "green solvent" to describe a type of solvent that is gentler on the planet because it uses renewable energy sources and generates little waste. Since ethanol can be easily produced by a large-scale fermentation process from the biomass waste, it is a "greener" solvent than N,N-dimethyl formamide. Based on environmental impact and energy used in production, Pfizer and Sanofi have categorised solvents as shown in Table 2 [28].

Table 1.The green quantitative metrics Esterification reaction of fatty acid under reflux using different catalyst [17]

Parameter	Catalyst	
	H_2SO_4	KSF mont
Yield (%)	90.0	52.0
Reaction mass efficiency(mg/g)	11.0	6.3
E-factor	12.0	0.7

Table 2. List of solvent recommendation according to Pfizer and Sanofi [28]

Class	Solvent	Pfizer recommendation	Sanofi recommendation
Alcohols	Methanol	Preferred	Recommended
	Ethanol	Preferred	Recommended
	1-Propanol	Preferred	Recommended
	2-Propanol	Preferred	Recommended
	1-Butanol	Preferred	Recommended
	Ethylene glycol	Usable	Substitution advisable
Hydrocarbons	*n*-Pentane	Undesirable	Banned
	n-Hexane	Undesirable	Substitution advisable
	Cyclohexane	Usable	Substitution advisable
	Benzene	Undesirable	Banned
	Toluene	Usable	Substitution advisable
	Xylene	Usable	Substitution advisable
Dipolaraprotic	Dimethyl sulfoxide	Usable	Substitution advisable
	Acetonitrile	Usable	Recommended
	N,N-dimethylformamide	Undesirable	Substitution advisable
Esters	Methylacetate	Preferred	Substitution advisable
	Ethylacetate	Preferred	Recommended
Ethers	Tetrahydrofurane	Usable	Substitution advisable
	Diethylether	Undesirable	Banned
	1,4-Dioxane	Undesirable	Substitution advisable
	2-methyltetrahydrofurane	Usable	Recommended
Ketones	Acetone	Preferred	Recommended
	Methylethylketone	Preferred	Recommended
Halogenated	Carbontetrachloride	Undesirable	Banned
	Chloroform	Undesirable	Banned
	Dichloromethane	Undesirable	Substitution advisable
Miscellaneous	Water	Preferred	Recommended
	Aceticacid	Usable	Substitution advisable
	Pyridine	Undesirable	Substitution advisable

The physicochemical properties of the solvent are typically taken into account when thinking about solvent replacement. Solvent replacement is feasible if the properties of the substitute solvent are similar to those of the original solvent. Solubility (d), acidity (a), basicity (b), and polarity are Kam-let-Taft parameters that describe a substance's physicochemical properties. Solvent replacement could be rationally designed if those factors were studied in depth. Table 3 details a number of solvent alternatives that have been proposed to lessen the impact of chemical production on the environment. Ionic liquids and supercritical fluids have both found new homes in a variety of chemical reactions as of late.

Table 3. List of the alternative Solvents for a safer chemical28

Solvent	Issues	Alternatives
n-Pentane	Low flash point	*n*-Heptane
Diethylether	Low flash point	2-methyltetrahydrofurane
Hexane	Toxic	Heptane
Benzene	Carcinogenic	Toluene
Chloroform	Carcinogenic	Dichloromethane
Pyridine	Carcinogenic	Triethylamine
N,N-dimethylformamide	Reproductivetoxicity	Acetonitrile

UTILIZATON OF RENEWABLE FEEDSTOCKS

To put it another way, "Feedstocks are better in renewable stage thus it could be stable either in technical or econo-mi-cally practise."Renewable sources, such as bio-sources, are becoming increasingly attractive as fossil material supplies dwindle.The plastics industry, which uses petroleum feed-stocks, is in trouble because demand exceeds supply. Be-cause of such, various companies strive to move from petroleum-based polymer to biomassderived poly-mer . Because it could be performed under mild conditions, the preparation of biopolymer via atom transfer radical polymerization (ATRP) was once thought to be environmentally friendly. Furthermore, the polymerization rate, polymerization degree, and polymerization selectivity could be well regulated by employing an appropriate catalyst material . Catalyst material is often constructed via impregnation on silica materials, which makes the method low-cost and practical for industrial scale production. To date, polylactide (polylactic acid) has proven to be a suitable alternative to polystyrene and polyethene. Why? Because unlike polystyrene or polyethene, polylactide degrades rapidly under aerobic conditions or when exposed to ultraviolet rays (1,000 years). Good news for Earth is that commercial production of polyglyconic acid and bio-polyethene from sugar beets and biomass fermentation, respectively, has occurred.

