Antibiotic Resistance in Pathogenic Microorganisms: Implications for Management on Healthcare in the 21st Century

RESEARCH ARTICLE

***Edward Oyekanmi**
Microbiology Programme, Biological Science Department, College of Natural and Applied Sciences, Wesley University, Ondo
📧 edward.oyekanmi@wesleyuni.edu.ng

Funmi Olatujoye
Microbiology Programme, Biological Science Department, College of Natural and Applied Sciences, Wesley University, Ondo

Mercy Adeyemi
Microbiology Programme, Biological Science Department, College of Natural and Applied Sciences, Wesley University, Ondo

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ABSTRACT

The menace of antibiotic resistance is of great concern globally making healthcare delivery much more challenging in the 21st century leading to a global health crisis. The study made use of a systematic (qualitative) review of peer-reviewed literature from 2016 to 2025, following the PRISMA-guided reviews by Gregory and Denniss with some modification. The findings showed that there is widespread resistance in pathogenic bacteria globally, in Africa, and in Nigeria, and middle to low-income countries are the most vulnerable. Several factors, such as misuse and overuse of antibiotics, over-the-counter antibiotic sales, growth-promoting and preventive use of antibiotics on healthy animals, and lack of or inadequate antibiotic resistance awareness, are responsible for the propagation of resistance. The result also identified bacteria species such as *Escherichia coli*, *Klebsiella pneumoniae*, *Pseudomonas aeruginosa*, *Acinetobacter baumannii*, Methicillin-resistant *Staphylococcus aureus* (MRSA), *Enterococcus*, *Streptococcus pneumoniae*, and *Salmonella* as the leading cause of antibiotic-resistant deaths. With this, last-line antibiotics such as the third-generation and broad-spectrum cephalosporin, extended-spectrum β-lactam antibiotics, vancomycin, colistin, methicillin, penicillin, carbapenems, and ampicillin are becoming substandard. Despite this, fewer novel antibiotics are entering the market to mitigate the situation. This study, therefore, concluded that antibiotic resistance represents a silent pandemic that demands urgent attention, and without effective action, the world may face a future where minor infections become untreatable. The study recommended that the government should embrace international collaboration because antimicrobial resistance is a transnational issue.

Methodology

Systematic qualitative review of peer-reviewed literature from 2016 to 2025 following PRISMA-guided approach

Key Focus

Global antibiotic resistance in pathogenic microorganisms with emphasis on Africa and Nigeria

Main Finding

Widespread resistance threatens healthcare delivery globally, particularly in low-to-middle income countries

Keywords: Antibiotic resistance, healthcare management, pathogenic, implication, stewardship

INTRODUCTION

Antibiotic resistance (AR) represents one of the most serious threats to global health, food security, and development today. The widespread and indiscriminate use of antibiotics in human medicine, veterinary practise, agriculture, and environmental management has increased the emergence of resistant microorganisms. Therefore, it renders standard treatments ineffective and leads to persistent infections and a higher risk of disease spread, severe illness, and death (Jassim, 2022). As we progress through the 21st century, antibiotic resistance poses more implications for healthcare management, both clinically and economically.

Antibiotic (antimicrobial) resistance (AMR) is now recognised as a major global health crisis. The World Health Organisation (WHO) warns that drug-resistant pathogens "threaten our ability to treat common infections and to perform life-saving procedures, including cancer chemotherapy and caesarean section, hip replacements, organ transplantation, and other surgeries" (WHO, 2023). AMR affects humans, animals, and the environment, weakening the effects of modern medicine and threatening food security (WHO, 2023).

01

Global Impact 2019

4.95 million deaths were related to bacterial AMR globally, with 1.27 million deaths directly linked to AMR, highest in western sub-Saharan Africa.

02

African Region Burden

WHO African Region had 1.05 million AMR-associated deaths, with 250,000 deaths directly caused by AMR in 2019.

03

Future Projections

Without action, there would be an increase in deaths of up to 10 million annually by 2050 due to antimicrobial resistance.

A study showed that in 2019, 4.95 million deaths were related to bacterial AMR globally, and 1.27 million deaths out of 4.95 million are directly linked to AMR (ARC, 2022). These deaths attributed to resistance were highest in western sub-Saharan Africa (ARC, 2022). Unfortunately, without any action, there would be an increase in deaths of up to 10 million annually by 2050 (de Kraker et al., 2016).

In Africa, and particularly in Nigeria, the AMR challenge is especially alarming. The WHO African Region evaluated that there were 1.05 million AMR-associated deaths, with 250,000 deaths directly caused by AMR in 2019 (ARC, 2024). A study review by Alabi et al. (2025) on antimicrobial resistance challenges in Nigeria explained how there is widespread high resistance in hospitals, communities, food animals, and the environment. The factors responsible for this include overuse and misuse of antibiotics, weak regulation/laws, poor water/sanitation, inadequate infection control, "poor access to quality and affordable vaccines, diagnostics and medicines; lack of awareness and knowledge; and lack of enforcement of relevant legislation" (Alabi et al., 2025; WHO, 2023).

This publication reviews current evidence from 2016 to 2025 on antibiotic resistance and its implications on healthcare management.

Objective of the Study

The objective of this study is to:

- examine the global perspective on antimicrobial resistance,
- assess related healthcare challenges with focus on Africa and Nigeria,
- analyse the implications of antibiotic resistance in microorganisms on healthcare management systems in the 21st century.

