

The Role of Chemistry in Achieving Sustainable Development Goals: Green Chemistry Perspective

Abstract

Green chemistry approaches have been fundamentally identified and widely employed as part of the successful means of achieving the 2030 United Nations Sustainable Development Goals (UN-SDGs). As a result of green chemistry, also known as Sustainable Chemistry, chemical products and processes are designed to minimize or eliminate the use of harmful substances. Green chemistry centers on the chemical product life cycle, including the design, manufacture, use, and final disposal of chemical products. Recognizing green chemistry as a vital area of chemistry to achieving the UN-SDGs is essential to decrease the impacts of pollution on global health, boost the health and well-being of the populace, achieve zero hunger, clean water and sanitation, affordable and clean energy, industry innovation and infrastructure, responsible construction and production, and climate action. All these and more can be achieved using the twelve developed principles of green chemistry, and a comprehensive view of how green chemistry can help in achieving UN-SDGs can be seen in these principles. Furthermore, green chemistry perspective is also a continuously developing tool for greener global impacts. In this chapter, we present the various pivotal roles green chemistry plays towards achieving sustainable development goals, a pivotal initiative that can aid in meeting the United Nations 2030 global plans.

Keywords: green chemistry, green synthesis, twelve principles, sustainable development, global impact.

1.0 Introduction

Africa is the second largest continent in the world after Asia, having 54 countries and covering around 30.3 million square kilometers [1]. In Africa, people have their unique cultures, languages, and history. Around this 21st century, educational evolution has evolved, and different African nations are paying attention to recent developments affecting humans and the environment, thereby involving in research and development to meet the United Nations 2030 Sustainable Development Goals. Of course, the idea for robust research and policy implementation of handling and managing these activities causing danger to health and the environment has become paramount and important in solving the issues associated with pollution from toxic waste, greenhouse gases, and more. For the average people in Africa, their day-to-day activities have and continue to endanger human health, the environment, and equally the air and water with very little awareness about the current and potential negative impacts of their activities. Although these can be characterized by low or poor education, what is more, alarming is that even some educated ones in the various communities of Africa are not exempted from these activities.

The chronicle about the worsening environmental, water, and air pollution which has badly impacted African communities including the human, animals, plants, water, and aquatic lives can't be completed without mentioning the foreigners who came from well-developed cities around the world where laws and orders are maintained but have ceased to apply such in Africa but rather have linked in the so-called anthropogenic activities from different oil refining and petrochemical companies such as SHELL, AGIP, and others. Their industrial activities alone have caused many oil spillages with very little or no effort to clean them up, thereby threatening both terrestrial and aquatic lives in different communities.

The impression and adequate practice of sustainable development are fantastically ideal for Africa as the United Nations SDGs 2030 agenda with different approaches, especially the green chemistry perspective, would aid in controlling and possibly bring to zero some of the activities that are posing a threat to lives and the environment and equally enhance the modern activities for the future.

1.1 Green Chemistry as the Future

As chemical science has grown in popularity over the past two centuries, it has enabled humans to produce an increasing variety of goods [2]. These include pharmaceuticals, fertilizers, semiconductors, and more. However, in years past and even at present, chemistry has been mishandled in numerous ways such as the release of toxic substances, and pollutants and the production of nonbiodegradable materials, resulting now as harm to the environment and living things. Considering the current state of chemical science, it is evident there must be a shift from an emphasis on the development of products that ultimately end up as waste to the application of chemistry in ways that support human needs without damaging the earth's ecosystem. Sustainable development is the practice that was designed by the United Nations which is aimed at achieving the best technologies that may reduce or eliminate the application or use of harmful/hazardous substances. The SDGs programs are basically designed to satisfy the current needs without compromising the intended capacity of upcoming generations to meet their own needs [3], thereby making the world greener. Consequently, green chemistry, otherwise known as sustainable chemistry, involves maximizing the benefit of chemistry activities while eliminating or greatly reducing its environmental impacts [2]. In principle, green/sustainable chemistry is set to reduce or eliminate the consumption or generation of hazardous substances in the design, manufacture, and application of chemical and biochemical products. In order to achieve these, chemistry is guided by 12 principles when designing materials and processes.

