

Review Article

## One Health and Roles of Chemical Sciences

**Chidozie Vivian Nwatoka<sup>1</sup>, Okan Hillary Ehgomare<sup>2</sup>, Mbah Amaechi<sup>3</sup>,  
Chukwu Otuh Chukwu<sup>4</sup> , Kagoro Mary Luka-Anzah<sup>5,\*</sup> **

<sup>1</sup>Department of Medical Laboratory Science, Federal College of Veterinary and Medical Laboratory Technology, Vom, Nigeria

<sup>2</sup>Department of General Studies, Federal College of Veterinary and Medical Laboratory Technology, Vom, Nigeria

<sup>3</sup>Department of Nutrition and Dietetics, Federal College of Veterinary and Medical Laboratory Technology, Vom, Nigeria

<sup>4</sup>Department of Public Health, Federal College of Veterinary and Medical Laboratory Technology, Vom, Nigeria

<sup>5</sup>Department of Chemistry, University of Jos, Jos North, Nigeria

### Abstract

One Health is a framework that recognises the interconnection between human health, animal health and environmental health. It is a collaborative, multidisciplinary approach that aims to develop strategies to prevent and control diseases, improve health outcomes, and address the global challenges of antimicrobial resistance (AMR), food safety, and environmental degradation. Chemical science plays a crucial role in supporting the One Health framework. Chemical sciences should have a significant role, but its integration has been insufficient. Specifically, the lack of systemic chemical surveillance, the continued use of environmentally persistent compounds, and inadequate chemical risk assessment models present substantial obstacles to achieving One Health objectives. This article examines the central yet underutilised role of chemical sciences in catalysing the One Health paradigm shift. The aim is to demonstrate how chemical sciences can provide molecular-level insights and technologies to predict, prevent, and mitigate health threats at the human-animal-environment interface. From the design of safer pharmaceuticals and veterinary drugs to the monitoring and remediation of environmental contaminants, chemistry is uniquely positioned to contribute transformative tools and knowledge. The integration of chemical sciences into One Health is challenged by a lack of research collaboration, insufficient interdisciplinary training, and regulatory frameworks that account for the ecological impact of chemicals. This review explores the contributions of chemical sciences to the One Health concept and advocates for the detection, analysis, and mitigation of chemical hazards that impact human, animal, and environmental health. This review also addresses possible solutions: (1) the incorporation of One Health principles into chemical science education and training; (2) the development of collaborative research platforms that bridge chemistry with epidemiology, veterinary sciences, and ecology; (3) policy reforms to strengthen regulation of chemical use across sectors; and (4) the advancement of green chemistry and sustainable design principles to minimise environmental and biological impacts at the source. Additionally, innovations in chemical informatics and sensor technologies can enhance real-time surveillance and facilitate data-driven decision-making. Meanwhile, chemical sciences should be repositioned as one of the core pillars of the One Health framework, and the practice should be holistic, sustainable and preventive instead of reactive.

### Keywords

One Health, Chemical Sciences, Animal Health, Human Health, Environmental Health

\*Corresponding author: [kagorom@unijos.edu.ng](mailto:kagorom@unijos.edu.ng) (Kagoro Mary Luka-Anzah)

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## 1. Introduction

One Health is not a new concept; it has been in use for a while, and it is a holistic look at the health of humans, their animals and the environment they both live in. COVID-19 and the loss of millions of lives should be avoided by all means known to man. Meanwhile, the emergence of the SARS-CoV-2 virus emphasizes the need to strengthen the disciplines explicitly captured under the One Health concept. Human health is sustained directly and indirectly through access to clean air and fresh water, safe food and healthy diets, and the availability of and access to medicines.

One aftermath of the COVID-19 global pandemic is the opportunity to strengthen collaborations and increase policy coordination towards a better understanding of the drivers of diseases, with a focus on prevention. This is opined to prevent future pandemics and provide resilient systems, environments, economies and societies. WHO and partner organizations are working to increase the adoption of the One Health approach in national, regional and international health policies through intersectoral political and strategic leadership. These quadripartite organizations (FAO, OIE, UNEP and WHO) [1], have developed a comprehensive One Health Joint Plan of Action which aims to mainstream One Health at the global, regional and national levels. To support countries in establishing and achieving national targets and priorities for interventions.

