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Federal Ministry of Health & Social Welfare
Federal Republic of Nigeria

NCDC
NIGERIA CENTRE FOR DISEASE CONTROL AND PREVENTION

National Action Plan (NAP) on Antimicrobial Resistance:

SITUATIONAL ANALYSIS

and Key Recommendations for the Development of NAP 2.0

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World Health Organization Nigeria

Food and Agriculture Organization of the United Nations

UNEP

World Organisation for Animal Health Founded as OIE

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This document provides an evidence-based understanding of the nation's status and progress towards the fight against AMR by providing details and data on the achievements, challenges, gaps, and barriers to AMR and provides clear recommendations to ensure a well-coordinated One Health approach to tackling AMR across the country.

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Abbreviations and Acronyms

AFENET	African Field Epidemiology Network
AMA	African Medicines Agency
AMR	antimicrobial resistance
AMRCC	antimicrobial resistance coordinating committee
AMS	antimicrobial stewardship
AMU	antimicrobial use
ARGs	antimicrobial resistance genes
ASLM	African Society for Laboratory Medicine
AST	antimicrobial susceptibility testing
ASV	anthrax spore vaccine
AWaRe	Access, Watch, Reserve
BQV	blackquarter vaccine
BV	brucella vaccine
CBPP	contagious bovine pleuropneumonia
CBPPV	contagious bovine pleuropneumonia vaccine
CDC	Centers for Disease Control and Prevention
CFID	Centre for Initiative and Development
DALYs	disability-adjusted life year
DASH	Dalhatu Araf Specialist Hospital
DRI	drug resistance index
E. coli	*Escherichia coli*
EML	Essential Medicine List
EQA	External Quality Assurance
EQuAFRICA	External Quality Assurance for Africa
ESBL	extended-spectrum beta-lactamase
ESBL-EC	extended-spectrum beta-lactamase *E. coli*
EVD	ebola virus disease
FAS	Food and Agriculture System
FCT	Federal Capital Territory
FCV	fowl cholera vaccine
FMAFS	Federal Ministry of Agriculture and Food Security
FMC	Federal Medical Center
FMCJ	Federal Medical Center, Jalingo
FMD	foot and mouth disease

FMEnv	Federal Ministry of Environment
FMoH	Federal Ministry of Health
FPV	fowl pox vaccine
FTV	fowl typhoid vaccine
GDP	gross domestic product
GIZ	Deutsche Gesellschaft fur Internationale Zusammenarbeit
GLASS	Global Antimicrobial Resistance and Use Surveillance System
HAIs	healthcare-associated infections
HCFs	healthcare facilities
HCW	health care workers
HIV	human immunodeficiency virus
HPAI	highly pathogenic avian influenza
HSV	haemorrhagic septicaemia vaccine
HV	hantavac vaccine
IBD	infectious bursal disease
IBDV	infectious bursal disease vaccine
ICU	intensive care unit
IPC	infection prevention and control
ISO	International Organization for Standardization
IVDs	in vitro diagnostics
JICA	Japanese International Cooperation Agency
K. pneumoniae	*Klebsiella pneumoniae*
KAP	knowledge, attitudes, and practices
KI	key informant
KII	key informant interview
LSDV	lumpy skin disease vaccine
MAAP	Mapping Antimicrobial resistance and Antimicrobial use Partnership
MARI	multiple antibiotic resistance index
MDC	Mental and Dental Council of Nigeria
MDR	multi drug resistance
MLSCN	Medical Laboratory Science Council of Nigeria
MRSA	methicillin-resistant *Staphylococcus aureus*
NAAW	National Antimicrobial Awareness Week
NACA	National Agency for the Control of AIDS
NAFDAC	National Agency for Food and Drug Administration and Control
NAP	national action plan
NBCCCG	National Behaviour Change Communication Consultative Group

NCD	non-communicable disease
NCDC	Nigeria Centre for Disease Control and Prevention
ND	Newcastle Disease
NDHS	Nigerian Demographic and Health Survey
NEDL	National Essential Diagnostics List
NESREA	National Environmental Standards and Regulations Enforcement Agency
NFETP	Nigeria Field Epidemiology Training Programme
NFID	Department for International Development
NGO	non-governmental organisation
NHIA	National Health Insurance Authority
NiCaDe	Nigeria Centre for Disease Control: Capacity Development for Preparedness and Response for Infectious Diseases
NIPRID	Nigerian National Institute for Pharmaceutical Research and Development
NOHCU	National One Health Coordination Unit
NOHSC	National One Health Steering Committee
NOHTC	National One Health Technical Committee
NPHCDA	National Primary Health Care Development Agency
NRL	national reference laboratory
NVRI	National Veterinary Research Institute
OH	One Health
OHT	One Health Trust
OOP	out of pocket
PAMS	paediatric antimicrobial stewardship
PCN	Pharmacist Council of Nigeria
PCV	pneumococcal conjugate vaccine
PEA	Political Economic Analysis
PEP	post-exposure prophylaxis
PEPFAR	President's Emergency Plan for AIDS Relief
PPE	personal protective equipment
PPR	peste des petits ruminants
PPRV	peste des petits ruminants vaccine
PSSHJ	Plateau State Specialist Hospital, Jos
RKI	Robert Koch-Institut
S. aureus	*Staphylococcus aureus*
SEDI	Sustainable Environment Development Initiative
SOP	standard operating procedure
STG	standard treatment guideline

TB	tuberculosis
TrACSS	Tripartite AMR Country Self-assessment Survey
TWG	technical working group
US CDC	United States Center for Disease Control and Prevention
UCH	University College Hospital
UDUTH	Usmanu Danfodiyo University Teaching Hospital
UHC	Universal Health Coverage
UNICEF	United Nations International Children's Emergency Fund
US	United States
USAID-MTaPS	United States Agency for International Development – The Medicines, Technologies, and Pharmaceutical Services Program
USD	US dollar
VCN	Veterinary Council of Nigeria
WAAW	World Antimicrobial Awareness Week
WASH	water, sanitation, and hygiene
WGS	whole genome sequencing
WHO	World Health Organization
WOAH	World Organisation for Animal Health
WUENIC	WHO and UNICEF estimates of national immunisation coverage
YLDs	years lived with disability

Glossary

Drug Resistant Index (DRI) is a metric that combines antibiotic use and antibiotic resistance in one single measure. It combines measurements of antibiotic consumption and resistance across multiple pathogen–organism combinations, to create a single metric that represents an aggregate level of drug resistance. The DRI score lies between 0 and 100, where 0 indicates 100% susceptibility and 100 indicates 100% resistance.

Disability-adjusted life year (DALYs) is an abbreviation for disability-adjusted life year. It is a universal metric that allows researchers and policymakers to compare very different populations and health conditions across time. DALYs equal the sum YLLs and YLDs. One DALY equals one lost year of healthy life. DALYs allow estimation of the total number of years lost due to specific causes and risk factors at the country, regional, and global levels.

Years living with disability (YLDs) describes years lived in less-than-ideal health due a range of conditions such as, for example, influenza, which may last for only a few days, or epilepsy, which can last a lifetime. YLDs are derived by multiplying the prevalence of the condition by the disability weight for that condition. Disability weights reflect the severity of different conditions and are developed through surveys of the general public.