STATEMENT OF THE STUDY

The global healthcare system faces an unprecedented crisis as pathogenic microorganisms develop resistance to our most critical antibiotics. Despite decades of medical advancement, common infections that were once easily treatable are becoming increasingly difficult to manage, leading to prolonged hospital stays, increased healthcare costs, and rising mortality rates (Jassim, 2022). The problem is particularly acute in developing countries where healthcare infrastructure is already strained and regulatory oversight of antibiotic use is limited.

Core Problems

- Widespread resistance in pathogenic bacteria
- Limited effectiveness of last-line antibiotics
- Inadequate infection prevention and control
- Lack of new antibiotic development

Research Gap

- Limited understanding of resistance mechanisms
- Need for comprehensive management strategies
- Assessment of global versus regional impacts
- Healthcare system preparedness evaluation

CONCEPTUAL REVIEW

Antibiotic resistance occurs when bacteria evolve or create mechanisms to withstand the drugs that were previously effective against them. This evolution is a result of genetic mutation and horizontal gene transfer (Adesola and Moses, 2022), especially in environments with high exposure to antibiotics. Resistance can be intrinsic or acquired. Intrinsic resistance means it is a natural insensitivity to antibiotics, while acquired resistance involves genetic adaptation. Moreover, healthcare settings serve as **centres** for the increase and spread of resistant strains, especially due to inappropriate prescription practices and lack of infection control (Jamrozik and Heriot, 2022).

Antimicrobials

Antimicrobials are substances against microbial existence, either by inhibiting or killing microbial life (Khanal et al., 2017). They are medicines/substances that prevent or treat infections in humans, animals or plants. They include antibacterials (for bacteria), antivirals (for viruses), antifungals (for fungi), and antiparasitics (for parasites), disinfectants, and antiseptics.

Antibiotics

Antibiotics are often called antimicrobials, and they are a type of antimicrobial specifically targeting microorganisms; they kill or inhibit microbial growth to treat infections (Al-Habaty et al., 2023).

Antimicrobial Resistance (AMR)

The AMR occurs when microorganisms (bacteria, viruses, fungi, or parasites) evolve and become less sensitive or non-responsive to medications that once were effective against them (Hambisa and Umer, 2023). The WHO reports that AMR now makes common infections harder to treat, causing more severe illness and the spread of disease.

Antibiotic Resistance

Ability of bacteria to change or acquire traits so that antibiotics no longer control them.

Healthcare Management

Planning, directing, coordinating, and supervising delivery of healthcare services and policies.

Infection Prevention

Evidence-based approach preventing patients and health workers from avoidable infections.

Antibiotic Resistance

Antibiotic resistance refers to AMR in bacteria. It is the ability of bacteria to change or acquire traits so that antibiotics no longer control them (Al-Habaty *et al*., 2023). For example, Methicillin-resistant *Staphylococcus aureus* (MRSA) is a strain that has altered penicillin-binding proteins and renders beta-lactam antibiotics ineffective. Antibiotic resistance occurs when bacteria mutate or adapt to survive exposure to antibiotics that would normally kill them. This process is an unavoidable evolutionary process that is enhanced by the misuse and overuse of antimicrobial drugs.

Intrinsic Resistance

Intrinsic resistance is an inherent or natural trait of a species that is present before antibiotic exposure. For instance, *Mycoplasma* species lack a cell wall and are intrinsically resistant to beta-lactam antibiotics

Acquired Resistance

Acquired resistance occurs as a result of genetic changes (mutations) or the gain of resistance genes such as through plasmids or transposons because of their exposure(s) to antibiotics. Acquired traits include, *Escherichia coli* obtaining beta-lactamase (an enzyme that hydrolyses a bound in beta-lactam antibiotics) genes on plasmids, or point mutations in a target gene that prevent drug binding.

Healthcare

Healthcare refers to services that aim at maintaining or improving health, including disease prevention, diagnosis, treatment, and rehabilitation (Charani *et al*., 2024).

Healthcare Management

This involves planning, directing, coordinating, and supervising the delivery of healthcare services, including the implementation of policies to ensure quality, efficiency, and patient safety (Gilbert and Kerridge, 2020).

Infection Prevention and Control (IPC)

Infection Prevention and Control (IPC) is a practical, evidence-based approach that prevents patients and health workers from being infected or hurt by infections that can be avoided (WHO, 2023b). It involves measures such as hand hygiene, sterilization, and isolation protocols to prevent the spread of pathogens within healthcare facilities. Good IPC is important to limit the transmission of resistant organisms. Without IPC, healthcare-associated infections will rise, and AMR spread of AMR will increase.

Misuse of Antibiotics

Misuse of antibiotics means prescribing antibiotics when not needed, such as for viral illnesses, using the wrong antibiotic, or patients not completing the dose prescribed to them.

Overuse of Antibiotics

Overuse of antibiotics means excessive use of antibiotics. For example, the prophylactic use of antibiotics in livestock or non-prescription use is an overuse of antibiotics.

THEORETICAL REVIEW

Theoretically, AMR, particularly Antibiotic Resistance (AR), is often examined through an evolutionary and socio-ecological view.