By linking humans, animals and the environment, One Health can help to address the full spectrum of disease control – from prevention to detection, preparedness, response and management – and contribute to global health security.



**Figure 1.** Illustration of one health concept. Image obtained from home page of Upper Midwest Agricultural Safety and Health Center. [2].

One Health is a collaborative approach that aims to balance and optimize the health of people, animals and ecosystems sustainably (Figure 1) [2]. It recognizes that the health of humans, domestic and wild animals, plants, and the wider environment are linked and interdependent. While health,

food, water, energy and environment are all wider topics with sector-specific concerns, the collaboration across sectors and disciplines contributes to protect health, address health challenges such as the emergence of infectious diseases, antimicrobial resistance, and food safety and promote the health and integrity of our ecosystems. To achieve this comprehensive vision, several key objectives are central to the One Health approach, aiming to address specific challenges and promote overall well-being.

1. Preventing Zoonotic Diseases – Many infectious diseases (e.g., COVID-19, Ebola, Avian Influenza) originate in animals and can spread to humans. Develop and implement strategies to prevent and control zoonotic diseases (diseases transmitted between animals and humans) and other health threats.

2. Addressing Antimicrobial Resistance (AMR) – Overuse of antibiotics in human medicine and agriculture leads to resistant bacterial strains.

3. Ensuring Food Safety and Security – Safe food practices prevent contamination and the spread of diseases. Ensure access to safe, nutritious, and sufficient food for all, while minimizing the risk of foodborne diseases.

4. Managing Environmental Health Risks – Pollution, climate change, and deforestation impact disease transmission and ecosystem balance. Protect and preserve the natural environment to prevent pollution, climate change, and other environmental health threats.

5. Improve communication and collaboration: Foster interdisciplinary collaboration among human, animal, and environmental health professionals to share knowledge, expertise, and resources.

6. Enhance disease prevention and control: Develop and implement strategies to prevent and control zoonotic diseases (diseases transmitted between animals and humans) and other health threats.

7. Promote sustainable agriculture and food systems: Support sustainable agricultural practices that minimize the risk of disease transmission and promote food safety. In addition, improve animal health and welfare by promoting animal health, welfare, and productivity through better veterinary care, husbandry practices, and disease control

8. Protect biodiversity and ecosystems: Conserve and protect natural ecosystems, including wildlife habitats, to prevent the loss of biodiversity and reduce the risk of disease emergence. Strengthen global health security by improving disease surveillance, detection, and response to public health threats.

9. Improve human health and well-being: Enhance human health and well-being by addressing the social determinants of health, such as poverty, education, and access to healthcare.

10. Build capacity and infrastructure: Strengthen healthcare systems, laboratories, and research institutions to support One Health activities and improve health outcomes.

Encourage interdisciplinary research, innovation, and development of new tools, technologies, and strategies to address One Health challenges.

Establish and enforce policies, laws, and regulations that support the One Health approach and protect human, animal, and environmental health.

These key objectives necessitate a strong foundation in various scientific disciplines, and among them, Chemical Science plays a particularly vital role in realizing the goals of One Health.

## 2. Role of Chemical Sciences

Chemical Science is the study of the composition, properties, and reactions of matter at the atomic and molecular level. It involves the application of chemical principles and methods to understand and manipulate the behaviour of chemicals and materials. Chemical Science plays a crucial role in propagating One Health, which is a multi-disciplinary approach that recognizes the interconnection of human, animal, and environmental health. It provides tools and knowledge for disease detection, pollution control, drug development, and sustainable practices.

To understand the impact of chemical sciences on One Health, it is essential to break down the major disciplines of chemistry and explore how each contributes to human, animal, and environmental well-being.