Years of life lost (YLLs) are years lost due to premature mortality. YLLs are calculated by subtracting the age at death from the longest possible life expectancy for a person at that age. For example, if the longest life expectancy for men in a given country is 75, but a man dies of cancer at 65, this would be 10 years of life lost due to cancer.

Executive Summary

Antimicrobial resistance (AMR) represents one of the most pressing global health problems today. Accumulating evidence points to its significant impact on health and the economy on a global scale, especially in resource-limited settings where inadequate access to healthcare and poor infrastructure contribute to high disease burden and incidence of infections that are becoming increasingly complex and costly to treat. The Global Action Plan on AMR, developed by the quadripartite in 2015, has served as a road map for the inception of national action plans (NAPs) to address AMR for many countries worldwide; however, critical operationalisation and implementation gaps remain, especially in the One Health context. As Nigeria develops its second NAP on AMR, it is vital to review progress and challenges and re-examine how mitigation efforts are organised.

A situation analysis of literature, organisational reports and documents, and consultation with AMR experts in the country highlights the progress achieved in establishing a national AMR surveillance network in human health and a foundation for AMR surveillance in animal health; improving infection prevention control, and promoting antimicrobial stewardship through training and education; developing tools and guidelines to address AMR in all sectors; and improving multisectoral collaboration through the creation of technical working groups on AMR. However, significant challenges remain, with funding of AMR activities being a critical barrier to strategy implementation. Heavy reliance on external financing and disparities of these funds across sectors hinder progress and challenge cooperation in the One Health context. Additionally, the lack of integration of AMR strategies with other health programmes contributes to inefficient use of limited resources available for addressing such an encompassing and multifaceted issue.

The challenges with implementing the strategies outlined in the NAP on AMR are not limited to the Nigerian context; however, recommendations to improve these strategies and their potential for operationalisation must be informed by country-specific evidence. At the core of these recommendations lies the need to utilise available evidence to quantify the AMR burden and then articulate this burden to all relevant stakeholders to obtain community buy-in and political support. While multisectoral collaboration to address AMR using a One Health approach is challenged by complexities, gaps, and needs in each sector, a strong foundation can be supported by a community of practice, and sharing of common challenges, best practices, and funding opportunities. In this context, closer collaborations with other health programmes could support AMR activities through existing infrastructure and assist with developing feasible targets for the new version of the NAP on AMR.

Key findings for National Action Plan 2.0

National Action Plan development

- Include all relevant stakeholders in the early stages of the NAP on AMR development.
- Identify targets and indicators for all sectors; define specific and AMR-sensitive interventions through collaborations with other programmes converging with AMR.
- Design S.M.A.R.T objectives (Specific – Measurable – Achievable – Realistic – Time-bound); develop broader goals and specific and measurable objectives, which can be monitored to evaluate progress.
- Engage experts from cross-cutting areas and programmes to inform and guide the selection of priority indicators to include in the plan's objectives.
- Develop national-level guidelines and tools across all pillars of the NAP on AMR, which can be adapted and leveraged by all sectors.
- Develop an operational plan with clear short-term and long-term objectives.
- Cost the NAP on AMR to inform the economic case for financing and budget allocations.

Governance

- Develop a governance operational plan, outlining the actors and their roles and responsibilities, decision-making, implementation, and monitoring frameworks.
- Advocate for creating a sector-independent governing body overseeing AMR activities in the One Health context or adopt rotating leadership to increase ownership and accountability by all sectors.
- Support the development of state-level AMR structures to coordinate the implementation of AMR activities.
- Increase collaborations with the government, private sector, and civil societies.

Antimicrobial Resistance and Consumption Surveillance

- Strengthen laboratory capacity to detect AMR in human, animal, food production, and environmental sectors.
- Expand AMR surveillance to remote areas and leverage existing infrastructure from other programmes.
- Establish an AMR surveillance reference laboratory for the environment.
- Establish standard parameters for monitoring and controlling antimicrobials in the environment.
- Assess current antimicrobial consumption data according to the AWaRe category
- Identify priority actions to improve data collection and reporting.

Infection Prevention and Control

- Create a legal framework for infection prevention control and biosecurity to increase resource mobilisation.
- Address geographical disparities in IPC interventions.
- Establish closer collaborations with Immunisation and WASH groups to increase AMR visibility in these programmes.
- Include measurable IPC, Immunisation, and WASH objectives in the NAP 2.0 as interventions that address AMR.

Awareness

- Improve grassroots awareness of AMR through closer collaboration with civil societies and community leaders.
- Improve AMR awareness in the government and private sectors.
- Include AMR in the educational curricula of all relevant professions in all sectors.
- Use available evidence to increase the political visibility of AMR and engage with other health programmes that address AMR.

Access and Optimal Use

- Establish national antimicrobial stewardship guidelines.
- Advocate for increasing Universal Healthcare Coverage to improve access to appropriate diagnostics and medicines.
- Improve the pathways and processes for registration, procuring, and distribution of antibiotics.
- Advocate for an increase in the domestic production of pharmaceuticals to overcome issues with access to quality antimicrobials.
- Support the enforcement of regulations around antimicrobial procurement, dispensing, and use.

Research and Development

- Identify priority AMR research questions in Nigeria.
- Conduct AMR research in areas with significant AMR surveillance gaps.
- Utilise available data to estimate the AMR burden and its impact on health and the economy in Nigeria.

Overview and Methodology

This situational analysis provides a One Health overview of antimicrobial resistance (AMR) in Nigeria and assesses progress with the implementation of AMR mitigation and control strategies. Findings contained in this document are informed by a review and analysis of various sources, including government reports, guidelines and strategic documents, peer-reviewed literature, and unpublished data. Additionally, information on progress, barriers, and opportunities to accelerate the implementation of AMR strategies was obtained by semi-structured interviews with AMR focal points and stakeholders in Nigeria conducted between March and September 2023

One Health Trust interviewed 33 key informants from diverse fields directly or indirectly related to mitigating AMR in Nigeria. The interviews, conducted between 23 March and 31 May 2023, included the following respondents:

- Experts from One Health sectors: human health, animal health, and environmental health.
- Experts whose job designation or description directly mentions AMR, such as the AMRCC Chair and AMR Surveillance Fellow
- Experts from the World Health Organization from the animal environmental and human health sectors
- Representatives from non-governmental organisations primarily focused on human health, including both social and medical aspects of human health.
- Academic experts
- A representative from National Agency for Food and Drug Administration and Control overseeing human and veterinary medicines.

Following background information on AMR trends and mitigating strategies in human health, agriculture, and environment sectors, this policy document aligns with the strategic objectives outlined in Nigeria's National Action Plan on AMR. It encompasses public awareness and understanding of AMR, surveillance and research, prevention of infections, optimised use of antimicrobials, and research and development. This document is intended to provide a basis for the identification of gaps and recommendations that can aid the development of the new National Action Plan on AMR.