Microbial Evolutionary Theory

Evolutionary theory explains antibiotic resistance as a process of natural selection, where resistant organisms survive and multiply under the selective pressure of antibiotics (Hasan et al., 2021). It explains the emergence of AMR as Darwinian selection. That is, antibiotic exposure kills susceptible bacteria, allowing resistant mutants (that are carrying resistance genes) to proliferate and spread. This process is inevitable unless antibiotic pressure is minimised (Kamere et al., 2022).

Ecological Theory (or One Health theory)

This views human, animal, and environmental health as a single ecosystem, where antibiotic usage in one niche can affect resistance in others. For example, antibiotics in livestock cause selective pressure on gut bacteria, which can contaminate water or food and infect humans. The One Health approach provides the most detailed theoretical framework for understanding and addressing antibiotic resistance. It integrates human, animal, and environmental health domains to tackle resistance from a holistic perspective (Asian Biomedicine, 2022).

Health Systems Theory

This is coined from Karl Ludwig von Bertalanffy's concept of system theory in 1969 (Anderson, 2016). It explains that the spread of AMR shows systemic weaknesses. It explains that poor governance, inadequate funding for healthcare, and weak laboratory capacity etc., lead to unchecked resistance growth.

Social Theories ("Tragedy of the Commons")

This is coined from Garrett Hardin's tragedy of the commons (Rankin et al., 2007). Applying this to AMR shows that individuals may use antibiotics irrationally for immediate benefit, but collectively this behaviour degrades and affects the common resource of antibiotic efficacy.

Global Health Economics Theory

This explains that resistant infections drive up healthcare costs and reduce workforce productivity. Studies estimate that AMR could cost trillions of dollars (NIH, 2023) and push millions into poverty by 2050 (World Bank Group, 2016) if unchecked. Global health economics is a field that applies economic principles to understand and address health issues, particularly in a global context (Standaert et al., 2024).

Evolutionary View

Natural selection process where resistant organisms survive under antibiotic pressure. Darwinian selection allows resistant mutants to proliferate.

One Health Approach

Integrates human, animal, and environmental health. Antibiotic use in one sector affects resistance in others through interconnected ecosystems.

Systems Theory

AMR spread shows systemic weaknesses including poor governance, inadequate funding, and weak laboratory capacity leading to unchecked growth.

EMPIRICAL REVIEW

Studies show that the environment plays a major role in the spread of resistance genes. Environmental reservoirs like urban soils are recognised as major contributors (Gentile et al., 2024). Similarly, hospital-acquired infections, that is, nosocomial infections, are worsened by multidrug-resistant organisms like *Klebsiella pneumoniae* and *Methicillin-Resistant Staphylococcus aureus* (MRSA) (Starling et al., 2021). Studies also emphasise the economic burden by showing that resistant infections result in longer hospital stays, increased mortality, and greater costs (Lonare, 2024).

Implications of Antibiotic Resistance in Microorganisms on a Global Scale

A multi-national analysis (Murray et al., 2022) estimated that in 2019, about 4.95 million deaths were associated with bacterial AMR globally. Out of these, 1.27 million were deaths that would have been avoided if infections were not resistant. The study also identified *Escherichia coli*, *Staphylococcus aureus*, *Klebsiella pneumoniae*, *Streptococcus pneumoniae*, *Acinetobacter baumannii*, and *Pseudomonas aeruginosa* as the six leading pathogens responsible for roughly 3.57 million AMR-associated deaths. *Methicillin-resistant S. aureus* (MRSA) alone caused over 100,000 deaths.

The most burdensome infections (syndromes) were lower respiratory infections, bloodstream infections, and intra-abdominal infections. Also, a 2024 Global Burden of Disease study (ARC, 2024) found that in 2021, there were an estimated 4.71 million deaths associated with bacterial AMR, of which 1.14 million deaths were directly caused by drug-resistant infections (GBD, 2024).

2019 Global Study (Murray et al.)

4.95 million deaths associated with bacterial AMR globally, with 1.27 million direct deaths. Leading pathogens identified: *E. coli*, *S. aureus*, *K. pneumoniae*.

2024 Global Burden Study

4.71 million deaths associated with bacterial AMR in 2021, with 1.14 million direct deaths. Projected rise to 1.9 million per year by 2050.

Implication on Africa

Regional analyses confirm that Africa has a large share of the AMR burden. A cross-country systematic analysis (ARC, 2023) found that in 2019 the WHO African region had about 1.05 million AMR associated deaths and 250,000 directly caused deaths. Lower respiratory and bloodstream infections were the leading causes, accounting for approximately 70% of AMR deaths in the region. *S. pneumoniae*, *K. pneumoniae*, *E. coli*, and *S. aureus* were the four major implicated pathogens and each causes over 100,000 deaths.

Implication on Nigeria

Nigeria, Africa's most populous country, shows the challenges of AMR in a lower-middle-income context. Recent narrative reviews and studies (2018 - 2024) document an alarming high resistance levels in Nigerian health and animal sectors. Alabi et al. (2025) report that Nigeria's AMR challenge is very serious, due to extensive antibiotic use in humans, animals, and the environment. High resistance patterns were observed in hospital isolates, such as urine, wound, and blood samples, and in *E. coli*, *S. aureus*, and *K. pneumoniae* from livestock and food supply chains (Hambisa and Umer, 2023).