### 2.1. Core Chemical Sciences

*Inorganic Chemistry*: Study of inorganic compounds, including their properties, reactions, and synthesis. *Organic Chemistry*: Study of organic compounds, including their properties, reactions, and synthesis. *Physical Chemistry*: Study of the physical principles underlying chemical reactions and processes. *Analytical Chemistry*: Study of the amount and identification of chemical substances.

#### 2.1.1. Interdisciplinary Branches

*Biochemistry*: Study of the chemical processes that occur within living organisms. *Medicinal Chemistry*: Study of the design, synthesis, and testing of pharmaceuticals. *Environmental Chemistry*: Study of the chemical processes that occur in the environment. *Materials Science*: Study of the properties and applications of various materials. *Clinical Chemistry* (also known as *chemical pathology*, *clinical biochemistry* or *medical biochemistry*) focuses on qualitative tests for several compounds (such as analytes or biomarkers) in blood and tissues [3]. It is an interdisciplinary field that includes knowledge from medicine, biology, chemistry, biomedical engineering, informatics, and applied biochemistry.

#### 2.1.2. Specialised Branches

*Theoretical Chemistry*: Study of the theoretical foundations

of chemistry. *Computational Chemistry*: Study of the use of computational methods to simulate and predict chemical behaviour. *Nuclear Chemistry*: Study of the chemical properties and reactions of radioactive isotopes. *Astrochemistry*: Study of the chemical processes that occur in space.

#### 2.1.3. Applied Branches

*Industrial Chemistry*: Study of the application of chemical principles to industrial processes. *Pharmaceutical Chemistry*: Study of the design, synthesis, and testing of pharmaceuticals. *Food Chemistry*: Study of the chemical properties and reactions of food. *Forensic Chemistry*: Study of the application of chemical principles to forensic analysis.

## 2.2. Key Objectives of Chemical Sciences

**Understanding Chemical Reactions**: Elucidating the mechanisms, kinetics, and thermodynamics of chemical reactions. **Synthesis and Characterization**: Designing, synthesizing, and characterizing new molecules, materials, and nanostructures. **Development of New Materials**: Creating advanced materials with unique properties for energy, environmental, and biomedical applications. **Energy Storage and Conversion**: Developing sustainable energy solutions, such as batteries, fuel cells, and solar cells. **Environmental Sustainability**: Designing eco-friendly processes, materials, and technologies to mitigate environmental pollution. **Improving Human Health**: Discovering new drugs, diagnostics, and therapeutics to combat diseases. **Food Security and Safety**: Developing sustainable agricultural practices, improving food processing, and ensuring food safety. **Advancing Analytical Techniques**: Developing innovative analytical methods and instruments for chemical analysis and detection. **Understanding Chemical Biology**: Elucidating the chemical mechanisms underlying biological processes. **Fostering Interdisciplinary Research**: Integrating chemical sciences with other disciplines, such as physics, biology, and engineering, to address complex challenges. **Nanotechnology and Nanoeengineering**: Designing and synthesizing nanomaterials for various applications. **Catalysis and Reactor Design**: Developing efficient catalysts and reactor systems for chemical reactions. **Computational Chemistry and Modelling**: Applying computational methods to simulate and predict chemical behaviour. **Materials Science and Engineering**: Developing advanced materials with unique properties for various applications. **Forensic Chemistry**: Applying chemical principles to analyze evidence and solve crimes. **Chemical Education and Outreach**: Promoting chemical literacy and education among the general public. **Chemical Safety and Risk Assessment**: Evaluating and mitigating chemical hazards to ensure safe handling and use. **Green Chemistry and Sustainability**: Developing environmentally friendly chemical processes and products. **Biochemical Engineering**: Applying engineering principles to understand and manipulate biological systems. **Chemical Instrumentation and Metrology**: Developing and

applying advanced instrumentation for chemical analysis and measurement.

## 2.3 Role of Chemical Sciences to Human Health

### 2.3.1. Disease Diagnosis and Treatment

1. Analytical Chemistry in Diagnostics
2. Development of biosensors and rapid diagnostic kits for detecting infectious diseases in humans, animals, and the environment.
3. Use of polymerase chain reaction (PCR) and mass spectrometry to identify pathogens.