1. Nigeria Country Profile

1.1. Human Health, Health Workforce, and Health Systems in Nigeria

Burden of Disease

In 2022, Nigeria's estimated population was 218.5 million, with a 2.4% annual population growth rate, as shown in Table 1.[1] Forty-seven per cent of the population lives in rural areas, 49% of the urban population lives in urban slums, and in 2018, approximately one-third of the total population lived at or below the international poverty line of US $2.15 per day.[2] Life expectancy at birth increased from 47 years in 2000 to 53 years in 2021.[1]

Table 1: Demographic, socioeconomic, and health indicators

Indicator	Estimates (see sources)
Demographic	
population	218,541,2121
annual population growth rate	2.41
crude birth rate (birth per 1,000 women)	372
crude death rate (death per 1,000 people)	6.433
life expectancy at birth (years)	532
Socioeconomic	
gross national income per capita, purchasing power parity (current $)	56,501
health expenditure as % of GDP (current $)	3.381
out-of-pocket expenditure (% of total health expenditure)	74.631
adult literacy rate, both sexes 15 years and above (%)	621
female literacy rate, adult 15–49 years (%)	653
Health	
HIV prevalence, adults 15–49 (%)	1.54
annual tuberculosis incidence (all cases/100,000)	2,191
malaria prevalence, children 6–59 months (%)	233
total fertility rate (per woman)	5.33
maternal mortality ratio (per 100,000 live births)	5,123
neonatal mortality rate (per 1,000 live births)	355
post-neonatal mortality rate (per 1,000 live births)	283
infant mortality rate (per 1,000 live births)	715
child mortality rate (per 1,000 live births)	693
under-5 mortality rate (per 1,000 live births)	1,115

Sources:

- World Bank (2022) Nigeria's Demographic, Socioeconomic, and Health indicators[1]
- World Bank (2022) Rural Population – Nigeria[2]
- National Population Commission (2018) Nigeria Demographic and Health Survey 2018[3]
- Federal Ministry of Health (2018) Nigeria HIV/AIDS Indicator and Impact Survey (NAIIS) 2018[4]
- United Nations Children's Fund (2021) Indicator Profiles: Nigeria 2021[5]

The top 10 leading causes of mortality in Nigeria in 2019 included neonatal disorders, malaria, diarrheal diseases, lower respiratory infections, human immunodeficiency virus (HIV), ischaemic heart disease, stroke, congenital defects, tuberculosis (TB), and meningitis (Table 2).[6] Nigeria continues to have the highest malaria burden in the world and faces several emerging and re-emerging infectious disease threats, including recurring epidemics of Lassa fever, meningitis, and cholera.[7]

Nigeria has the 185th highest age-standardised mortality rate per 100,000 population associated with AMR across 204 countries. In 2019, there were 64,500 deaths attributable to AMR and 263,400 deaths associated with AMR in Nigeria. This makes the number of AMR deaths in Nigeria higher than deaths from enteric infections, respiratory infections and tuberculosis, maternal and neonatal disorders, neglected tropical diseases and malaria, and cardiovascular diseases (Figure 1).

Table 2: Burden of disease in Nigeria, 2019

Disease	Deaths per 100,000 (Mortality)	YLDs per 100,000 (Morbidity)	DALYs, per 100,000	Rank in top 10 causes of death, per 100,000
Malaria	88.96	296.88	6,027.55	2
Diarrheal diseases	84.32	191.88	6,418.6	3
Lower respiratory infections (includes pneumonia)**	80.52	8.59	5,857.96	4
HIV/AIDS	38.3	121.1	2,045.17	5
Tuberculosis	21.08	72.29	964.66	9
Meningitis	20.91	22.7	1,643.41	10
Maternal sepsis and other maternal infections	0.39	2.21	25.17	
Neonatal sepsis and other neonatal infections	12.66	46.52	1,171.46	
Typhoid fever	1.67	1.33	127.3	
Paratyphoid fever	0.067	0.027		
Upper respiratory infections	0.1	70.55	78.35	

DALY, disability-adjusted life year; YLD, years lived with disability.

Source: Global burden of disease 2019[8]

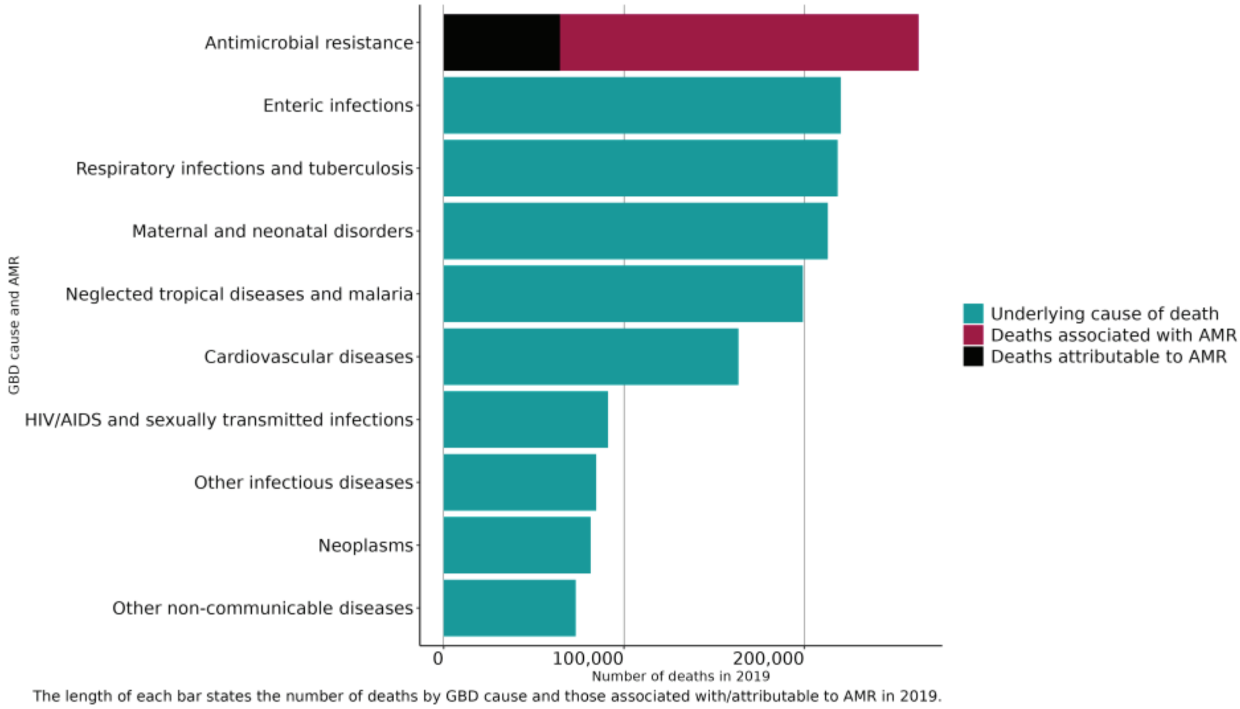

Figure 1: The number of deaths associated with or attributed to AMR in Nigeria in 2019

Source: Global Research on Antimicrobial resistance (GRAM) project[9]

Healthcare

Healthcare services in Nigeria are provided by both private and public sectors; 73.7% of human healthcare facilities (HCFs) are operated by the government, while 26.3% are privately owned. In 2019, there were 39,093 HCFS in the country providing primary (85.1%), secondary (14.5%), and tertiary (0.4%) care.[10] The number of operational HCFs across the 36 states in Nigeria is summarised in Figure 2, whereas the distribution of registered pharmacies and licensed pharmacists is presented in Figures 3 and 4, respectively.

