

The Role of the Chemical Industry (Green Chemistry) in Sustainable Development and the Green Economy

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Abstract

The chemical industry processes natural and synthetic raw materials, altering their properties and creating new substances. The chemical industry, which produces goods for various sectors of the economy, also ensures the sustainability of production. In the context of sustainable development and a green economy, the chemical industry not only produces economically efficient and socially responsible products but also operates in an environmentally friendly manner without harming human health. In Azerbaijan, the chemical industry is represented in the fields of petrochemicals (synthetic rubbers, synthetic fibres, plastics, etc.), basic chemicals (acids, alkalis, mineral fertilisers, etc.), pharmaceuticals (medicinal preparations, biochemical products, etc.), and household chemicals (detergents, cleaners, cosmetic products, etc.). However, these fields are almost not working at their full capacity, and their activity is based on imported products. Furthermore, the chemical industry can, in some cases (technical accidents, negligence during the production process, outdated technology, etc.), cause harm to the environment and its components. In such a context, the implementation of green chemistry, as practised in leading countries of the world, is being emphasised, aligning with the demands of the modern era. This is because green chemistry minimises environmental impact and is characterised by its technological innovations. It is precisely in this context that the present article discusses the advantages of green chemistry.

Keywords: green economy, sustainable development, chemical industry, green chemical industry, natural and synthetic raw materials, extraction, processing

Introduction

In the modern era, the chemical industry plays an essential role across nearly all sectors of modern society, including extraction and processing industries, agriculture, services, and other sectors. As a result, these activities contribute to the depletion of natural resources and environmental pollution due to industrial waste. From this perspective, the chemical industry requires new and innovative approaches, which can be addressed through the green chemistry approach. Given that the chemical industry spans all sectors of human activity, it is increasingly important for tackling global challenges and safeguarding the welfare of future generations. This entails preventing the depletion of natural resources, ensuring sustainable environmental management, eliminating hazardous production processes, minimising waste to zero through technological innovations in consumption, discontinuing the use of harmful synthetic chemicals in agriculture, and applying biotechnology in the processing of agricultural products (Figovsky & Gumerov, 2019). In this process, the organization of production, consumption, and management is made possible through the application of green chemistry. This is because green chemistry is considered a specialised field that implements policies aimed at reducing greenhouse gas and other toxic emissions, while also supporting the rational use of alternative energy sources.

Sustainable Development and green chemistry

In 2015, the United Nations (UN) summit identified 17 Sustainable Development Goals for the period up to 2030. A significant portion of them (6. Clean Water and Sanitation, 9. Industry, Innovation, and Infrastructure, 12. Responsible Consumption and Production, 13. Combating Climate Change, 14. Life Below Water, 15. Protection of land ecosystems) can be linked to the development and modernization of the chemical industry. This also allows green chemistry in the chemical industry to be characterized not only as a new philosophy of chemistry and chemical technology but also as an effective tool for sustainable development (Atlaskin et al., 2024). However, at the 4th session of the UN Environment Assembly held in Nairobi in March 2019, the report titled “Global Chemicals Outlook II: Innovative Solutions for Environmental Challenges and Sustainable Consumption and Production” concluded that the global target to minimize the adverse impacts of chemicals and waste would not be achieved by 2020 (UNEP, 2019). In such a context, it should not be overlooked that modern science is increasingly focusing on sustainable development and the green chemical industry. Green chemistry seeks to ensure that production processes are safe, resource-efficient, and generate minimal waste.

The present analysis indicates that the chemical industry, and particularly green chemistry, plays a crucial role in achieving the Sustainable Development Goals. These can be summarized in the following three aspects:

- 1) Cognitive Chemistry – the development of science and educational processes;
- 2) Industrial Chemistry – technologically innovative approaches and their application;
- 3) Environmental Chemistry – efficient use of natural resources and the transition to waste-free technologies.

The Role of the Chemical (Green Chemistry) Industry in the Economic System

The chemical industry involves the processing of hydrocarbons, minerals, and other raw materials. The primary objective of the chemical industry is the efficient use of natural resources. This strategic goal encompasses not only extraction but also advanced processing using the latest technologies, enabling the production of high-quality products that are in strong demand in both domestic and international markets (Gurbanmyradova et al., 2025). Green chemistry refers to the design and implementation of processes for the production of chemical products that do not generate toxic waste and that incorporate continuously improved, innovative technologies, thereby minimizing adverse impacts on human health and the environment. This industrial sector aims to mitigate environmental impacts through the development of alternative and safer technologies (Saleh & Koller, 2018). One of the criteria used in the evaluation of technological processes is the principle of chemical reaction efficiency. In this context, the concept of waste-free production is emphasized, or, where waste generation is unavoidable, ensuring that it is non-hazardous (Sheldon, 1992). As a result, several approaches have been proposed to enable the near-complete utilization of renewable raw materials, which has had a significant impact on fields such as chemical metallurgy, construction, advanced materials, medical biology, pharmaceuticals, and the generation of alternative energy (Dyukarev et al., 2012). This approach accelerates the transition toward sustainable development and a green economy. In this context, a green economy is understood as the achievement of economic growth with minimal environmental impact, promoting the efficient use of natural resources. The transition to a green economy is widely recognized as a primary pathway for addressing global environmental challenges.