### 2.3.2. Pharmaceutical Chemistry in Drug Development

1. Design and synthesis of antibiotics, antivirals, and vaccines to combat emerging infectious diseases.
2. Discovery of new antimicrobials to tackle drug-resistant bacteria.

### 2.3.3. Medicinal Chemistry in Personalized Medicine

1. Development of targeted therapies and biomolecules for better treatment outcomes.
2. Advancements in nanomedicine for efficient drug delivery.
3. Antimicrobial Resistance (AMR) Mitigation

### 2.3.4. Tracking Antibiotic Residues in Food and Water

1. Chemical sensors detect antibiotic residues in animal products and wastewater.
2. Regulatory frameworks limit excessive use of antibiotics in agriculture.

### 2.3.5. Developing Alternative Treatments

1. Research into antimicrobial peptides, probiotics, and phage therapy.
2. Green chemistry approaches to synthesize safer and more effective drugs.

## 2.4. Role of Chemical Sciences in Environmental Health

### 2.4.1. Food Safety and Agriculture

#### a) Chemical Preservation of Food

1. Safe preservatives and antioxidants to enhance food shelf life.
2. Development of biodegradable food packaging to reduce contamination.
3. Food preservation: Chemical science develops methods for food preservation, reducing food waste and ensuring

a stable food supply.

#### b) Pesticide Management and Sustainable Agriculture

1. Creation of eco-friendly pesticides and fertilizers to prevent harmful residues.
2. Detection of pesticide contamination in crops and water sources.
3. Food analysis: Chemical scientists detect contaminants, such as pesticides, heavy metals, and mycotoxins, ensuring food safety.

### 2.4.2. Role of Chemical Sciences in Pollution Control

#### a) Monitoring and Reducing Chemical Pollutants

1. Detection of heavy metals, microplastics, and toxic chemicals in water and soil.
2. Green chemistry innovations to develop biodegradable plastics and sustainable materials.

#### b) Water Purification and Waste Management

1. Use of advanced filtration systems, nanomaterials, and catalytic reactions to purify water.
2. Conversion of waste into biofuels and sustainable chemicals.
3. Water quality analysis: Chemical scientists develop and apply analytical techniques to detect and quantify pollutants in water, such as heavy metals, pesticides, and industrial contaminants.

#### c) Remediation

Chemical science provides solutions for cleaning up contaminated soil, reducing the risk of toxic substances entering the food chain.

Air quality monitoring: Chemical scientists track air pollutants, identifying sources and impacts on human and animal health.

### 2.4.3. Role of Chemical Sciences in Climate Change

1. Research into carbon capture and storage to reduce greenhouse gas emissions.
2. Development of biofuels and hydrogen-based energy to decrease dependence on fossil fuels.
3. Chemical analysis of climate-related health risks, such as heat stress and air pollution.

## 2.5. Role of Chemical Sciences in Animal Health

1. Synthesis of veterinary drugs and vaccines to control animal diseases.
2. Development of nutritional supplements to enhance livestock health and productivity.
3. Use of chemical biomarkers to monitor animal stress and disease outbreaks.
4. Nutritional Chemistry in Animal health
  - a) Study of vitamins, minerals, and bioactive compounds to enhance nutrition.
  - b) Use of fortified foods to prevent malnutrition.
  - c) Nutrition and nutraceuticals: Chemical science inves-



tigates the chemical composition of foods and develops nutraceuticals that promote animal health.

### 3. Solutions to Human Health and Wellbeing

Chemical science improves human health and wellbeing by developing pharmaceuticals, assessing toxicology and risk, and investigating environmental health. Some key aspects of chemical science in human health and wellbeing include: **Pharmaceutical Development:** Chemical science plays a crucial role in pharmaceutical development, creating new medicines and therapies. **Toxicology and risk Assessment:** Chemical science assesses the risks associated with chemical exposure, informing strategies for protecting human health. **Environmental Health:** Chemical science investigates the impact of environmental pollutants on human health, informing policies for environmental protection.