By 2050, Nigeria is projected to be one of the most populous countries in the world. As such, its healthcare system must keep pace with the anticipated increasing complexity of healthcare needs as the prevalence of NCDs rises, drug-resistant pathogens emerge, and the high burden of infectious diseases persists (see section 20).[11] In 2022, there were approximately 86,548 doctors, 122,000 nurses and midwives, 18,277 pharmacists, 20,392 environmental health workers, and 86,600 community-level health staff in Nigeria. These numbers indicate that there were only 2.3 doctors, 92 nurses and midwives, 7.8 pharmacists, and 64 community-level health staff per 100,000 individuals in the population.[12] For critically ill patients in 2021, only 161 ICU beds were available nationwide.[13]

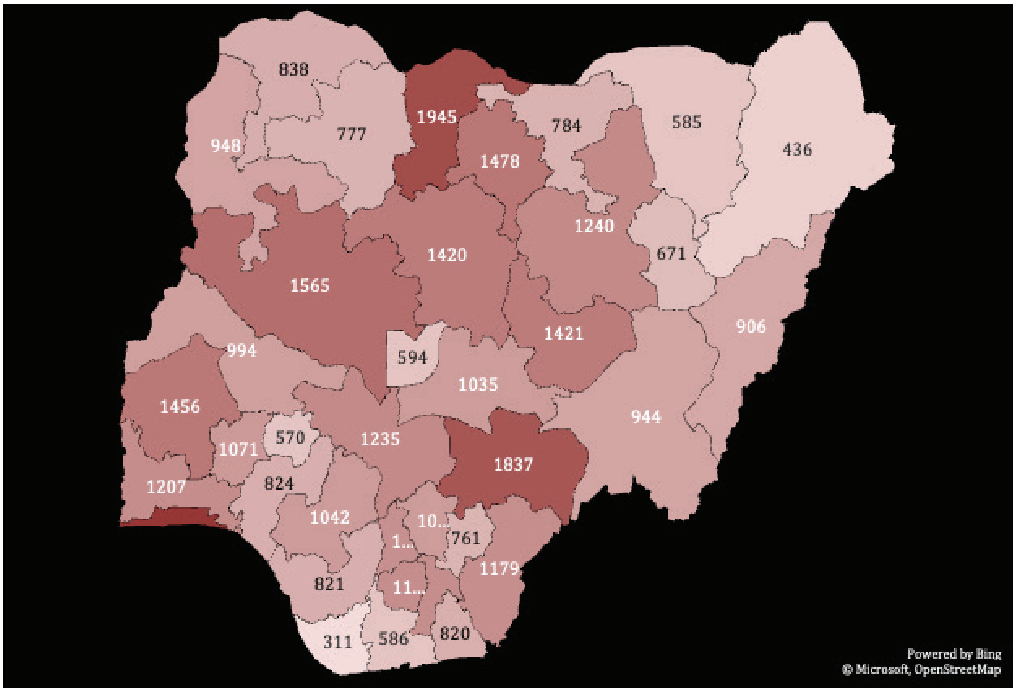

Figure 2: Operational hospitals and clinics across the 36 states in Nigeria

Source: Nigeria Health Facility Registry, 2023

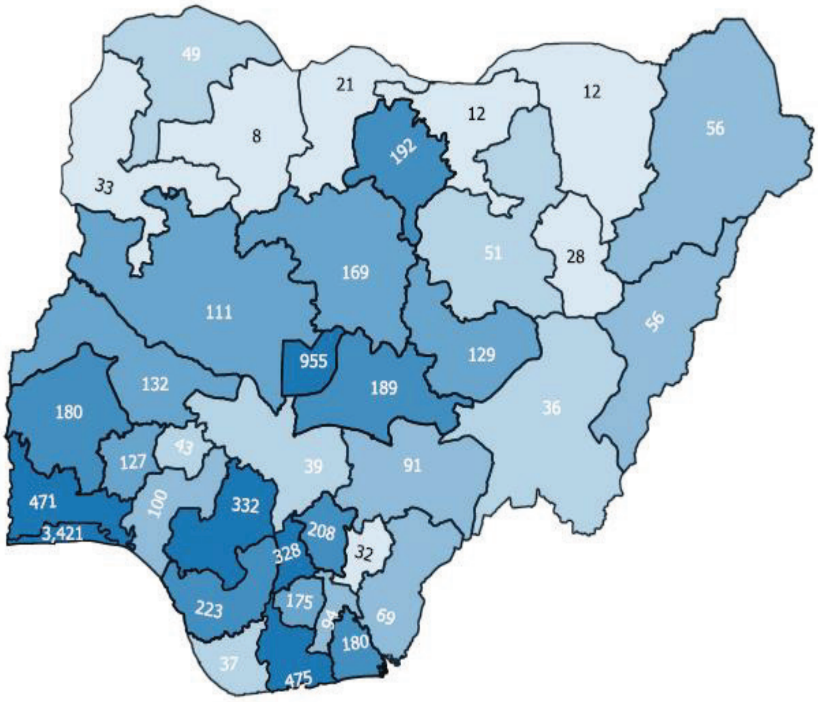

Figure 3: Distribution of registered community pharmacies in Nigeria from 1 January 1 to 31 December 2021

Source: Pharmacists Council of Nigeria, 2023

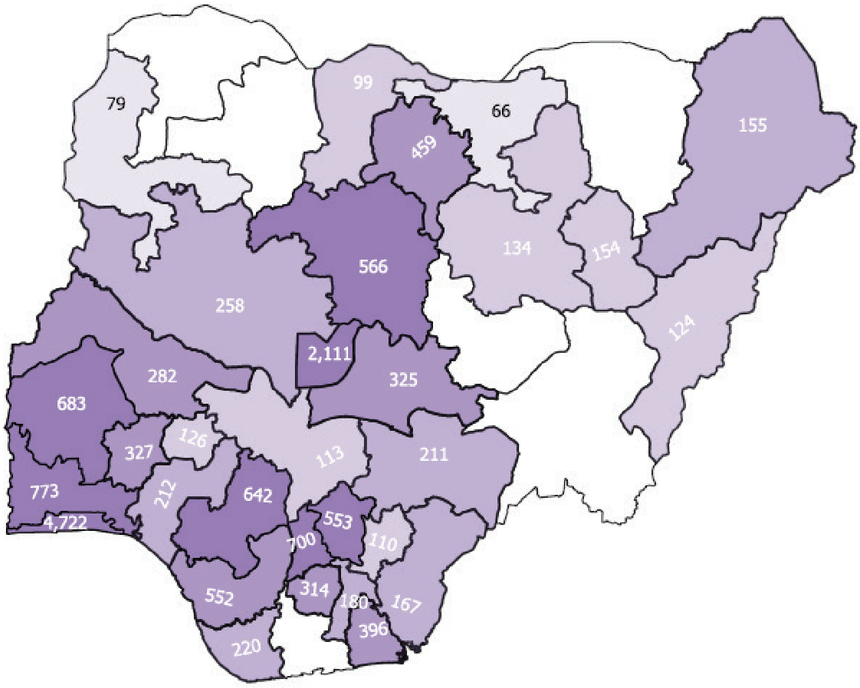

Figure 4: Distribution of Licensed Pharmacists in Nigeria between 1 January and 31 December 2021