1.2 The Basic Principles of Green Chemistry

The principles of green chemistry were set out to strategically and effectively manage chemical products in a way that fosters clean, less toxic, and environmentally friendly procedures that have a sustainable shelf life. In order to meet these requirements, in 1998 Anastas and Warner, in their work narrated the theory and practice in detail that provides an understanding of the emerging green chemistry movement that describes the 12 principles of green chemistry [4]. In some parts of the world, and mostly Africa where the culture of good chemical handling practices is very low, the application of these green chemistry rules becomes vital. According to this rule, the best way to treat hazardous waste is to prevent it from being disposed of in the environment. Unfortunately, failure to follow this simple rule has left the world (especially Africa)

with most of the difficult hazardous waste locations. According to Anastas and Warner 1998, the 12 principles are titled and defined as highlighted below.

- 1) Waste Prevention: The best way to prevent waste is to prevent it from being created in the first place.
- 2) Atom economy: It is essential to design synthetic methods so that all materials used in the process are incorporated into the final product.
- 3) Less hazardous chemical syntheses: In order to minimize harm to human health and the environment, synthetic methods should be used and generate substances that possess little or no toxicity.
- 4) Designing safer chemicals: Product design should include minimizing the toxicity of chemicals while achieving the desired function.
- 5) Safer solvents and auxiliaries: Auxiliary substances (e.g., solvents, separation agents, etc.) should be used sparingly when possible and be innocuous when employed.
- 6) Design for energy efficiency: When possible, synthetic methods should be conducted at ambient temperature and pressure to minimize the environmental and economic impacts of chemical processes.
- 7) Use of renewable feedstocks: The use of renewable raw materials or feedstock wherever technically and economically possible is preferable to depleting materials.
- 8) Reduce derivatives: If possible, derivatization should be minimized or avoided (blocking functions, protection/deprotection, temporary modifications of physical/chemical processes) because such steps require additional reagents and can generate waste.
- 9) Catalysis: The incorporation of catalytic reagents is better and superior to stoichiometric reagents.
- 10) Design for degradation: The design of chemical products should ensure that, after their function is complete, they disappear into harmless degradation products in the environment.
- 11) Real-time analysis for pollution prevention: Further development of analytical methodologies is required for real-time, in-process monitoring and control earlier to hazardous substance formation.

12) Inherently safer chemistry for accident prevention: The choice of substances used in a chemical process should be carefully made in order to reduce the probability of a chemical accident.

2.0 Application of Green Chemistry

In the 21st century, great success has been recorded in different sectors of chemical industries with the application of green methods in various production processes. For instance, green chemistry has been greatly employed in different laboratories and chemical manufacturing sectors including polymer, fabrics, colour/paint, paper, and pharmaceutical industries. Due to the health and environmental impact of combustion fuel, the idea of green energy from many energy sectors is a game changer as the design of innovative techniques for renewable energy batteries for automobiles, solar cells, and panels for housing and industries. These green technologies offer more advantages such as low cost, energy storage, and environmental friendliness.

2.1 Green Chemistry in the Energy Industry

In African industries, green methods are desirably important virtually in every manufacturing sector to incorporate fewer chemicals and generate less waste and finally end up with a good product. As fossil fuels and coal have provided Africa with most of its energy, they are also the significant polluter of Africa's freshwater supply, and air which is at risk due to climate change. Moreover, one of the major contributors to global warming is the combustion emitted from vehicles or industrial machines. However, great efforts have been made by manufacturers in order to design alternative sources of energy or means of empowering their machines/vehicles. The green method in this process resulted in the manufacturing of clean energy batteries. An example shows of these clean energy manufacturers is Northvolt; A Swedish solar battery manufacturing company established in 2016, that is committed to creating batteries with an 80% carbon footprint reduction compared to those made using coal. They are using them to enhance the environment and make it a better place to live in. This type of technological invention is needed in Africa as it is safer, healthy, and best for the replacement of fossil fuel.