#### 3.1. Solutions for Human Health

##### 3.1.1. Accelerating Drug Discovery

*Artificial Intelligence (AI) and machine learning* can help speed up the identification of new drugs and vaccine candidates by predicting molecular structures and testing compounds in silico [4].

##### 3.1.2. Repurposing Existing Drugs

Repurposing known drugs for new diseases, such as using ivermectin for COVID-19, can reduce the time and cost of development [5].

##### 3.1.3. Combating AMR

*Antimicrobial Stewardship:* Implementing more robust stewardship programs that monitor and regulate the use of antibiotics and ensure their *responsible use* in both humans and animals [6].

##### 3.1.4. Development of Novel Antibiotics

Encouraging the development of bacteriophage therapies and novel antibiotics that target resistant bacteria [10, 11].

#### 3.2. Toxicology and Chemical Exposure Risks

##### 3.2.1. Regulating Hazardous Chemicals

*Stronger Regulatory Policies:* Governments and international organizations (such as WHO and EPA) should enforce stricter regulations on the use of chemicals in industries, especially in food production, pharmaceuticals, and pesticides [7].

##### 3.2.2. Chemical Safety Standards

Implementing better chemical safety standards for workers in industries to prevent long-term exposure to harmful substances [7].

##### 3.2.3. Improved Detection and Monitoring Systems

*Advanced Detection Tools:* Developing new, rapid testing technologies (e.g., portable biosensors) for the detection of chemical contaminants in air, water, and food [8].

*Health Surveillance Systems:* Establishing *global health surveillance systems* to monitor emerging health risks related to chemical exposure.

#### 3.3. Ethical and Regulatory Issues in Chemical Research

##### 3.3.1. Ethical Alternatives to Animal Testing

*In Vitro Models:* Using cell cultures, organ-on-chip models, and computational models for drug testing can reduce the reliance on animal testing [9].

##### 3.3.2. Ethical Review Committees

Strengthening ethics review boards and regulatory frameworks to ensure that all drug and chemical studies prioritize humane practices.

### 4. Solutions to Animal Health and Wellbeing

#### 4.1. Veterinary Drug Resistance and Residues

##### 4.1.1. Restricting Antibiotic Use in Agriculture

**Banning Non-Therapeutic Use:** Enforcing policies that limit the use of antibiotics to treating specific diseases in animals, thus reducing the risk of antimicrobial resistance [10, 11].

**Veterinary Stewardship Programs:** Similar to human health, veterinary antimicrobial stewardship should monitor and regulate drug usage in animals [7].

##### 4.1.2. Monitoring Drug Residues in Animal Products

**Improved Testing Protocols:** Implementing regular testing for antibiotic residues and other harmful substances in animal products and ensuring compliance with food safety regulations [7].

**Consumer Education:** Educating consumers on the benefits of choosing organic or residue-free products, thus encouraging safer farming practices.

## 4.2. Limited Veterinary Chemical Testing

1. Access to Diagnostic Infrastructure
2. Mobile Labs and Point-of-Care Tests
3. Public-Private Partnerships
4. Access to Diagnostic Infrastructure

## 4.3. Mobile Labs and Point-of-Care Tests

Developing mobile diagnostic laboratories and point-of-care testing kits to provide rural and underserved regions with veterinary care.

## 4.3. Public-Private Partnerships

Encouraging partnerships between governments, NGOs, and private industries to develop affordable diagnostic tools for animal health.

# 5. Solutions for Environmental Health

## 5.1. Pollution and Climate Change

Green Chemistry and Cleaner Production

Sustainable Manufacturing: Encouraging industries to adopt green chemistry principles such as using less harmful chemicals, reducing waste, and adopting clean production technologies [10, 11].

Circular Economy Models: Promoting recycling, upcycling, and resource efficiency through the circular economy to reduce chemical waste and pollution [10].

## 5.2. Pollution Monitoring and Remediation

Advanced Pollution Sensors: Deploying new sensors and satellite monitoring systems to track pollutants like CO<sub>2</sub>, heavy metals, and microplastics in real-time [6].

