International Journal of Scientific World, 12 (1) (2026) 13-21

International Journal of Scientific World

Website: www.sciencepubco.com/index.php/IJSW
https://doi.org/10.14419/t8s8f276
Research paper

Chemistry As A Key Driver of Human Survival And Societal Development: A Review

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Received: December 31, 2025, Accepted: February 15, 2026, Published: February 18, 2026

Abstract

A fundamental component of human existence, chemistry influences the advancement of industry, agriculture, healthcare, environmental management, and security. Critical issues like food security, disease prevention, access to clean water, infrastructure development, and international security are all addressed by its applications. Using examples from international research and Nigerian contexts, this review offered a thorough evaluation of chemistry's function in daily life. Examined are the major contributions of chemistry to biological processes, construction, healthcare, agriculture, environmental protection, and security are examined. The results showed that chemistry influences biological processes, societal development, and technological advancement, and is essential from birth to death. This reviewemphasized how important chemistry is to maintaining human life and advancing global development.

Keywords: *Chemistry; Agriculture; Healthcare; Security; Human Survival; Daily Life; Environment; Pharmaceuticals.*

1. Introduction

Chemistry, widely recognized as the central science, forms a vital link between physics, biology, and other scientific disciplines, providing the conceptual and practical foundation for understanding matter and its transformations [1]. Its principles are fundamental to human survival and societal development, influencing key sectors such as agriculture, healthcare, industry, environmental management, security, and biological systems [2]. Chemistry plays a foundational role in addressing human needs, including food, energy, materials, and health, illustrating its broad relevance to quality of life and economic development, as discussed by [3]

Through the development of fertilizers, pesticides, soil conditioners, and post-harvest preservatives, chemistry has significantly increased agricultural productivity and contributed to the mitigation of global malnutrition and food insecurity [4]. Chemical innovations in crop protection, soil nutrient optimization, and post-harvest technology have been particularly significant.

Chemistry plays a pivotal role in enhancing agricultural productivity and resilience in both developed and developing countries through climate-smart agricultural practices, improved fertilizer formulations, soil amendments, and sustainable pest management strategies [5]. These chemical innovations contribute to improved soil fertility, increased crop yields, and greater adaptability to climate variability, thereby strengthening food security. In healthcare, chemistry provides the basis for drug discovery, pharmaceutical formulation, diagnostic techniques, and the development of medical devices, thereby enhancing disease management, life expectancy, and overall quality of life [6]. Chemotherapeutic agents used in cancer treatment, such as alkylating agents, antimetabolites, and platinum-based compounds, are direct products of medicinal and coordination chemistry, illustrating the critical role of chemical science in modern oncology [7]. Furthermore, chemistry underpins vaccine development, diagnostic reagents, and novel biomaterials for medical applications, reflecting its cross-disciplinary impact on public health [8].

Industrial chemistry supports infrastructure development and economic growth through innovations in materials science, energy production, fuel processing, polymers, cement, and manufacturing technologies [9]. Advances in industrial chemical processes also promote sustainability through waste minimization, green chemistry practices, and energy-efficient production, as emphasized by [10].

Environmental protection and water resource management depend heavily on chemical processes such as coagulation, flocculation, disinfection, adsorption, and advanced oxidation for water purification, pollution control, and waste treatment [11]. In Nigeria, municipalities such as Lagos and Kano employed these chemical technologies in water treatment plants to ensure access to potable water, reduce waterborne diseases, and improve public health outcomes, reflecting practices widely adopted across both developed and developing nations [12].

Chemistry also plays a critical role in security and defense through the development of protective materials, controlled explosives, corrosion-resistant alloys, forensic analytical techniques, and non-lethal chemical agents used for civilian and military safety [13].

At the biological level, life itself is controlled by chemical reactions, including metabolism, respiration, enzymatic catalysis, and molecular interactions. Fundamental processes such as photosynthesis, cellular energy transfer (ATP synthesis), redox reactions, and biochemical regulation sustain both plant and animal life and enable applications in biotechnology, food processing, forensic science, and medical research [14].