Source: Pharmacists Council of Nigeria, 2023

Healthcare Financing

Nigeria's gross domestic product (GDP) in 2021 was 440.83 billion US dollars (USD), a 3.6% increase compared to 2020.[1] However, despite its positive economic and population growth outlook, healthcare infrastructure remains underdeveloped and overburdened with a lack of consistent funding and limited human resources.[14-16] In 2019, governmental per capita healthcare expenditure was 71.47 USD, while per capita out-of-pocket (OOP) expenditure was 47.42 USD.[6] Since 2006, government health expenditure as a proportion of the GDP has remained between 3.4 and 4.1%, a far cry from the consensus reached among African leaders during the Abuja Declaration of 2001 to allocate at least 15% of government expenditure to health.[7] However, the 2023 budget allocates 5.75% of government spending to health.[16,17]

The Lancet Nigeria Commission estimated that less than half (42.7%) of the population in Nigeria had access to healthcare services in 2019, an increase from 30.1% in 1998.[11] However, only 3% of people aged 15–49 had some form of health insurance coverage in 2018, according to the Nigerian Demographic and Health Survey (NDHS). Urban-dwelling Nigerians were more likely to possess employer-based health coverage than those living in rural areas.[3] Recent efforts to expand access to healthcare services include passing the National Health Insurance Authority (NHIA) Act – initially created as the national health insurance scheme in 2005, which enrolled less than 5% of Nigerians – into law in May 2022 after decades of development.[14,15] Under this act, the NHIA is mandated to ensure health insurance coverage for all citizens and legal residents of Nigeria with the ultimate objective of achieving universal health coverage.[17,18] In 2019, the universal health coverage (UHC) effective coverage index – which approximates service coverage across population health needs and accounts for how these services contribute to improved health – was 38.3, up from 31.6 in 2010 and 22.6 in 1990, indicating a slow expansion of insurance coverage among the Nigerian population.[6]

Amid other competing public health priorities, opportunities exist to increase investment in activities that address AMR. Rather than being placed as a vertical programme, the fight against AMR must be integrated into currently-funded programmes within the health system, such as reproductive, mother, newborn, and child health, HIV, TB, and malaria. A previous assessment on AMR resource mobilisation identified several national and international partners who could play a role in securing funding for AMR control in the country (Table 3 and Figure 5).[18,19] A more comprehensive list of AMR stakeholders can be found in Annex 1.

Table 3: Key stakeholders for AMR resource mobilisation

NAP Strategic Objective	Key Stakeholders	
	Local	International
Awareness and education	• Federal Ministry of Agriculture and Food Security (FMAFS) • Federal Ministry of Education • Federal Ministry of Health (FMoH), Family Health Division • Federal Ministry of Information and Culture • Medical and Dental Council of Nigeria (MDCN) • National Agency for Food and Drug Administration and Control (NAFDAC) • National Environmental Standards and Regulations Enforcement Agency (NESREA) • National Orientation Agency (NOA) • National Primary Healthcare Development Agency (NPHCDA) • Nigeria Centre for Disease Control and Prevention (NCDC) • Pharmacist Council of Nigeria (PCN) • Veterinary Council of Nigeria (VCN)	• Africa Centre for Disease Control and Prevention (Africa CDC) • United Nations International Children's Emergency Fund (UNICEF) • World Health Organization (WHO)

AMR surveillance	• Federal Ministry of Agriculture and Food Security (FMAFS) • Federal Ministry of Environment (FMEnv) • Federal Ministry of Health (FMoH) • Medical Laboratory Science Council of Nigeria (MLSCN) • National Primary Healthcare Development Agency (NPHCDA) • Nigerian Centre for Disease Control and Prevention (NCDC) • National Veterinary Research Institute (NVRI) • Veterinary Teaching Hospitals • Private Veterinary Clinics • Nigerian National Institute for Pharmaceutical Research and Development (NIPRD) • National Veterinary Research Institute (NVRI)	• Africa Centres for Disease Control and Prevention (Africa CDC) • African Field Epidemiology Network (AFENET) • Deutsche Gesellschaft fur Internationale Zusammenarbeit (GIZ) • Global fund • Japanese International Cooperation Agency (JICA) • Nigerian Centre for Disease Control and Prevention (NCDC) • President's Emergency Plan for AIDS Relief (PEPFAR) • Robert Koch Institute • United Kingdom Health Security Agency (UK HSA) • US Centre for Disease Control and Prevention • World Bank • World Health Organization (WHO)
Infection prevention and control / Biosecurity	• Family Health Services • Federal Ministry of Agriculture and Food Security (FMAFS) • Federal Ministry of Environment (FMEnv) • National Environmental Standards and Regulation and Enforcement Agency (NESREA) • National Primary Health Care Development Agency (NPHCDA) • Nigeria Centre for Disease Control and Prevention (NCDC)	• Africa Centres for Disease Control and Prevention (Africa CDC) • Department for International Development (DFID) • GAVI, The Vaccine Alliance • Robert Koch Institute • United Nations International Children's Emergency Fund (UNICEF) • United States Centre for Disease Control and Prevention (US CDC) • Water Aid • World Bank
Antimicrobial stewardship	• Federal Ministry of Agriculture and Food Security (FMAFS) • Federal Ministry of Health (FMoH) • Medical and Dental Council of Nigeria (MDCN)	• Africa Centres for Disease Control and Prevention (Africa CDC) • African Field Epidemiology Network (AFENET) • Christian Aid

	• National Agency for Food and Drug Administration and Control (NAFDAC) • National Environmental Standards and Regulation and Enforcement Agency (NESREA) • National Health Insurance Agency • National Primary Healthcare Development Agency (NPHCDA) • National Veterinary Research Institute (NVRI) • Nursing and Midwifery Council of Nigeria (NMCN) • Pharmacist Council of Nigeria (PCN)	• United Nations International Children's Emergency Fund (UNICEF) • World Health Organization (WHO) • World Organisation for Animal Health (WOAH)
Research and development	• Federal Ministry of Agriculture and Food Security (FMAFS) • Medical Laboratory Science Council of Nigeria (MLSCN) • National Veterinary Research Institute (NVRI) • Nigerian Centre for Disease Control and Prevention (NCDC) • Nigerian National Institute for Pharmaceutical Research and Development (NIPRD) • Pharmaceutical Industry	• Africa Centres for Disease Control and Prevention (Africa CDC) • African Field Epidemiology Network (AFENET) • World Health Organization (WHO) • Tertiary Education Trust Fund (TETFund)