Bioremediation Techniques: Encouraging the use of microbial or plant-based methods to clean up chemical spills and pollutants in soil, water, and air [12].

## 5.3. Waste Management and Green Chemistry Adoption

### 5.3.1. Hazardous Waste Management

Sustainable Waste Disposal: Encouraging companies to comply with eco-friendly disposal methods for hazardous chemical waste and to implement systems for waste reduction [7].

Biodegradable Materials: Shifting industries toward biodegradable or non-toxic materials to reduce plastic pollution and chemical contamination.

### 5.3.2. Incentivizing Green Chemistry

Financial Incentives: Offering tax incentives and subsidies

to companies adopting sustainable chemical processes and green chemistry technologies [10, 11].

Public Awareness Campaigns: Educating the public about the environmental and health benefits of green chemistry and eco-friendly products.

Biodiversity Loss Due to Chemical Pollution

Pesticide and Herbicide Regulation

Safer Agricultural Chemicals: Implementing stricter regulations on the use of pesticides and herbicides and promoting the use of natural pest control methods [12].

Integrated Pest Management (IPM): Encouraging the use of IPM strategies to control pests without relying heavily on chemicals [12].



Figure 2. Regenerative agriculture practices.

# 6. Future Perspectives and Challenges in One Health and Chemical Science

## 6.1. Advancements in Green Chemistry for Sustainable Health Solutions

Green chemistry plays a vital role in reducing environmental pollutants and ensuring that chemical processes are sustainable. Some key future developments include:

Biodegradable and Non-Toxic Alternatives: Designing eco-friendly chemicals for agriculture, medicine, and industry to minimize environmental damage.

Reduction of Chemical Waste: Innovations in synthetic chemistry to develop efficient reactions with minimal waste production.

Renewable Resources for Drug Development: Exploring plant-based and microbial sources for drug discovery instead

of synthetic chemicals with high environmental costs.

## 6.2. Innovations in Chemical-Based Disease Detection and Treatment

**Point-of-Care Diagnostic Tools:** Portable chemical sensors and lab-on-a-chip devices for rapid disease detection in remote or resource-limited areas.

**AI-Driven Drug Discovery:** Use of artificial intelligence and computational chemistry to predict and design new antimicrobial compounds efficiently.

**Smart Drug Delivery Systems:** Nanotechnology-based targeted drug delivery to improve treatment efficacy and reduce side effects.

**Addressing Climate Change and Emerging Diseases**

Climate change alters disease patterns and increases the risk of zoonotic disease transmission. Chemical science can play a crucial role in:

**Developing Climate-Resilient Crops:** Using biochemical research to engineer crops that withstand extreme weather conditions.

**Tracking Disease-Related Environmental Changes:** Chemical biosensors to monitor environmental factors that influence disease outbreaks.

**Renewable Energy for Healthcare Systems:** Implementing sustainable energy solutions (e.g., solar, biofuels) to power medical and agricultural facilities.

## 6.3. Strengthening Regulations and Policies

**Strengthening Regulations and Policies:** To maximize the benefits of chemical science in One Health, strong regulatory frameworks are needed to:

**Limit Harmful Chemical Use:** Enforce restrictions on hazardous pesticides, industrial pollutants, and pharmaceutical waste.

**Promote Ethical Pharmaceutical Practices:** Encourage responsible antibiotic production and usage to combat antimicrobial resistance.

**Enhance Global Surveillance Systems:** Develop international collaborations for tracking and responding to chemical-related health threats.

## 7. Recent Innovations by Scientists in Chemical Sciences to Improve Human, Animal, and Environmental Health

In recent years, chemical sciences have made remarkable advancements, contributing to improving human, animal, and environmental health.

Innovations across various fields of chemistry have led to new therapeutic solutions, safer agricultural practices, greener industrial processes, and better environmental protection technologies. Below are some of the key innovations.

### 7.1. Human Health

#### Targeted Drug Delivery Systems

**Nanotechnology and Drug Delivery:** Recent advances in nanomedicine have led to the development of nano-drugs that can deliver medications precisely to affected cells, increasing the efficacy and reducing side effects of treatments. Scientists have designed nanoparticles that can target specific tumours or infected tissues, allowing for personalized medicine [14].