Implications on Animal Health

In Nigeria and across Africa, antibiotics are widely used in poultry and cattle, often without veterinary oversight. A review in Sub-Saharan Africa in 2025 identified that the key factors, which drives livestock AMR are overuse and misuse of antimicrobials, inadequate veterinary oversight, and weak regulation across the beef value chain (Musuka *et al.*, 2025). The antimicrobials used as growth promoters contaminate feed, water, and manure, spreading resistant bacteria to farm workers and consumers (Musuka *et al.*, 2025).

Nigerian studies (Alabi *et al.*, 2025; Alhaji and Ishola, 2018) report that farmers often administer antibiotics prophylactically to animals, and antibiotic residues have been found in poultry products. Resistant strains common to both animals and humans, such as *E. coli* with CTX-M genes, show that cross-transfer is highly possible (Alabi *et al*., 2025; Alhaji and Ishola, 2018). The Livestock-Associated MRSA (LA-MRSA) explained by Gaddafi *et al*. (2020) shows that ~60% of MRSA from Nigerian livestock carried the *mecA* gene, indicating high resistance.

Factors Responsible for Antibiotic Resistance

Inappropriate Antibiotic Use

Misuse and overuse in medicine such as the use of antibiotics for viral infections, incomplete doses, and the use of broad-spectrum when narrow-spectrum antibiotics can do the work, create strong selection pressure. In many regions, antibiotics are overprescribed due to diagnostic uncertainty or patient demand. And easy availability of antibiotics such as over-the-counter sales in some countries fuels misuse.

Veterinary and Agricultural Use

A large volume consumption of antibiotics livestock and aquaculture is a factor. Inappropriately use of antibiotics on healthy animals for growth promotion or prevention enables resistance in bacteria, which can spread to humans through food or the environment. For example, WHO reports that around 80% of antimicrobials in the U.S. are consumed by agriculture.

Poor Infection Control and Sanitation

Weak IPC in hospitals, such as poor hand hygiene, overcrowding, and inadequate disinfection, allows resistant strains to spread among patients. Similarly, lack of access to clean water and sanitation increase the risk of transmitting resistant pathogens in the community (WHO, 2023). For instance, contaminated water can spread *Enterobacteriaceae* carrying ESBLs. These environmental factors allow resistant bacteria to multiply unchecked.

Global Travel and Trade

International travel, migration, and global food trade disseminate resistant strains worldwide. A resistant infection acquired in one country can quickly appear elsewhere. For example, how NDM-1 carbapenemase from India spreads to Europe.

Lack of New Antibiotics

Few novel antibiotics have reached the market recently, meaning that each resistance gene has more time to spread because of less antimicrobial backup. As a result, some last-line drugs, such as carbapenems vancomycin, and colistin face increasing resistance with no new alternatives.

Inadequate Resources and Policies

In low and middle-income countries (LMICs), fragile health systems, lack of regulatory enforcement, and limited diagnostic tools lead to broad-spectrum or inappropriate antibiotic use. Poor drug supply chains can also lead to the spread of less effective or expired antibiotics, which contribute to resistance.

Mechanism of Antibiotic Resistance by Microorganisms

Enzymatic Inactivation/Modification

Bacteria produce enzymes such as beta-lactamases, and aminoglycoside-modifying enzymes that chemically destroy or modify antibiotics, neutralising their effect (Belay *et al*., 2024). For example, *E. coli* or *Klebsiella* often carry extended-spectrum beta-lactamases (ESBLs) that hydrolyse penicillins and cephalosporins.

Target Site Alteration

Antibiotic's target within a microbe can be altered through genetic mutations or acquired genes. For instance, MRSA has a modified penicillin-binding protein (PBP2a) that does not bind methicillin, and *Enterococcus faecalis* can acquire vanA to change cell wall precursors, rendering vancomycin ineffective.

Efflux Pumps

Bacteria increase the level of membrane proteins that pump antibiotics out of the cell, and through that, they reduce intracellular drug concentration. Many Gram-negative bacteria use RND-family pumps such as AcrAB-TolC that expel a broad range of drugs. Efflux can confer multidrug resistance by lowering effective antibiotic levels in the cell.

Reduced Permeability

This is seen especially in Gram-negative bacteria, where loss or mutation of porin channels reduces antibiotic uptake. For example, *Pseudomonas aeruginosa* often reduces the effect of OprD porin to resist carbapenems. Intrinsic structural features such as the double membrane and lipopolysaccharide layer also naturally limit antibiotic entry (Belay *et al*., 2024).

Biofilm Formation

Bacteria can form biofilms, dense communities encased in a self-produced matrix. Biofilms on devices or tissues can block antibiotic penetration. As a result only surface cells are reached by drugs, while deeper cells survive. Therefore, biofilm-associated bacteria tolerate antibiotics orders of magnitude better than planktonic cells (Belay *et al.*, 2024), resulting to chronic and device-related infections.

Horizontal Gene Transfer (HGT)

Resistance genes can increasingly spread between bacteria by HGT. Conjugation, which is plasmid exchange, transformation, which is uptake of free DNA, and transduction, which is phage-mediated transfer are responsible for moving resistance traits across species. Plasmids usually carry multiple resistance genes, such as carbapenemase plasmids and enables simultaneous acquisition of multidrug resistance. Therefore, HGT accelerates the spread of resistance in environments like hospitals, farms, and the gut microbiome. Figure 1 illustrates the various mechanisms by which bacteria develop antibiotic resistance.