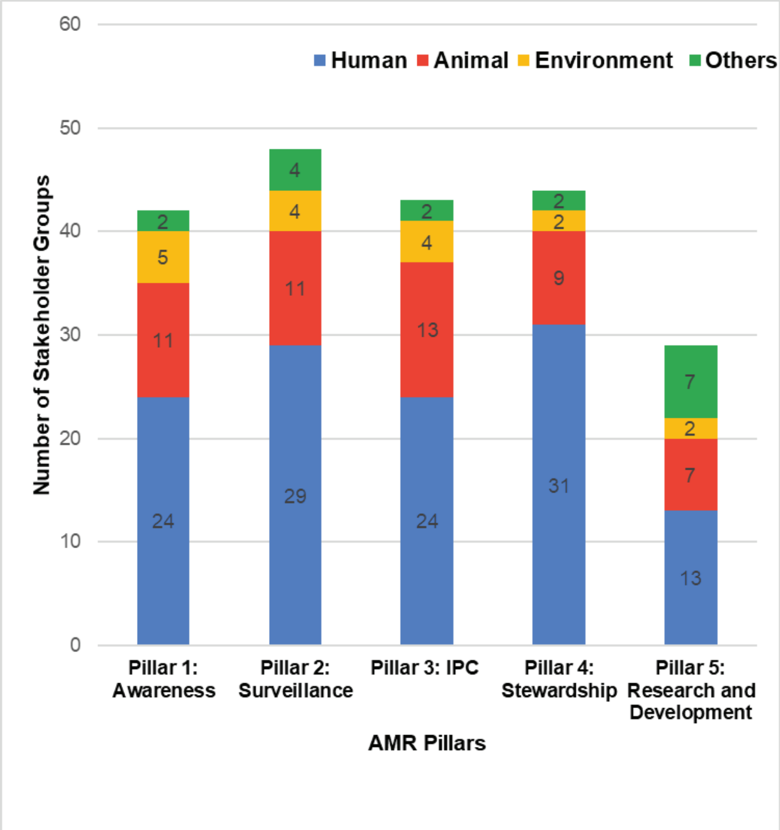

Figure 5: Stakeholder groups involved in AMR resource mobilisation across sectors and AMR pillars

1.2. Food and Agriculture, Animal Health Services and Veterinary Workforce in Nigeria

In Nigeria, veterinarians work in the public and private sectors, including academic institutions (universities, research institutes and other higher education institutions), government veterinary hospitals, private veterinary practices, businesses, pharmaceutical firms, feed manufacturers, public health sector, and the armed forces. By enhancing veterinary public health, veterinarians and other licensed animal health providers play a crucial role in ensuring the steady and sustained growth of a safe and equitable food system.[20] However, several factors prevent veterinarians from playing their full part in addressing the nation's food security and public health, including a lack of funding for research, poor compensation, lax policy enforcement, and inadequate representation in the creation, formulation, and implementation of policies.[21]

Of the 10,000 veterinarians registered with the Veterinary Council of Nigeria, roughly 3,500 actively practice veterinary medicine, with the remaining individuals working in different fields.[22] Additionally, there are 200,000 veterinary paraprofessionals in Nigeria. With a total livestock population of 883,058,659, equivalent to 88,177,740 livestock units, the ratio of practising veterinarians is estimated at roughly 1 to 25,000 livestock units and the ratio of total animal health workers at 1 to 433. Disparities in access to veterinary services and facilities in Nigeria are a major challenge.[23]

1.3. Agriculture, Aquaculture, Livestock Ownership and Health System in Nigeria

Livestock Production and Consumption in Nigeria

Agriculture, crop, livestock, forestry, and fisheries subsectors, has a significant impact on Nigeria's economy. With more than 70% of Nigerians engaged in agricultural practices, this sector contributes significantly to the country's GDP at 23.7%, although less than 2% of GDP comes from the livestock.[24] Poultry and ruminants (cattle, sheep and goats) are the most commonly owned farm animals at the household level.[25]

According to the Federal Ministry of Agriculture and Food Security (FMAFS), Nigeria's livestock population in 2023 comprised 58,776,242 cattle; 60,284,445 sheep; 108,755,793 goats; 695,545,007 poultry; 16,648,471 Pigs; 1,824,943 horses and 356,233 camels. Most livestock are raised in smallholder semi-intensive and pastoralist production systems, with some intensive/commercial production in the poultry, aquaculture and dairy value chains.[26]

Nigeria's annual beef consumption stands at approximately 360,000 tonnes, constituting almost half of the total beef consumption in West Africa. According to a 2022 report, Lagos State's annual beef consumption was estimated to be worth approximately NGN 328 billion, with most of the cattle consumed originating from northern Nigeria or further afield in West Africa.[27] While the per capita beef consumption in Nigeria remains relatively low compared to high-income countries, it is rapidly increasing and projected to quadruple by 2050.[28]

Over the past decades, Nigeria's pig and pork industry has expanded, with an average growth of 1.7% per year.[29] Oke Aro farm settlement in Ogun State, established over two decades and occupying over 30 hectares of land, has the largest concentration of pig farmers in all of West Africa, with at least 1 million pigs.[30,31]

Nigeria consumes over 3.2 million metric tonnes of fish yearly, making it the largest fish consumer in Africa and one of the largest in the world. One of the fastest expanding subsectors in the nation is its fisheries and aquaculture, with an annual fish output of close to one million metric tonnes (313,231 metric tonnes from aquaculture and 759,828 metric tonnes from fisheries).[32] Aquaculture production is mostly semi-intensive or intensive and is sometimes integrated with other forms of agriculture such as poultry or rice.[33] The most common fish species grown are tilapia and catfish.[34,35]

Health Threats Associated with Meat Processing and Sale

Abattoirs represent a key human-animal-environment interface where infectious diseases, including those caused by drug-resistant pathogens, may emerge or spread. Infection prevention and control (IPC) practices, including environmental sanitation and other safe slaughtering procedures, are crucial in mitigating the transmission of AMR and zoonotic diseases among abattoir workers and consumers.[36,37]

Infection prevention behaviour among abattoir workers and traders in live animal markets has been consistently reported as inadequate in Nigeria.[38-40] Behaviours that promote the risk of infection are further compounded by inadequate WASH infrastructure and lack of access to PPE. Furthermore, a low degree of awareness about zoonotic risks from animals also exacerbates the risk of infection in this demographic.[41,42] Abattoir personnel do not consistently wear PPE or maintain hygienic practices; animals are often slaughtered on the floor; wastewater is recycled for meat processing; and transport and storage facilities are inadequate.[36,37,43,44] To address some of these challenges, the Federal Ministry of Agriculture and Rural Development (FMARD) constructed 2 new abattoirs, renovated 27 abattoirs, and procured 37 vans for transporting meat from the abattoir to the markets across the nation.[45]

Interactions between humans and different animal species in abattoirs, combined with poor adherence to IPC and biosecurity measures, increase the potential for transmission of infectious organisms between humans and animals.[46,47] Zoonoses such as salmonella, brucellosis, cysticercosis, and tuberculosis have been reported in abattoir workers, and zoonotic organisms such as *Escherichia coli (E. coli)*, Salmonella spp., Leptospira spp., and Campylobacter spp. have been isolated from animals at slaughterhouses in Nigeria.

Biosecurity, Infection Prevention and Control

Biosecurity and IPC measures, such as vaccination, hygiene and sanitation, and quarantine practices, are critical to preventing the incidence and transmission of infectious diseases among livestock, between wild and domestic animals, and across human-animal-environmental interfaces.[48,49] Zoonotic risk in abattoirs and live bird markets can be controlled through strict adherence to IPC and biosecurity protocols such as regular sanitation of abattoir slabs, adequate housing and slaughter environments, use of PPE in these locations, and regular handwashing.[39,41] Researchers have also advocated for market rest days in live bird markets to control the risk of avian influenza outbreaks in the markets.[41]

The World Organisation for Animal Health (WOAH) Terrestrial Animal Health Code provides guidelines and standards for biosecurity measures in animal production and emphasises its necessity for optimal disease prevention and control in husbandry. However, poor adherence to guidelines for PPE, hand hygiene, quarantine of new animals, and other hygiene and biosecurity practices has been observed at the farm and community level across livestock value chains.[50-53] Access to veterinary professionals has a positive influence on animal husbandry and IPC practices among farmers.