**Example:** Researchers at MIT developed a *nanoparticle-based drug delivery system* that improves cancer treatment by delivering drugs directly to cancer cells while minimizing damage to surrounding healthy tissue [14].

#### Artificial Intelligence (AI) in Drug Discovery

**AI for Drug Discovery:** AI and machine learning are revolutionizing drug discovery by enabling faster identification of potential drug candidates. AI algorithms analyze vast amounts of chemical data to predict how drugs will interact with biological systems, significantly speeding up the drug development process.

**Example:** *In-silico Medicine* developed an AI-driven platform that identified a potential treatment for COVID-19 in just a few weeks, demonstrating the power of AI in the rapid development of drugs [15].

#### Green Chemistry in Pharmaceutical Production

**Sustainable Drug Manufacturing:** Chemists have introduced greener pharmaceutical production methods that reduce toxic by-products and use less hazardous chemicals. This includes developing solvent-free reactions and biocatalysts to produce drugs more efficiently while minimizing environmental impact.

**Example:** Pfizer implemented greener processes in their manufacturing, reducing *solvent use* and employing *biocatalysis* to create more sustainable pharmaceutical products [16].

#### Antimicrobial Resistance (AMR) Solutions

**Alternative Antimicrobial Agents:** To combat antimicrobial resistance (AMR), scientists have been exploring novel antimicrobial agents derived from natural sources. Research into bacteriophage therapy (viruses that target bacteria) has gained attention as a promising solution to resistant bacteria in animals and humans.

**Example:** Researchers in Georgia Tech developed a bacteriophage-based treatment for multi-drug-resistant infections in livestock, showing effectiveness in eliminating resistant bacteria without affecting beneficial microbes [10, 11].

### 7.2. Animal Health

#### 7.2.1. Precision Livestock Farming (PLF)

**PLF Technologies:** Precision livestock farming integrates advanced sensor technologies, data analytics, and genetic testing to monitor and improve animal health. These innovations allow farmers to monitor animal well-being, track disease outbreaks, and optimize feed and breeding programs for

healthier livestock.

*Example:* IoT-based sensors that monitor cattle health in real-time, allowing for early detection of diseases and reducing the need for antibiotics in animal care [17].

### 7.2.2. Vaccination and Immunotherapy for Animals

*Vaccine Innovations:* In response to zoonotic diseases, scientists have developed advanced vaccines for animals to prevent the transmission of diseases to humans. Recent breakthroughs include mRNA vaccines designed for livestock to prevent diseases like foot-and-mouth disease and avian influenza.

*Example:* Moderna has extended its mRNA technology to animal health, partnering with companies like Zoetis to develop vaccines for pigs and poultry [18].

## 7.3. Environmental Health

### 7.3.1. Green Chemistry and Pollution Control

*Biodegradable Plastics:* Scientists have developed biodegradable plastics made from renewable resources such as corn starch or algae. These materials help reduce the environmental impact of plastic pollution and are less harmful to ecosystems.

*Example:* Companies like NatureWorks and Danimer Scientific have developed PLA-based bioplastics that decompose quickly and safely in nature [19].

### 7.3.2. Climate Change Mitigation and Carbon Capture

*Carbon Capture and Storage (CCS):* Innovations in carbon capture technology allow for the removal of CO<sub>2</sub> emissions from the atmosphere, contributing to the fight against climate change. New chemical processes, such as amine-based CO<sub>2</sub> capture, have been developed to absorb CO<sub>2</sub> from industrial processes before it reaches the atmosphere.

*Example:* The Clime works plant in Iceland uses direct air capture technology to extract CO<sub>2</sub> from the air and store it underground, demonstrating the potential for large-scale carbon sequestration [20].

### 7.3.3. Green Pesticides and Integrated Pest Management

*Biopesticides:* To reduce the impact of chemical pesticides on the environment, scientists have developed biopesticides derived from natural organisms such as bacteria, fungi, and plants. These alternatives are safer for both the environment and non-target species.