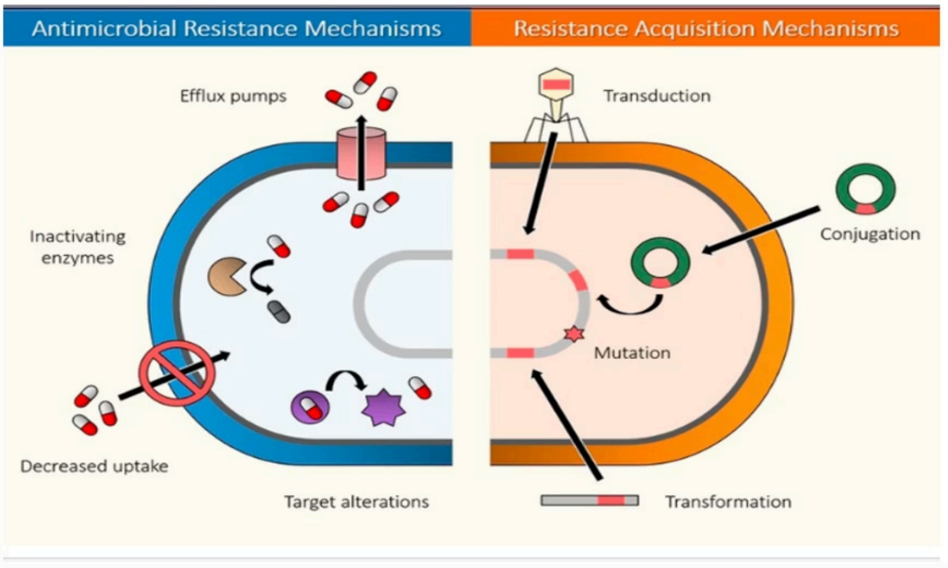

Figure 1: Antibiotic Resistance Mechanism (Source: Francisco, 2020)

Approaches taken to Mitigate or Eliminate Antibiotic Resistance

On the policy side, Nigeria developed a National Action Plan (NAP) on AMR in 2017. However, the initial implementation (NAP 1.0, 2017-2022) had limited success, requiring a complete revision. Consequently, Nigeria launched NAP 2.0 in October 2024. This slow policy implementation has directly contributed to poor antibiotic regulation. A critical issue is that antibiotics are often sold over-the-counter without prescription, despite pharmacists knowing the risks; a recent study revealed that 98.1% of community pharmacists dispense antibiotics this way. This lax regulation fuels widespread consumer misuse: 72.5% of Nigerian consumers used antibiotics in the last 12 months. Disturbingly, 57.4% were unaware of antibiotic resistance, and only 14.7% had adequate antibiotic knowledge. A common misuse pattern involves amoxicillin (42.4%) being inappropriately used for malaria (38.9%), a condition antibiotics cannot treat. Compounding these issues, antibiotic costs have increased by up to 1000% in Nigeria, potentially driving consumers towards substandard drugs that further contribute to resistance. Non-compliance with infection control and lack of routine laboratory surveillance also allow resistant strains to spread unknowingly. Environmental surveys even detect resistant coliforms in river waters near cities, linked to human and animal antibiotic use (Alabi et al., 2025). This creates a direct causal pathway: weak policy implementation leads to regulatory violations, which enable consumer misuse, ultimately driving resistance outcomes and necessitating the launch of NAP 2.0.

Other approaches such as Antimicrobial Stewardship (AMS), Infection Prevention and Control (IPC), One Health Approach, Surveillance and Rapid Diagnostics, Research and New Technologies, Education and Public Awareness and Global Policies and Governance were also introduced to mitigate antibiotic resistance (Belay et al., 2024; WHO, 2023; WHO, 2023b). However, some of these were not followed up for proper implementation especially in Nigeria, which has caused an increase in antibiotic resistance. Furthermore, there is an absence of funding and resource support to back them up.

Economic Urgency and Healthcare System Capacity

This section reinforces the urgency argument with specific economic projections for Nigeria regarding Antimicrobial Resistance (AMR).

Economic Projections for Nigeria:

Nigeria faces an estimated 249,000 AMR-associated deaths by 2030 if current trends continue, exceeding the UN target of 231,000 (a 10% reduction from 2019 baseline). Currently, 50,500 deaths are attributable to AMR annually, with 227,000 deaths associated with AMR in 2021 alone. The largest number of AMR-related deaths occurs among children under 5, indicating a critical threat to Nigeria's future workforce and economic development.

249K

Projected Deaths by 2030

If current AMR trends continue, exceeding UN target.

227K

AMR-Associated Deaths (2021)

50,500 deaths annually are directly attributable to AMR.

—

Children Under 5

Largest number of AMR-related deaths, threatening future workforce.

Healthcare System Capacity vs. AMR Burden:

- Nigeria's healthcare infrastructure is already strained, with AMR adding significant pressure through prolonged hospital stays and increased treatment costs.

- The most deadly pathogen-drug combinations (MRSA, carbapenem-resistant A. baumannii, and cephalosporin-resistant S. pneumoniae) are overwhelming existing treatment capacity.
- Rising antibiotic costs (up to 1000% increases) are creating a dual crisis of affordability and effectiveness.