Against this background, this review examines the central role of chemistry in human survival and development by integrating global perspectives with context-specific examples from Nigeria. It explores the contributions of chemistry to agricultural productivity and food preservation, pharmaceutical development and medical diagnostics, water treatment and environmental protection, industrial and construction processes, security and defense technologies, and the fundamental biochemical processes that sustain life. By adopting this integrated approach, the review highlights chemistry as an indispensable driver of public health improvement, food security, technological advancement, and sustainable development at both national and global scales [15].

1.1. Review methodology

This study adopted a narrative literature review approach to synthesize existing scholarly knowledge on the role of chemistry in human survival, development, and sustainability. A narrative review was considered appropriate because it allows for a broad, integrative discussion of theoretical, applied, and interdisciplinary contributions of chemistry across agriculture, healthcare, environment, industry, security, and biological systems.

1.2. Databases and sources of literature

Relevant literature was sourced from reputable academic databases and platforms, including Google Scholar, ScienceDirect, PubMed, SpringerLink, Wiley Online Library, Taylor & Francis, and selected reports from international organizations such as UNESCO, WHO, FAO, and UN agencies. Additional context-specific studies were obtained from African Journals Online (AJOL) to capture Nigerian and regional perspectives.

1.3. Search keywords and strategy

The literature search employed combinations of keywords and phrases such as: “chemistry as the central science,” “role of chemistry in human survival,” “chemistry in agriculture and food security,” “chemistry in healthcare and pharmaceuticals,” “environmental chemistry and water treatment,” “industrial chemistry and energy,” “chemistry in security and defense,” and “biochemistry and life processes.” Boolean operators (AND, OR) were used to refine the search and ensure comprehensive coverage.

1.4. Time frame of the review

The review primarily covered publications from 2000 to 2024 to reflect contemporary developments in chemical sciences, while a limited number of seminal and foundational works published earlier were included to provide theoretical grounding and historical context.

1.5. Inclusion and exclusion criteria

Inclusion criteria consisted of peer-reviewed journal articles, academic textbooks, conference proceedings, and authoritative institutional reports written in English and directly relevant to the thematic focus of chemistry’s role in human survival and development.
Exclusion criteria included non-scholarly articles, opinion pieces without empirical or theoretical backing, duplicate studies, and publications with limited relevance to the objectives of the review.

1.6. Screening and selection process

Titles and abstracts of retrieved studies were first screened for relevance. Full-text articles were then reviewed to ensure agreement with the review objectives. Selected studies were thematically organized and critically synthesized under key domains, including agriculture, healthcare, environmental protection, industry, security, and biological systems.

1.7. Background theory

The conceptual framework for understanding the changes in matter and energy that underlie biological, environmental, and technological systems is provided by chemistry[16]. The formation and behavior of substances necessary for food, medicine, materials, and living tissues are explained by interactions between atoms and molecules that are controlled by thermodynamics, kinetics, and bonding theories [17].
Reaction kinetics and catalysis determine the viability and efficiency of biochemical and industrial reactions, while thermodynamic principles control energy flow in metabolic pathways, respiration, photosynthesis, and industrial processes [18]. Water quality, soil fertility, and the physiological stability of living things are all preserved by acid-base equilibria and buffering systems [19]. While analytical chemistry makes it easier to identify and measure chemical species essential for healthcare, environmental monitoring, and security, redox chemistry controls cellular energy production, corrosion control, and environmental remediation [20].
Human life is regulated by chemical processes from the beginning of respiration at birth to the end of metabolic reactions at death [21]. Together, these theories established chemistry as the unifying science underlying human survival and sustainable development. Biochemical theory integrates these chemical principles within living systems, explaining metabolism, enzymatic catalysis, molecular recognition, and energy transfer.
Conceptual Model (Textual Flow Framework)

1.8. Foundational chemistry principles

(Atomic structure, bonding, thermodynamics, kinetics, equilibrium, redox reactions)
Chemical Mechanisms

(Energy transfer, reaction rates, catalysis, pH regulation, electron transfer, molecular recognition)
System-Level Processes

(Biological metabolism, soil and water chemistry, industrial synthesis, material formation)
Applied Domains

(Agriculture, healthcare, environmental protection, industry, security, energy)
Societal Outcomes