In 2021, the National Veterinary Research Institute (NVRI) produced over 19 million doses of livestock bacterial vaccines (for contagious bovine pleuropneumonia, black quarter, anthrax, haemorrhagic septicaemia, brucella, fowl typhoid and fowl cholera) and over 23.3 million doses of viral vaccines (for infectious bursal disease/gumboro, fowl pox and Newcastle disease in poultry; peste des petits ruminants, lumpy skin disease, sheep/goat pox in ruminants; and rabies in dogs).[54] Although Federal and State governments sporadically implement mass vaccination campaigns, they are insufficient, resulting in low and irregular vaccine coverage across the country.[55] Vaccination coverage has been constrained by insufficient resources for the production and delivery of vaccines.[56]

Health Burden, Health Threats, and Livestock-associated Zoonoses

Infectious diseases are a persistent challenge to livestock production, lowering output and revenue.[57] Endemic diseases such as helminthiasis, PPR, CBPP, FMD, brucellosis, and mastitis, have a devastating impact on the livestock industry and result in hundreds of millions of dollars in losses each year.[58] Nigeria is a high-risk country for the emergence and spread of zoonoses.[59,60] Zoonotic infections (TB, toxoplasmosis, taeniasis, rabies, Lassa fever, yellow fever) are endemic while zoonotic food-borne infections (*Campylobacter* spp., *Salmonella* spp., *E. coli*, and cryptosporidiosis) are becoming increasingly prevalent. Animal handlers such as pastoralists, farmers and butchers are at high risk for these zoonotic diseases.[40,60-62] However, knowledge and risk perception of zoonotic diseases remains low among these high-risk groups, leading to negative attitudes and high risk practices.[63-65]

1.4. Companion Animals and Zoonotic Risk Transmission

Pet Ownership in Nigeria

There is a paucity of data describing the population of pets and the factors influencing pet ownership in Nigeria. One source estimates that there are between three and five million owned and free-roaming dogs in the country, with dog ownership being greater in urban than rural households.[65-67]

Health Burden, Health Threats, and Pet-associated Zoonoses

Despite being a vaccine-preventable disease, rabies poses a serious public health threat in Nigeria, as in many other Asian and African nations, where 99% of global rabies-related fatalities occur.[68] Rabies is endemic in Nigeria.[54,55] According to WHO, rabid dogs are responsible for around 94% of documented human infections, and the rabies death toll in Nigeria is around 55,000 annually. Endemicity of rabies in Nigeria is driven by low vaccination coverage, poor knowledge and public awareness of the disease, poverty.[69]

Zoonotic fungal infections transmitted from animals to humans include dermatophytosis, , sporotrichosis, paracoccidioidomycosis, and penicilliosis.[70] Companion animals, especially cats and dogs, may be the most vulnerable to zoonotic fungal infections and may be the primary source of infections in humans, which are difficult to treat.[71] Pet owners have very limited knowledge of zoonoses and are not aware of the public health implications.[72,73]

1.5. Wildlife Health, Establishments, Practice Assessment, and Constraints

Protected wildlife areas constitute 3% of Nigeria's land area. Although there is no current data on species distribution or population, protected wildlife areas are home to a wide variety of mammals and over 900 bird species.[74-76] Protected wildlife areas and zoos frequented by tourists present human-animal interfaces where infectious diseases may emerge and spread; however, there little research and evidence describing the infectious disease burden among wild animals and the risk of disease transmission.[77,78]

Wildlife comprises critical infectious disease reservoirs. Therefore, when wildlife breaches the boundaries of protected areas, there is a risk of disease transmission between wildlife, livestock and humans.[79,80] Due to the changing nature of environmental and ecological factors, pathogens that originate in wildlife may pose outbreak and/or epidemic risks to domestic animal and human populations; however, this risk has not been well quantified.[81] Human T-lymphotropic virus, Ebola virus disease (EVD), chicken pox, measles, smallpox, monkeypox, yellow fever, rubella, yaws, TB, and rabies are only few of the diseases that have been linked to wild animals.[82]

1.6. Environmental Health, Challenges, and Consequences

The emergence and transmission of infectious diseases are largely influenced by environmental factors, including climate and human activities such as hunting, wildlife trade, population expansions, deforestation, and farming.[83] Zoonotic disease emergence and spread are highly impacted by deforestation, as intensive farming and logging bring humans in direct contact with wildlife reservoirs and increase the risk of infectious disease spillover.[84,85] Access to clean water and appropriate waste management are other critical factors in mitigating infectious disease spread; however, only 31% of Nigerians have access to clean drinking water sources, about 57 million people lack access to clean water, and over 46 million Nigerians practice open defecation.[86,87]

Climate change not only causes water scarcity from prolonged droughts but also water pollution due to flooding.[88] According to UNICEF, 1.5 million children were at increased risk of contracting waterborne diarrheal diseases due to severe flooding in 2022. Compounding these challenges is the poor water quality in Nigeria due to poor waste disposal, open dumping, incineration, uncontrolled landfills, composting, and dumping into drain channels, streams, and rivers, which are common practices.[89]

Agro-chemical Use in Nigeria – Regulations, Practices, and Risk to Environmental Health

Nigeria is a major consumer of agrochemicals in sub-Saharan Africa, and enforcement of regulations regarding their appropriate use is weak.[90] Large quantities of pesticides are imported for use in agriculture and households. Many are highly hazardous pesticides, harmful to the environment, animal health, and human health, which are banned in other countries.[91,92]

Nigerian farmers employ agrochemicals for weed and pest control and to boost crop yields and food production. However, poor knowledge and awareness lead to widespread misuse. Unsafe application of pesticides, biopesticides and herbicides; the use of less expensive but toxic pesticides; inadequate legislation and lax enforcement of existing legislation; a lack of training on the proper handling of pesticides; and the absence of monitoring are just a few of the problems associated with the use of agrochemicals in Nigeria.[93-95]

The widespread use of agrochemicals has resulted in a significant build-up of residues in the environment, making its way into the food chain and drinking water.[96,97] The impact of agrochemical pollution on human and animal health is poorly defined, but studies have suggested negative impacts.[98] Drift, residual, and run-off effects from the excessive and irresponsible use of agrochemicals have negatively impacted beneficial organisms, marine and terrestrial biodiversity, soil biota, soil processes, and ecological balance. Agrochemical overuse has resulted in the destruction of biomass, environmental degradation, soil impoverishment, development of resistant pests, and pollution of water bodies.[99]

Waste Management and Associated Health Risks

Municipal waste

Municipal waste is a major source of environmental degradation in Nigeria. Poor collection and disposal techniques, poor maintenance culture for waste management facilities, poorly implemented government policies, inappropriate technology, limited waste management databases, inadequate funding, failure to comply with legal requirements, and a lack of understanding of the risks associated with unhygienic practices are some of the barriers to sufficient solid waste management in Nigeria.[100,101]