2.2 Green Chemistry in Pharmaceutical/Drug Industries

Green chemistry has played a key part in the pharmaceutical industry by revolutionizing the drug design and production process. Ideally, choosing a solvent-free or green solvent (preferably water) and alternative reaction medium, green chemistry (GC) can be comprehensively applied to pharmaceutical synthesis by considering one-pot synthesis, multicomponent reactions (MCRs), continuous processing, and process intensification approaches to reduce atom economy and final waste (Kar *et al.* 2022) [5]. Various types of drug synthesis including metal complexation and co-crystallization have been done using the green chemistry method. Uchenna and Olufunso in their paper on co-crystallization published in 2022, highlight the advantages of green synthetic approaches such as the use of benign solvent, stirring at room temperature, in an environmentally friendly way, and the method resulted in an excellent yield of 91% [6]. In 1961, ibuprofen was developed by Boots Pure Drug Company in six steps, including a toxic aluminum chloride stage (Acceti *et al.* 2008) [7]. However, after the improvement in the synthetic procedure, a three-step process can now be used to distribute ibuprofen globally, but a simpler, more efficient, and stereospecific route is still needed (Ha and Paek, 2021) [8]. For years, Zocor (simvastatin), a drug used to treat high cholesterol, was synthesized using a complex method involving large quantities of hazardous reagents resulting in a large amount of toxic waste. A bio-catalysis company, Codexis, developed a method to synthesize a drug using a low-cost feedstock and an engineered enzyme [9].

2.3 Green Chemistry in Oil Production

Petrochemical industries are where the refining and processing of different chemical raw materials including crude take place. There are thousands of products that are made from petrochemicals, such as plastics, detergents, lubricants, pharmaceuticals, fertilizers, and others. In Africa, particularly Nigeria, oil companies are raging up to an upsurge in petrochemical production. For example, the Dangote refinery, one of the biggest oil refineries in the world was recently built in Nigeria and will start operation by May 2023. Upon completion, it will be the world's largest single-train refinery capable of processing about 650,000 barrels of crude oil per day [10]. The project was estimated to cost more than 19 billion dollars. This newly built industry and other existing ones in Africa were built to bridge the gap between shipping crude

oil abroad for refining and hence making locally refined products available. However, the real pollution problems affecting the environment are not yet addressed as more refining facilities, especially unauthorized refiners (an act of sabotage) whose aim is to make a fortune while destroying livelihood and causing more pollution.

In line to meet the set target of reducing carbon emissions by 2050, it's of global environmental interest to ambitiously achieve this goal before then. Therefore, an alternative design would be such that causes fewer hazards to humans and the environment. Thus, green fuel is the best alternative to fossil fuel. Interestingly, carbon-neutral and also carbon-free alternatives to fossil fuels are green fuels made from hydrogen and electricity from renewable sources. They are considered crucial for the future decarbonization of industries such as heavy industry, shipping, and power production.

3.0 Sustainable Development Goals Associated with Chemistry

3.1 Zero Hunger

Chemistry can play a key role in achieving SDG 2, by ending hunger, achieving food security and improved nutrition, and promoting sustainable agriculture in different societies around the world including Africa. The implementation of green chemistry particularly will not only affect food production but will equally protect the agricultural environment. As a result of breakthroughs in green chemistry, plants will be better protected from pest infestations, food will be produced and distributed more efficiently, packaging will last longer, and food safety and quality will be maintained.

3.2 Good Health and Wellbeing

SDG 3, Good health and Well-being is essential for everyone to have the enablement to work and accomplish their goals and make developments. To achieve the goal of good health and well-being, chemistry is necessary. Advances in chemistry have enabled breakthroughs in medicine and technologies that provide a deeper understanding of the impact of disease and hazardous chemicals on human health. Guégan, et al. 2018 discussed in their paper; ensuring good health and encouraging well-being for everybody regardless of age syndicates two viewpoints: first, in addition to being a human right, health is also an insurance capital that encourages

nation-building and sustainable development and second, it is a state of health or happiness that is related to a variety of physical or psychological factors taken individually or in combination. Therefore, the ability to be in good physical health and satisfy one's basic needs is a key factor in determining physical well-being, whereas psychological well-being depends on one's personal judgment and is often influenced by factors such as social or economic success, pleasure, and harmony with oneself, others, or the environment [11].