(Food security, public health, environmental sustainability, technological development, human survival)
Strength: This works well as a conceptual framework figure or as a narrative bridge between theory and literature review

2. Literature Reviews

2.1. Chemistry as the central science in human survival

Chemistry has long been described as the "central science" because it bridges the physical sciences with life and applied sciences, enabling a holistic understanding of matter and energy transformations that sustain life and technology [22]. Several scholars have emphasized that virtually all natural and anthropogenic processes, ranging from cellular metabolism to industrial manufacturing, are regulated by chemical principles [23]. The indispensability of chemistry to human survival lies in its ability to explain, manipulate, and optimize these processes for societal benefit.
Studies have shown that advances in chemistry support technological revolutions in agriculture, medicine, energy, and environmental management, thereby shaping modern civilization [24]. Without an understanding of chemistry, meeting basic human needs, such as food, clean water, shelter, health, and security, would be impossible, demonstrating how deeply chemistry is woven into human existence.

2.2. Role of chemistry in agriculture and food security

Agricultural productivity has been profoundly transformed by chemical innovations, particularly through the development of synthetic fertilizers, pesticides, herbicides, and soil conditioners. According to [25], nitrogen, phosphorus, and potassium fertilizers alone account for a significant proportion of global food production, supporting billions of people worldwide. Chemical control of pests and plant diseases has further reduced crop losses and enhanced yield stability [26].
Food preservation techniques such as chemical preservatives, antioxidants, and modified atmosphere packaging have extended shelf life, reduced post-harvest losses, and improved food safety [27] In Nigeria, studies have reported that the application of fertilizers and agrochemicals has contributed to increased yields of staple crops such as maize, rice, and sorghum, particularly in states like Kano, Kaduna, and Niger [28] However, literature also highlights the need for sustainable and environmentally friendly chemical practices to mitigate soil degradation, water contamination, and human health risks associated with excessive agrochemical use.

2.3. Contributions of chemistry to healthcare and pharmaceutical

Chemistry forms the backbone of modern healthcare through its role in drug discovery, pharmaceutical formulation, diagnostics, and biomaterials. Advances in medicinal chemistry have made it possible to design and synthesize therapeutic agents for the treatment of infectious diseases, chronic disorders, and cancer [29].
Chemotherapeutic drugs such as cisplatin, methotrexate, and cyclophosphamide exemplify the application of coordination chemistry, organic synthesis, and structure–activity relationship studies in oncology[30].
Analytical chemistry supports disease diagnosis through techniques such as spectroscopy, chromatography, and immunoassays, which are essential for clinical testing and patient monitoring [31].
In Nigeria, chemical sciences have contributed to pharmaceutical manufacturing, quality contrand public health interventions, including vaccine formulation, drug stability studies, and toxicological assessments [32]. Literature consistently demonstrates that improvements in life expectancy and disease management are closely tied to advances in chemical research and pharmaceutical innovation.

2.4. Chemistry in environmental protection and water resource management

Environmental sustainability and public health protection rely heavily on chemical processes for pollution control, waste management, and water treatment. Conventional water purification methods such as coagulation, flocculation, filtration, chlorination, and ozonation are rooted in applied chemistry and have significantly reduced the burden of waterborne diseases globally [33]. Advanced techniques, including adsorption using activated carbon, membrane filtration, and advanced oxidation processes, further enhance water quality by removing emerging contaminants.

In Nigeria, chemical treatment processes are widely employed in municipal water treatment plants, particularly in urban centers such as Lagos, Abuja, and Kano [34]. Studies have reported measurable improvements in potable water quality and reductions in disease prevalence following the application of these chemical technologies. Environmental chemistry also plays a critical role in monitoring air, soil, and water pollution, enabling risk assessment and evidence-based regulatory decision-making.

Beyond routine environmental management, chemical principles are also central to emergency response and disaster mitigation, particularly during fire outbreaks. In firefighting operations, water is often supplemented with synthetic chemical additives such as foaming agents and wetting agents to enhance heat absorption, suppress flames, and prevent re-ignition. In indoor fire incidents, fire extinguishers designed using applied chemical knowledge are commonly deployed; for example, carbon dioxide (CO_2) extinguishers operate by displacing oxygen around the fire and interrupting the combustion reaction, thereby effectively extinguishing flames. These applications further demonstrate the critical role of chemistry in protecting human life, property, and the environment during emergencies.