In Azerbaijan, the chemical industry is primarily based on a raw material foundation comprising oil and natural gas, sulfur pyrite, alunite, oilfield waters, rock salt, and other resources. These resources include iodine–bromine waters located in Neftchala, Xilli, Babazenen, Mushovdagh, Maghan, and Shirvan; the Boyukshor and Masazır lakes on the Absheron Peninsula, as well as sedimentary salt deposits in the Gobustan region; barite deposits at the Bashlıqlar (reserves of 133 thousand tons) and Chovdar (reserves of 68 thousand tons) sites in the Goygol district; sulfur pyrite occurrences in the Toraghanlı area of the Balaken district and the Chiraqdere area of the Gadabay district; copal deposits in the villages of Qurchu and Yukharı Agach in the Lachın district; and rock salt deposits in Nakhchivan (with reserves of approximately 1.3 billion tons), among others (Imrani et al., 2014). Currently, the chemical and petrochemical industry in Azerbaijan is considered one of the most significant components and a driving force of the national economy. This industrial sector provides a foundation for socio-economic development and plays a significant role on the sectoral and regional structure of the economy.

The development of the chemical industry in Azerbaijan has been closely linked to the oil and gas sector and is reflected in the “Strategic Roadmap for the Development of the Oil and Gas Industry (including Chemical Products)” (President of the Republic of Azerbaijan, 2016). As a strategic goal, the establishment of several new large-scale chemical industry enterprises and their diversification has become a strategic development priority. For example, the heavy industry enterprises in Sumgayit, which have been in operation since 1945—including chemical, pipe-rolling, synthetic rubber, aluminium, and superphosphate plants—were reorganized on December 21, 2011, as the Sumgait Chemical Industrial Park, established on a 167.66-hectare site within the territory of the “Azerikimya” Production Association (Azerbaijan State News Agency, 2011). Currently, the area of the Sumgait Chemical Industrial Park has been expanded to 508.14 hectares. According to the most recent report, the total investments in the industrial park amount to 2.1 billion USD, with 23 resident companies and a workforce of 10,000 employees (Suleymanli, 2021). The efforts undertaken aim to increase the production capacity of competitive, high-quality, and export-oriented chemical industry products, as well as to establish the manufacture of green chemistry products within the industrial park.

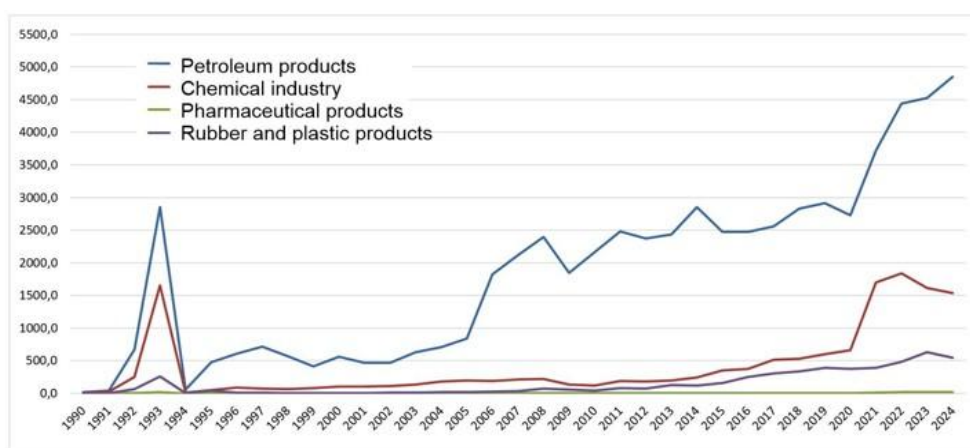


Figure 1. Volume of products produced by enterprises related to the chemical industry, million manats. Source: Azerbaijani Industry. Baku, 2025.

An examination of the statistics on the number of industrial enterprises in Azerbaijan and the volume of their production reveals a pronounced trend of growth between 1994 and 2024. Specifically, while the volume of industrial products produced amounted to 224 million manats in 1994, this figure is projected to increase to 64.9 billion manats by 2024 (Budagov, 2025). The production capacity of enterprises related to the chemical industry increased from 33.4 million manats to 6.9 billion manats over the corresponding years (fig. 1). These data indicate that those enterprises related to the chemical industry—including oil, pharmaceutical, and rubber and plastic products—are expected to account for 10.7% of total industrial production in 2024, with chemical industry enterprises alone representing just 2.4% of this figure.