*Example:* The development of *Bacillus thuringiensis* (BT), a natural bacterium that produces proteins toxic to insects, has revolutionized sustainable farming practices, reducing the need for traditional synthetic pesticides [12].

*Wastewater Treatment and Environmental Remediation*

*Chemical Remediation:* Researchers are working on advanced materials like adsorbents, biochar, and nanomaterials for environmental clean-up of pollutants such as heavy metals, pesticides, and pharmaceuticals in wastewater.

*Example:* Graphene-based filters are being developed to remove heavy metals and other pollutants from water, improving access to clean drinking water in regions affected by industrial contamination [21].

## 8. Conclusion

Chemical science is integral to the One Health framework, connecting human, animal, and environmental health through disease prevention, toxicology, pharmaceutical development, and pollution control. By integrating chemical sciences with healthcare, veterinary medicine, and environmental conservation, societies can develop effective strategies for sustainable development, biodiversity preservation, and global health security.

It is vital to the One Health approach by enhancing disease detection, combating antimicrobial resistance, ensuring food safety, and addressing environmental challenges. Interdisciplinary collaboration between chemists, biologists, medical professionals, and environmental scientists is essential to developing sustainable solutions for global health issues. Through innovative research and responsible practices, chemical science will continue to support One Health in building a healthier world for humans, animals, and the environment. Through responsible chemical research and sustainable practices, we can build a resilient and healthier planet for future generations. By integrating chemical science with biological and medical research, One Health can effectively address global health challenges such as antimicrobial resistance, zoonotic diseases, food safety, and environmental pollution. Strengthening interdisciplinary collaboration and promoting green chemistry innovations will be key to building a healthier and more sustainable future.

The role of chemical sciences in human, animal, and environmental health is undeniably important, but challenges such as antimicrobial resistance, pollution, toxic exposures, drug development costs, and regulatory barriers limit its full potential. Addressing these challenges requires:

1. Stronger regulations on chemical safety and pollution control.
2. Increased investment in research on sustainable chemicals and pharmaceuticals.
3. Better global cooperation to manage antimicrobial resistance and environmental contamination.

By overcoming these challenges, chemical sciences can continue to play a transformative role in promoting global health and sustainability. Recent innovations in chemical sciences are driving substantial improvements in human, animal, and environmental health. From the development of targeted drug delivery systems, AI-driven drug discovery, and



biodegradable materials to advances in veterinary health and pollution control technologies, the impact of chemical innovations is vast and transformative. These developments hold the potential to address pressing global health challenges, ensuring a healthier and more sustainable future for all.

## Abbreviations

AMR	Antimicrobial Resistance
PCR	Polymerase Chain Reaction
COVID-19	Coronavirus Disease
SARS-CoV-2	Pathogen for COVID-19
FAO	Food and Agricultural Organization of the United Nations
OIE	World Organisation for Animal Health
UNEP	United Nations Environmental Protection
WHO	World Health Organization
EPA	Environmental Protection Agency
NGOs	Non-Governmental Organizations
IPM	Integrated Pest Management
MIT	Massachusetts Institute of Technology
CCS	Carbon Capture and Storage
IoT	Internet of Things
mRNA	Messenger Ribonucleic Acid
PLA	Poly lactic Acid
CSN	Chemical Society of Nigeria
BT	<i>Bacillus Thuringiensis</i>

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## Author Contributions

**Chidozie Vivian Nwatoka:** Validation, Visualization, Writing – original draft

**Okan Hillary Ehgomare:** Validation, Visualization, Writing – original draft

**Mbah Amaechi:** Data curation, Investigation, Writing – original draft

**Chukwu Otuh Chukwu:** Conceptualization, Formal Analysis, Funding acquisition, Resources, Supervision, Visualization

**Kagoro Mary Luka-Anzah:** Conceptualization, Data curation, Formal Analysis, Supervision, Writing – review & editing

## Conflicts of Interest

The authors declare no conflicts of interest.

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