2.5. Chemistry in industry, construction, and energy

Industrial and materials chemistry has driven infrastructural development and economic growth through innovations in cement production, polymers, ceramics, alloys, and composites. The chemical composition and hydration reactions of cement, for instance, determine the strength and durability of buildings, bridges, and roads [35]. Polymer chemistry has revolutionized manufacturing, packaging, healthcare materials, and electronics.

Energy production and storage are equally dependent on chemistry, with fossil fuel processing, petrochemicals, batteries, solar cells, and hydrogen technologies all grounded in chemical principles [36]. In Nigeria, industrial chemistry supports the oil and gas sector, construction industry, and emerging renewable energy initiatives, highlighting its strategic importance to national development.

2.6. Role of chemistry in security and defense

Chemistry contributes significantly to national and global security through the development of protective materials, forensic science, corrosion inhibitors, controlled energetic materials, and non-lethal agents. Forensic chemistry enables the detection and analysis of explosives, drugs, poisons, and trace evidence, playing a crucial role in crime investigation and justice systems [37].

Materials chemistry has led to the production of bullet-resistant vests, fire-retardant materials, and corrosion-resistant alloys used in military and civilian infrastructure. Literature also emphasizes the ethical responsibility of chemists to ensure that chemical knowledge is applied for protection and safety rather than harm, particularly in the context of chemical weapons regulation and environmental security.

2.7. Chemistry in biological processes and life itself

Life is fundamentally rooted in chemical processes, with interconnected biochemical reactions including metabolism, enzymatic activity, respiration, and signal transduction maintaining cellular structure and function [38].

Processes including photosynthesis, ATP synthesis, redox reactions, and molecular recognition illustrate the chemical basis of energy transfer and biological regulation.

These biochemical principles underpin applications in biotechnology, food science, medical research, and forensic biology. The literature consistently affirms that from birth, when oxygen intake triggers biochemical respiration, to death, when chemical processes cease, human existence is inseparable from chemistry.

2.8. Synthesis of literature and research gap

3. Discussion and Comparison

Existing literature overwhelmingly confirms the central role of chemistry in agriculture, healthcare, environmental protection, industry, security, and biological systems. However, many studies focus on isolated sectors, with limited integrative analyses that holistically examined chemistry's contributions to human survival and development, particularly within developing country contexts such as Nigeria. This review addressed this gap by synthesizing global research with Nigerian examples, providing a comprehensive perspective on chemistry as a unifying and indispensable driver of human progress.

Table 2: Summary of Environmental and Chemical Risk Interventions, Their Benefits, Limitations, and Strength of Supporting Evidence

Intervention/Exposure	Benefits/ Utility	Risks/ Limitation	Evidence Strength Source
Agrochemical fertilizers increase crop yields. Soil acidification, water eutrophication			moderate - strong (Recent meta-analyses
Pesticides (Organophosphate)	Broad pest control	Neurotoxicity residues	High(FAO, WHO, recent field studies)
Industrial effluent controlshave reduced pollutants. High cost, tech gaps.			Emerging evidence (case studies)
Security-related chemical Hazard.	Threat modeling, data scarcity, reporting, Bias		Weak- moderate
Phytoremediation/ Bioremediation	Use plant/Microbes to remove or stabilize, contaminants (Heavy Metals and agrochemicals	Variable efficiency depending on species,slow heavy metal uptake. metals may take a long time	Several plant species show Phytochemical extracts reduce metal levels in soil in controlled studies [39]
Safe Agrochemical improves crop yield.		Unsafe handling leads to	

Application Practices Environmental damage. farmer surveys show poor PPE use and high-risk behavior [40].	with reduced (exposure, poisoning)	leads to health risks poisoning) Primary	(exposure,
Regulated Industrial Effluent Treatment, the ecosystems	Reduced pollutant discharge into in Nigeria	Costly: regulatory enforcement weak limit	Industrial effluent studies. show metal levels above [41]
Environmental Monitoring and Risk Assessment Models exposure and policy funding. guidance,	Provides quantitative risk profiles for risks, especially for children [40]	Requires extensive data, consistent sampling,	Systematic reviews using HQ, and HI show significant
Public Education & Awareness Programs Practice (farmers, informal waste recyclers)	Reduce unsafe literacy, resources	Uptake depends on in knowledge and practice	Surveys indicate major gaps

Key roles of chemistry in agriculture, healthcare, security, construction, materials, and energy.