Researchers are creating biomaterials from waste oils [17] as the supply of fossil-based resources dwindles. Several types of biolubricants, biogreases, and bio-surfactants have been developed, and their potential commercial use has been assessed . Previous work of ours [17] utilised discarded frying oil as a raw material for the preparation of cyclic ketal of 9,10-dihydroxyoctadecanoates and other het-erocyclic compounds. Transesterification, hydrolysis, and oxidation were performed on the used frying oil to produce 9,10-dihydroxyoctadecanoic acid. The unintended result was obtained by esterifying the fatty acid in question and then reacting it with carbonyl molecules. It has been used to successfully create dioxane-dione (A), dioxepame (B), dioxolane (C, F-I), and diox-aspiro (D, E). Figure 2 displays their chemical structures, while Table 4 lists their physical characteristics.

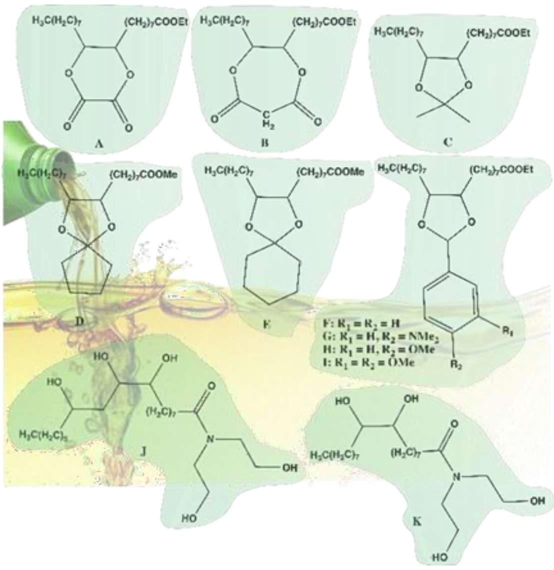

Figure 2. Structure of Biolubricant compound A-K

Evaluation of the lubricants' physicochemical qualities revealed that types A through E of biolubricant had much lower total acid number (TAN) and iodine value (IV) than either utilised frying oil or a fossil-based lubricant. Meanwhile, the connected substituents on the heterocyclic moiety cause a wide range in the total base number (TBN), from low to medium. In contrast, biogreases F-I likewise showed reduced TAN and IV but increased TBN, suggesting their potential use as a biomaterial in mechanised chemical processes [20]. Nonionic biosurfactants J and K are prepared from plant oils, providing yet another application for these oils. The results of an analysis of their physicochemical properties showed that their surface tensions are 16.1 and 14.2 mN/m, that their foam stability values after 100 minutes are 3.0 and 42 mL, that their critical micelle concentrations are 1.5 and 1.5 g/L, and that their emulsi-fication indices after 4 days of observation are 10.0 and 68.0%, respectively. The produced nonionic biosurfactants have favourable physicochemical properties, as demonstrated by the afore mentioned findings .

Table 4. Physicochemical properties of several biolubricants, biogreases, and biosurfactants synthesized from used frying oil waste

No	Compounds	Physicochemical properties			
		Density(g/mL)	TAN (mgKOH/g)	TBN (mgKOH/g)	IV (mgI_2/g)
1	A	1.045	1.37	3.53	0.72
2	B	0.939	2.89	6.61	0.69
3	C	0.824	14.5	48.95	0.76
4	D	0.916	11.0	24.24	21.28
5	E	0.913	5.46	14.04	17.73
6	F	-	1.71	14.12	0.25
7	G	-	3.95	5.71	0.78
8	H	-	2.53	9.03	0.51
9	I	-	2.87	8.92	0.51
10	Used frying oil	0.910	7340	0.41	5380
11	Fossil-based lubricant	0.893	85.37	5.36	31.73

CONCLUSIONS

In conclusion, it is essential that we pay close attention to detail if we are to build a reliable and successful design of an organic synthesis process that is also environmentally sustainable. To obtain this state, one could use green chemistry practises, such as.

1) Reducing trash by following the quantitative metrics of green chemistry.

2) The use of more secure and environmentally friendly solvents.

3) Employing a method of synthesis that makes efficient use of energy, and

4) Pondering the possibility of using renewable feedstocks, such as byproducts from other processes. This means that the green chemistry

approach to managing the chemical industries for the benefit of future generations of Earth can no longer be ignored.

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