An analysis of the most recent five years, from 2020 to 2024, shows that the number of enterprises related to the chemical industry increased by 228 units, reaching a total of 511. Of these, 51.3% are state-owned enterprises, while 48.7% are non-state enterprises. However, in the overall structure of industrial enterprises (fig. 2), this indicator is not as prominently reflected. Specifically, while the share of enterprises related to the chemical industry in the overall structure of industrial enterprises was 10.1% in 2020, it increased slightly to 10.7% by 2024 (Azerbaijan State News Agency, 2011). These developments further highlight the potential for advancing the chemical industry in the country at a new pace. This is because the chemical industry continues to evolve through technological innovation, resulting in environmental protection and sustainable ecological benefits. This can be clearly observed in the case of the Sumgait Chemical Industrial Park.

In Azerbaijan, the chemical industry should leverage the advantages of green chemistry and its applications, as is done in developed countries, to achieve sustainable development and a green economy. Green chemistry is primarily applied in the pharmaceutical and organic chemical industries using modern technologies. This factor also affects both the quality of the products produced and their export orientation.

Conclusion

Green chemistry is characterized by engineering processes that emphasize by low energy consumption, high efficiency and cost-effectiveness, and minimal waste generation, aiming to achieve economic benefits in production while adhering to the principles of sustainable development. From this perspective, the implementation of green chemistry in Azerbaijan is particularly important. This is because green chemistry contributes to the modernization of industrial production and achieve environmentally sustainable industrial development. In Azerbaijan, the chemical industry is primarily based on the production of oil and gas products and is considered the largest industrial consumer. During such processes, harmful waste is generated, which green chemistry seeks to reduce through the adoption of innovative, technology-driven solutions. In this context, green chemistry aims to minimize potential harm in the production of oil, pharmaceutical, and rubber and plastic products-and it is has demonstrated considerable potential in achieving this objective.

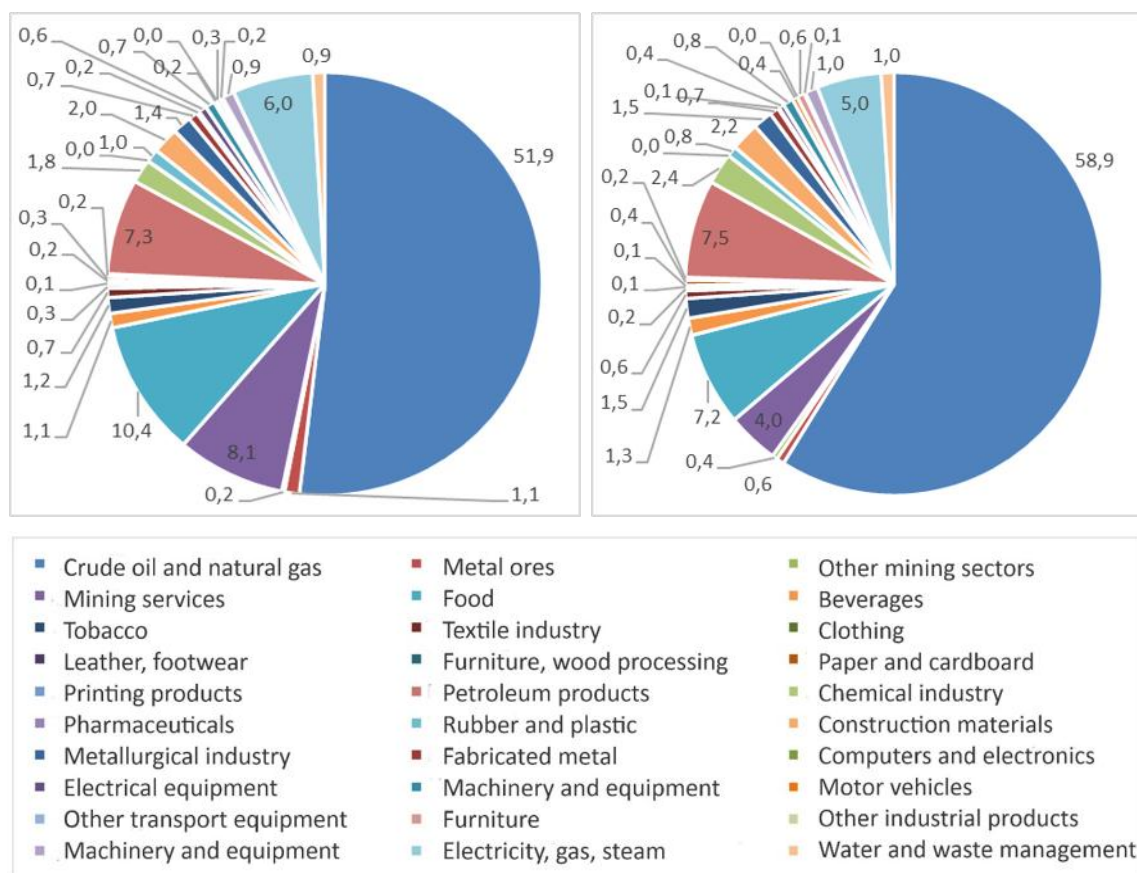


Figure 2. Structure of industrial enterprises, %. Source: Azerbaijani Industry. Baku, 2025

Competing interests

The authors declare that they have no competing interests.

Authors' contribution

All authors provided critical feedback and helped shape the research, analysis and manuscript.

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