Fig. 1: Roles of Chemistry in Agriculture.

Fig. 2: Role of Chemistry in Healthcare and Pharmaceutical.

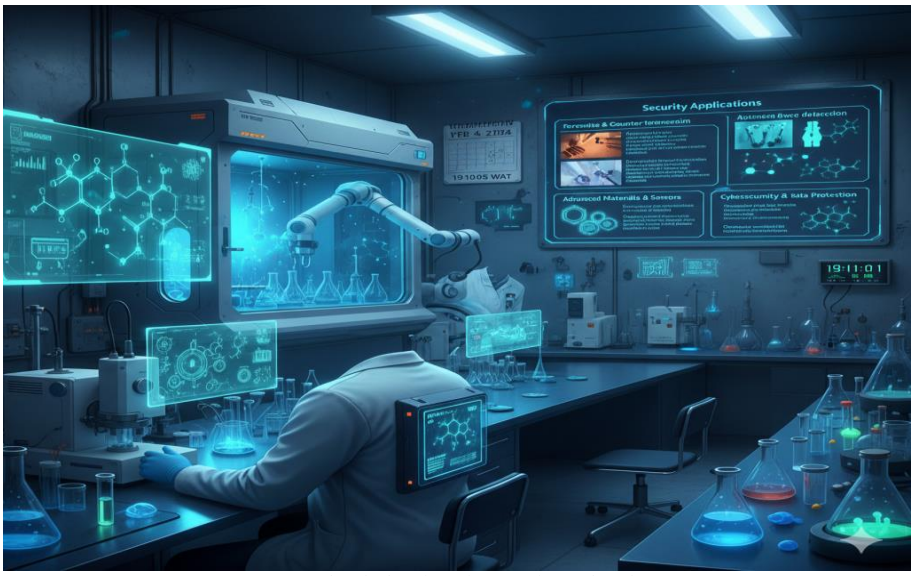

Fig. 3: Role of Chemistry in Security and Defense.

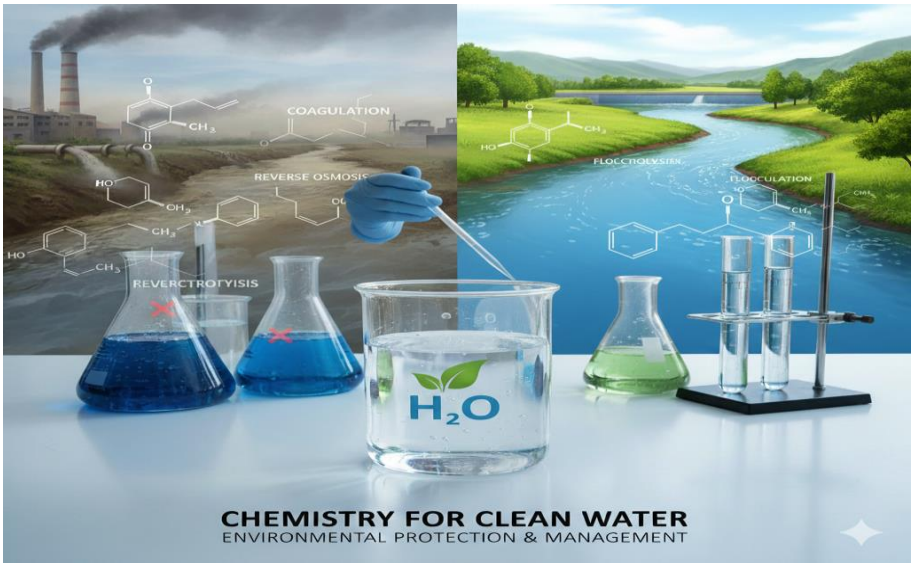

Fig. 4: Role of Chemistry in Environmental Protection and Water Resource Management.