Economic Benefits of Immediate Action:

Early intervention through effective NAP 2.0 implementation could prevent thousands of deaths and save billions in healthcare costs (NIH, 2023). Delayed action exponentially increases economic burden, as resistant infections require more expensive treatments and longer hospital stays. Investment in AMR prevention today yields significant returns through reduced healthcare expenditure and preserved workforce productivity.

> This economic analysis demonstrates that strengthening policy implementation isn't just a health imperative–it's an economic necessity for Nigeria's sustainable development.

METHODOLOGY

This study made use of secondary data through a systematic (qualitative) review of peer-reviewed literature from 2016 to 2025. Data from 2016 to 2025 were used because they are able to cover recent evolution in AMR within a decade. Databases such as PubMed, Scopus, Google Scholar, and regional sources like AJOL were searched for articles on "antibiotic resistance", "antimicrobial resistance", "health care management", "Africa", "Nigeria", "One Health", and related terms.

The criteria that were sought included: publication date 2016-2025, focus on antibiotic resistance in microorganisms in human and animal health contexts, and relevance to health system or management implications. English-language journal articles (original research, systematic reviews, and meta-analyses) were prioritised, and non-scientific sources were excluded. Titles and abstracts were screened for relevance, followed by full-text review. Data on AMR prevalence, health outcomes, drivers, and intervention outcomes were extracted and synthesised qualitatively. Key international reports (WHO, Lancet consortium) were also reviewed. The approach follows the PRISMA-guided reviews by Gregory and Denniss (2018) with some modification.

Study Limitations

- **Timeframe Limitation (2016-2025):** While this period effectively captures recent advancements and the evolution of AMR within the last decade, it may inadvertently omit crucial historical context and baseline data from earlier periods. Such omissions could potentially hinder a more comprehensive trend analysis of AMR.

- **Potential Publication Bias:** Systematic reviews inherently face the risk of publication bias. Studies with negative or inconclusive results are often underrepresented in published literature, which could lead to an overestimation of the severity or prevalence of certain resistance patterns in the synthesised findings.
- **Geographic and Linguistic Bias:** The prioritisation of English-language articles and the selection of specific databases might lead to a geographic and linguistic bias. This could result in the underrepresentation of significant regional research from non-English speaking countries, which is particularly critical for understanding the diverse AMR patterns across Africa.
- **Data Heterogeneity Challenges:** The diverse methodologies, definitions, and reporting standards employed across various studies can lead to significant data heterogeneity. This variability may limit the potential for direct comparisons and comprehensive meta-analysis, thereby affecting the generalisability of findings.
- **Gap Between Global Findings and Nigeria-Specific Recommendations:** Although global data provides essential context, translating these broader findings into actionable, Nigeria-specific policy recommendations necessitates more localised evidence. The availability of country-specific data may limit the precision and applicability of such recommendations.

Data Sources

- PubMed, Scopus, Google Scholar
- Regional sources like AJOL
- WHO and Lancet consortium reports

Search Terms

"Antibiotic resistance", "antimicrobial resistance", "healthcare management", "Africa", "Nigeria", "One Health"

Method

Systematic qualitative review following PRISMA-guided approach with modifications for AMR focus

RESULT AND FINDINGS

The rate of Antibiotic resistance

Table 1 summarises the global, African, and Nigerian burden of AMR, showing the comparative mortality rates across different regions.

Worldwide, 4.95 million deaths were associated with bacterial AMR in 2019 (de Kraker et al., 2016). Low-resource regions, including sub-Saharan Africa, had the highest death rates per capita. The leading pathogens, *E. coli*, *S. aureus*, *K. pneumoniae*, *S. pneumoniae*, *A. baumannii*, and *P. aeruginosa*, accounted for about 3.57 million AMR-linked deaths (ARC, 2022).

In the WHO African region (2019), about 1.05 million deaths were linked to AMR. Lower respiratory infections and sepsis (bloodstream infections) were the primary causes of over 70% of AMR deaths in Africa. The mortality rate was highest for *S. pneumoniae* and *K. pneumoniae* among pathogens. Importantly, third-generation cephalosporin-resistant *K. pneumoniae* and MRSA were the top resistant threats across many African countries (ARC, 2024).

Studies show Nigeria has extremely high resistance rates. For example, pooled data indicate 61% (95% CI 44 - 76%) of bacterial isolates in Nigeria were multidrug-resistant (Diop et al., 2025). Hospital surveys report that *E. coli* and *Klebsiella* isolates frequently carry extended-spectrum β-lactamases (ESBLs), and MRSA rates are often >30% (Alabi et al., 2025). Neonatal sepsis data indicate 50% of *E. coli* and 86% of *S. aureus* strains are resistant to first-line drugs (Ajekiigbe et al., 2025).