3.3 Clean Water and Sanitation

It is often said that “Water is precious to Life!” Hence, water is basic for almost every process of life, but its cleanness is important for every organism and human consumption. Ensuring the availability and sustainable management of water and sanitation for everyone is the prime aim of SDG 6. One of the major challenges African communities are facing today is bad water and poor sanitization, even though water is one of the basic amenities for livelihood but is drastically lacking in this part of the world, Africa. According to the United Nations, several plan indicators have been suggested to target the achievement of SDG 6 [12]. There are six outcome targets in the plan: Safe, affordable drinking water, sanitation, and hygiene access, increased water efficiency, wastewater treatment, safe reuse, integrated water resource management (IWRM) implementation, protection and restoration of water-related ecosystems, and reducing open defecation. As stated by Bartram et al (2018), In order to achieve these implementation targets, Water and Sanitation support will be expanded to developing countries, and local engagement in water and sanitation management will be supported [13].

3.4 Affordable and clean energy

The seventh sustainable development goal (SDG 7) aims to provide access to affordable, reliable, sustainable, and modern energy in order to address numerous problems. As part of the goals of the United Nations 2030; the agenda is targeted at economic development, poverty alleviation, and well-being for all through access to energy [14]. There are many activities that require energy, such as jobs and transportation, food security, health, and education [15]. SDG 7 agenda has birthed innovations in various energy sectors such as solar energy for both housing and

industry electricity supply, clean cooking solutions, and clean/renewable energy for automobiles, thereby gradually eliminating the use of CO₂ emission fuels which is greatly harmful to both humans and the environment.

3.5 Climate Action

Sustainable development goal thirteen (SDG 13), is focused on solving the issues of climate change which is one of the most endangering issues of the world today. Based on the (2013) Climate Change, fifth assessment Intergovernmental Panel report, the impact of climate change is gradually becoming severe as they are being felt across the globe and might become adverse and irreversible if not well controlled in the coming years [16]. In fact, climate change is already impacting agriculture, human health, and water supplies, according to the report, and rising temperatures will affect everyone on the planet eventually. As greenhouse gases in the atmosphere increase, temperatures will probably rise over most land surfaces [16].

In addition to catastrophic effects caused by climate change, scientists predict that extreme weather events such as storms, droughts, hurricanes, and floods will become more common, and that water and food will become scarcer. Small island nations and many coastal cities will be destroyed by rising sea levels and the destruction of numerous plants, fish, and animals (Baehr L, Harvey C, 2014) [17].

However, as climate change grows and becomes more severe, atmospheric chemistry research has become increasingly important for understanding the causes and predicting the impacts of the change. WHO (2019), reported that there is a close correlation between SDG 13 and SDG 7 on clean energy, but the official mission statement of this SDG 13, is to " Fight the effects of climate change by taking immediate action." [18]

4.0 Green Chemistry Roles in Sustainable Development Goals for Africa

In search of solutions in order to make the world a better place, the United Nations in collaboration with other scientific bodies such as UNESCO and IPAC came together to foster an idea to prevent disasters by focusing on different key solution areas including green chemistry. These goals were targeted to spontaneously touch every critical aspect of human life and the inhabiting environments, air, water, and every

part of nature that misuse of chemicals can affect. Studies in green chemistry as a cutting-edge effectiveness for sustainable development equally cut across other science and engineering such as biotechnology, biochemistry, pharmacy, and ecology; giving researchers the broad prospect to make great contributions.

Chemistry plays a significant role and has identified several priority Sustainable Development Goals that are integral to the community's work. In addition to technology, economics, and human health, chemistry has a broad impact on global sustainable development, and chemists in various sectors of practice are already taking many steps to do so. Some of the chemistry-associated SDGs programs as highlighted in this chapter showed clearly that chemistry is the bedrock to achieving UN-SDGs 2023 agenda.

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