Fig. 5: Chemistry in Industry, Construction, and Energy.

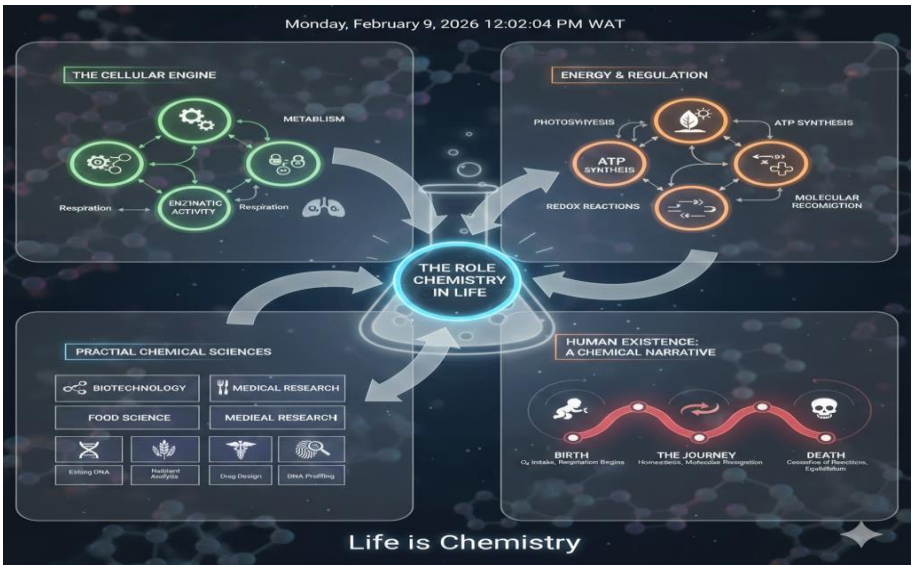

Fig. 6: Role of Chemistry in Biological Processes and Life Itself.