Table 1: Global, African, and Nigerian Burden of AMR

S/N	Author(s)	Country/Region	Study Focus	Key Findings	Pathogens Involved
1.	WHO Regional Office for Africa, 2024	Global	WHO statements on AMR burden	WHO reports ~4.95 million human deaths were associated with bacterial AMR in 2019. Highlights AMR as a top global threat.	Broad (bacterial)
2.	Sartorius *et al.*, 2024	WHO African Region (Africa)	Regional AMR burden (2019)	Systematic analysis found ~1.05 million deaths associated with AMR and 250,000 attributable in African region (2019). Leading pathogens were *S. pneumoniae, K. pneumoniae, E. coli*, and *S. aureus*.	*S. pneumoniae, K. pneumoniae, E. coli*, and *S. aureus*
3.	Institute for Health Metrics and Evaluation, 2023	Nigeria	National AMR burden (2019)	In Nigeria (2019) there were ~64,500 AMR-attributable deaths and ~263,400 AMR-associated deaths. Nigeria ranked 20th highest globally in AMR mortality rate.	Multiple (nationwide data)

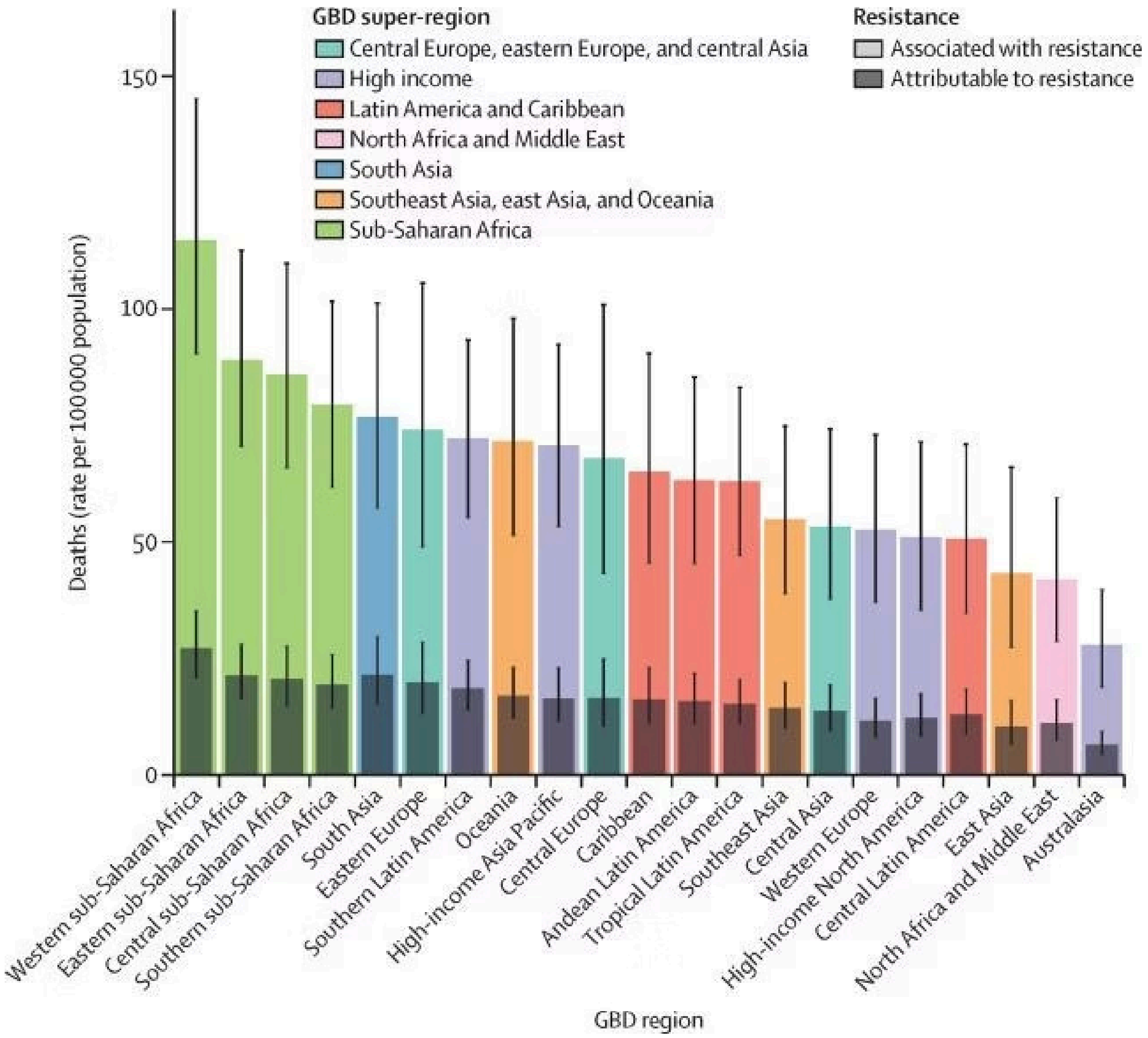

Figure 2: All-age rate of deaths attributable to and associated with bacterial Antimicrobial Resistance by GBD region, 2019

Source: Antimicrobial Resistance Collaborators, 2022

Drivers of Antibiotic Resistance

As illustrated in Figure 2, the burden of AMR varies significantly across global regions, with sub-Saharan Africa bearing a disproportionate share of deaths. Common drivers of antibiotic resistance identified across the literature reviewed include over-the-counter antibiotic sales, inappropriate prescription, and use of antibiotics for viral illnesses, poor patient adherence to instruction, lack of awareness and lack of stewardship programmes (Alabi et al., 2025; WHO, 2023). In animal farming, routine use of antibiotics as growth promoters and prophylaxis are the major drivers (Musuka et al., 2025). Additional factors are inadequate water, sanitation, and hygiene (WASH), weak infection prevention in clinics, presence of counterfeit/substandard drugs, and insufficient AMR surveillance (Alabi et al., 2025; WHO, 2023).