Figure 1demonstrates the the applications of chemistry in agriculture; chemical inputs such as fertilizers, pesticides, herbicides, and preservatives are crucial for improving soil fertility, protecting crops from pests and diseases, and reducing post-harvest losses. In Nigeria, national agricultural programs coordinated by the Federal Ministry of Agriculture and Rural Development [42]]including the Growth Enhancement Support Scheme, have promoted the use of inorganic fertilizers, contributing to improved maize and rice yields in major producing states such as Kano and Kaduna [43] Fertilizer use has been a key driver of agricultural productivity, although overall consumption per hectare in Nigeria remains below global standards due to reliance on imports [44]. Reports from the National Bureau of Statistics and FAO confirm that agrochemical use has significantly improved cereal yields. Similar strategies support high productivity in countries such as India and Brazil, where fertilizer subsidies, mechanization, and strict agrochemical regulation are more advanced [45]
However, while developed countries increasingly employ precision agriculture, controlled-release fertilizers, and integrated pest management to minimize environmental impacts, many Nigerian farms still face challenges such as inappropriate chemical application, limited extension services, and weak enforcement of agrochemical regulations [46] Farmers' low training levels and non-compliance with usage instructions further increase health and environmental risks associated with agrochemical use [47]
From Figure 2, in healthcare, chemistry underpins pharmaceuticals, diagnostics, and medical technologies. Chemotherapy, a core component of cancer treatment, relies on chemically synthesized compounds that inhibit cancer cell growth through DNA damage, enzyme inhibition, and disruption of cell division [6] In Nigeria, chemotherapy is the most accessible cancer treatment in tertiary hospitals such as University College Hospital (Ibadan), Ahmadu Bello University Teaching Hospital (Zaria), and National Hospital (Abuja), targeting cancers such as breast, cervical, prostate, and hematological malignancies using imported drugs [48] In contrast, healthcare systems in Europe, North America, and parts of Asia increasingly combine chemotherapy with targeted therapies, nanoparticle-based drug delivery, and personalized medicine approaches, which improve efficacy and reduce toxicity [49]. Limited access to these advanced therapies in Nigeria highlights the critical role of chemistry in national cancer management [50].
Figure 3, Chemistry also enhances security and defense through explosives, protective materials, detection systems, forensic analysis, and non-lethal agents [51]. In Nigeria, these applications are used for quarry blasting, explosive ordnance disposal, forensic toxicology, and crowd-control operations, whereas Europe and North America benefit from stricter regulations, advanced sensor technologies, and international chemical conventions that reduce risks [52].
From figure4, Environmental protection and water treatment also demonstrated chemistry's practical relevance in Nigeria. Urban water supply systems in Lagos, Kano, and Abuja rely on chemical treatment processes like coagulation, flocculation, sedimentation, filtration, and chlorination to ensure potable water quality and reduce water-borne diseases [8][12]. Nigerian water authorities report that these chemical processes significantly reduce microbial contamination and turbidity. Meanwhile, developed countries have advanced to membrane filtration, ozonation, and advanced oxidation for removing emerging contaminants such as pharmaceuticals, microplastics, and heavy metals [53]. In Nigeria, limited funding, technical expertise, and aging infrastructure slow the adoption of these advanced technologies [54].
From Figure 5, Industrial chemistry is another driver of economic development. In Nigeria, chemical industries support cement manufacturing, petroleum refining, fertilizer production, soap and detergent formulation, plastics, and paints, particularly in industrial hubs such as Lagos, Ogun, Rivers, and Kaduna States [55]. These industries contribute significantly to employment, import substitution, and infrastructure development. Developed countries, in contrast, operate highly specialized chemical industries producing pharmaceuticals, specialty chemicals, advanced materials, and renewable-energy components, guided by green chemistry and circular-economy principles [56]. Pollution from chemical emissions and workplace exposure remain ongoing challenge in Nigeria [57]. As shown in From figure6, at the biological level, chemical reactions govern metabolism, respiration, photosynthesis, enzymatic activity, and molecular interactions across all living systems [14]. Nigerian laboratories apply biochemical and toxicological techniques for nutrition studies, disease diagnosis, environmental monitoring, and forensics. Laboratories in developed countries increasingly use omics technologies, molecular diagnostics, and high-throughput analytical platforms [58]. Despite technological differences, the chemical principles underlying these biological processes are universal.
Comparisons between Nigeria and other regions demonstrate that chemistry is universally applicable but context-dependent. Developed countries benefit from stronger infrastructure, funding, and regulations, while Nigeria continues to use chemical science to address food security, healthcare, industrial growth, and environmental sustainability [59]. This underscores the need for sustainable chemical practices, improved regulation, and equitable access to chemical innovations to maximize societal benefits while minimizing environmental and health risks.

4. Conclusion

<Life is sustained by continuous chemical reactions that regulate respiration, metabolism, growth, and cognitive functions, confirming chemistry as the foundation of biological existence.
<The initiation of respiration at birth activates essential biochemical processes, while the cessation of these reactions marks the end of life.
Chemistry plays a critical role beyond human physiology by supporting agriculture, medicine, water treatment, and industrial development.
<Modern technological advancement and healthcare delivery are strongly dependent on applied chemical knowledge.
Although often unnoticed, chemistry remains central to human survival, well-being, and sustainable development.

4.1. Implications

The study emphasizes the importance of chemistry education in addressing national challenges related to health, food security, and environmental management in Nigeria.
Increased awareness of chemistry's relevance can promote evidence-based decision-making and policy formulation in science and technology sectors.
Strengthening chemical sciences can enhance interdisciplinary research and innovation critical to national development.

4.2. Limitations

The study is qualitative and conceptual, lacking empirical data to support a quantitative evaluation of biochemical processes.
Detailed examination of specific chemical pathways and industrial applications was beyond the scope of this work.

4.3. Recommendations for future work

Future research should incorporate experimental and clinical data to evaluate specific chemical processes involved in human physiology.
Interdisciplinary studies integrating chemistry with medicine, agriculture, and environmental sciences are recommended.
Further investigations should focus on sustainable chemical technologies relevant to public health and environmental protection in developing countries.

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