61%

Nigeria MDR Rate

Bacterial isolates showing multidrug resistance

50%

***E. coli* Resistance**

Neonatal *E. coli* resistant to first-line drugs

86%

***S. aureus* Resistance**

S. aureus strains resistant to first-line antibiotics

Bacteria mostly implicated in Antibiotic Resistance

In healthcare settings, most studies emphasize Gram-negative bacteria such as *E. coli*, *Klebsiella pneumoniae*, *Pseudomonas aeruginosa*, *Acinetobacter baumannii*, and Gram-positives such as *MRSA*, *Enterococcus*, *S. pneumoniae* as major MDR pathogens. In the animal sector, data mostly from livestock and aquaculture show a high prevalence of resistant *E. coli*, *Salmonella*, and other zoonotic bacteria (Alabi et al., 2025; Musuka et al., 2025).

Antibiotics that bacteria are resistant to third-generation and broad-spectrum cephalosporin, extended-spectrum β-lactam antibiotics, vancomycin, colistin, methicillin, penicillin, carbapenems, and ampicillin.

Most burdensome AMR-implicated Infections

The most burdensome infections (syndromes) were lower respiratory infections, bloodstream infections, and intra-abdominal infections.

Mechanism of Antibiotic Resistance

The review has shown that the mechanism of resistance is mutation and improved already existing traits in these bacteria. This is broken down into enzymatic inactivation/modification, target site alteration, efflux pumps, reduced permeability, biofilm formation, and horizontal gene transfer (HGT) mechanisms. Recent genomic studies reveal that mobile genetic elements such as plasmids and integrons that carry multiple antibiotic resistance determinants are widespread in hospital pathogens, facilitating rapid horizontal spread. These complex and evolving resistance mechanisms pose significant challenges to healthcare systems, often leading to increased treatment costs and longer hospital stays (Standaert et al., 2024) (Belay et al., 2024).

Approaches taken to Mitigate or Eliminate Antibiotic Resistance

On the policy side, Nigeria developed a National Action Plan (NAP) on AMR in 2017, but implementation has been slow (FMAEH, 2017). One aspect of poor antibiotic regulation is that antibiotics are often sold over-the-counter without prescription, increasing misuse (Alhaji and Isola, 2018). Non-compliance with infection control and lack of routine laboratory surveillance allow resistant strains to spread unknowingly.

Other approaches such as Antimicrobial Stewardship (AMS) (Kamere et al., 2022), Infection Prevention and Control (IPC), One Health Approach, Surveillance and Rapid Diagnostics, Research and New Technologies, Education and Public Awareness and Global Policies and Governance were also introduced to mitigate antibiotic resistance (Belay et al., 2024). However, some of these were not followed up for proper implementation especially in Nigeria, which has caused an increase in antibiotic resistance. Furthermore, there is an absence of funding and resource support to back them up.

Policy Implementation

Nigeria's National Action Plan on AMR developed in 2017 but implementation has been slow due to inadequate funding and resource support.

Antimicrobial Stewardship

AMS programmes introduced to optimise antibiotic use but lack proper follow-up and enforcement in healthcare facilities.

One Health Approach

Integrated approach addressing human, animal, and environmental health domains to tackle resistance holistically.

Global Collaboration

International coordination needed through surveillance data sharing, policy harmonisation, and resource mobilisation.

CONCLUSION

Antibiotic resistance (AMR) is a critical 21st-century healthcare challenge (Lonare, 2024; Khanal et al., 2017). Globally, and particularly in countries like Nigeria with weak health systems, AMR threatens disease control and undermines healthcare management. This escalating resistance indicates current antibiotics may soon be ineffective against common pathogens, leading to higher mortality, longer hospital stays, and increased costs.

Addressing this requires justified antibiotic use through stewardship, strengthened infection control, and the development of new treatments and diagnostics. Well-designed strategies, including One Health policies, national action plans, and stewardship programmes, are crucial to slowing this silent pandemic. Without effective action, the world faces a future where minor infections become untreatable.

RECOMMENDATIONS

01

Implement National Action Plans

African countries, including Nigeria, should fully implement AMR action plans through dedicated funding and intersectoral coordination across human, animal, and environment sectors.

02

Strengthen Surveillance Systems

Expand routine surveillance of resistance patterns by integrating WHO's GLASS system for accurate data to guide policy decisions. Investment in microbiology laboratories, data systems, and research on novel antibiotics, vaccines, and diagnostics is essential.

03

Regulate Antibiotic Access

Eliminate over-the-counter sales of antibiotics and monitor pharmacies and markets to prevent misuse and misprescription.

04

Enhance International Collaboration

Embrace international collaboration through regional AMR networks, surveillance data sharing, and coordinated policy implementation, recognizing AMR's transnational nature.

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CONFLICTS OF INTEREST

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ABOUT THE AUTHOR(S)

Edward Oyekanmi

📧 edward.oyekanmi@wesleyuni.edu.ng

Microbiology Programme, Biological Science Department, College of Natural and Applied Sciences, Wesley University, Ondo

Funmi Olatujoye

Microbiology Programme, Biological Science Department, College of Natural and Applied Sciences, Wesley University, Ondo

Mercy Adeyemi

Microbiology Programme, Biological Science Department, College of Natural and Applied Sciences, Wesley University, Ondo

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