Household waste

Many states across Nigeria, with large population sizes and inadequate waste disposal facilities and practices, have reported waste management problems.[100,102] Open dumping, landfilling, and open burning are the most common solid waste management techniques in Nigeria, and incineration is rare.[103] The amount of waste produced is directly related to the size of the population, income level, and extent of urbanisation; rural settlements generate less municipal solid waste than metropolitan areas and manage it in backyards by means of open burning, composting, feeding animals, and occasionally dumping in landfills.[103-105]

Waste disposal areas pose significant health risks to the entire population. Nigeria has one of the world's highest malaria burdens, responsible for one-third of all malaria deaths in 2020.[106] Refuse dumps act as mosquito breeding grounds, increasing the risk of malaria infections.[107] Cholera, a recurrent and endemic illness that occurs predominantly during the rainy season and more frequently in places with inadequate sanitation, is another illness linked to inadequate waste disposal.[108,109]

Healthcare waste

Healthcare waste includes any waste produced within healthcare institutions, research institutes, and laboratory facilities connected to healthcare operations.[110] In Nigeria, where various health issues compete for scarce resources, it is no surprise that healthcare waste management has received less attention than it deserves.[111] The most prevalent factors responsible for poor healthcare waste management are inadequate understanding of the associated health risks, insufficient training in efficient waste disposal, lack of waste collection and disposal systems, poor funding and staffing, and insufficient priority assigned to the issue.[112-117] Although the treatment and disposal of medical waste minimise dangers, potential health hazards may exist due to the release of hazardous substances into the environment during the process of treatment or disposal itself.[112,113] Little provision is made for proper education, safety and treatment of health care workers, regarding handling and exposure to medical waste and subsequent negative consequences.[115]

Industrial waste

Most industrial establishments in Nigeria lay minimal focus on good waste management and choose the least costly practices of garbage disposal over the most appropriate techniques.[118-121] Industrial wastewater is complex in nature, comprising organic and inorganic pollutants harmful to both humans and animals.[122] Considerable disparities exist between different types of industries and locations across the country. For example, environmental contamination with industrial waste from crude oil extraction and processing in the Niger Delta result in food insecurity and high morbidity while industries in Kaduna largely complied with National Environmental Standards and Regulations Enforcement Agency (NESREA) waste disposal regulations.[119,123]

Abattoir waste

Unsanitary disposal of solid and liquid waste represents a significant challenge and health risk at abattoirs and slaughterhouses nationwide. The most common approach for getting rid of solid animal waste was to dispose of it on the grounds of slaughterhouses, while liquid waste, effluents and wastewater were disposed of into surrounding streams and drainage.[124-126]

Manure

Increasing livestock production in Nigeria has led to a rise in waste generation, affecting both terrestrial and aquatic species.[127,128] Inappropriate waste management practices have been reported across the country, including the disposal of untreated manure into nearby waterways and around farms.[129,130] Some poultry farmers sun-dry and then burn the manure, while others recycle it as biogas or fish feed.[131-133]

Increasing urbanisation has led to a rise in peri-urban farms – both previously existing farms now close to the borders of expanding cities and those newly established – to take advantage of the increased demand for livestock products. This applies particularly to intensive poultry farms. Thus, environmental and water pollution risks have grown significantly, comprising air and noise pollution, unpleasant odours, contamination with faeces, faecal coliforms, and heavy metals.[134-137] Due to the increased proximity of farms to residential areas, this has both immediate and long-term effects on the health and well-being of residents and farm workers alike.[126,127,132,137,138]

2. Antimicrobial Resistance and Use in Nigeria

2.1. Antimicrobial Use and Resistance in the Human Health Sector

Antibiotic Use in Humans

Antimicrobial overuse is common in Nigeria, with many studies citing irrational use stemming from both clinical and societal factors. Poverty and infectious disease burden, limited local manufacturing, poor regulation of the quality of antibiotics in circulation, and indiscriminate antibiotic consumption are all factors that drive AMR.[139] Antimicrobial consumption data from the Mapping Antimicrobial Resistance and Antimicrobial Use Partnership (MAAP) consortium revealed that six compounds – metronidazole, amoxicillin, amoxicillin/clavulanic acid, cefuroxime, and ciprofloxacin – comprised more than 55% of all antibiotics used in the country. Frequent use of a low variety of antibiotics may partially contribute to their loss of effectiveness. Antibiotic use in the WHO Access category (54%) was lower than the recommended threshold of 60%, with corresponding overuse of antibiotics from the Watch category (46%). According to the report, Nigeria's Drug Resistance Index (DRI) – a metric that indicates antibiotic effectiveness in a country – was calculated to be 65.90%. Of note, a DRI below 25% indicates that AMR is under control.[140] These findings are in agreement with various studies looking at the most frequently used antibiotics in Nigerian HCFs.[141,142]

Healthcare workers also contribute to antibiotic misuse, as many health care facilities do not have policies or guidelines for antimicrobial use, and not all those who have them refer to them when prescribing antimicrobials. Many healthcare workers regularly prescribe antibiotics for typical viral infections (sore throats, common cold, measles and influenza) and are aware that their actions might encourage the development of AMR.[143-145]

Antibiotic prescription rates remain high in Nigerian hospitals, with point prevalence rates of 60–98% in hospitals across the country.[141,146] Paediatric wards show similar results with PPS rates of 77–92%.[147] Prescriptions remain largely empirical, with few backed by microbiological evidence. The most prescribed compounds were third-generation cephalosporins. Poor awareness among healthcare workers, lack of guidelines and pressure from patients were some risk factors associated with high prescription rates. Research shows that self-medication is common among the general population in Nigeria, with many seeking antibiotics from local pharmacies without prescriptions and not using them properly once acquired.[148-150]

Overconsumption of antimicrobials increased during the early stages of the pandemic due to lack of diagnostics and fear of secondary infections. Amoxicillin, ciprofloxacin, metronidazole, erythromycin, chloroquine and hydrochloroquine were used without prescription for the treatment of perceived symptoms of COVID-19.[144,151]

Antimicrobial Resistance in the Human Health Sector

AMR contributes to infections which are increasingly difficult to treat and can be fatal. Global estimates show that in 2019, about 4.95 million deaths were associated with, and 1.27 million deaths were attributable to antibiotic-resistant infections, with the greatest burden identified in sub-Saharan African countries.[152] However, this may be underestimated considering the AMR surveillance gaps worldwide. According to regional estimates across all ages in western sub-Saharan Africa, AMR is responsible for 27.3 deaths per 100,000 people, a rate higher than the global estimate of 16.4 deaths per 100,000.[152] It is important to note that in addition to the impact on mortality, GDP loss attributable to AMR in developing countries like Nigeria has been forecasted to be at 5–7% by 2050.[153]

AMR data from Nigeria indicate elevated levels of resistance. A retrospective study of AMR data from 25 laboratories between 2016 and 2018 suggests moderate to high levels of third-generation cephalosporin-resistant *Enterobacterales* (67–73%), methicillin-resistant *Staphylococcus aureus* (MRSA) (58–82%), carbapenem-resistant *Pseudomonas aeruginosa* (30–53%), and fluoroquinolone-resistant *Salmonella* species (46–75%).[141]

The national AMR surveillance network has submitted data to GLASS from six of its sentinel sites between 2017 and 2022. Of 12,251 samples, 5,601 returned bacterial isolates, with high resistance levels to most antibiotics tested. The most prevalent resistance profiles were ESBL-producing Enterobacteriaceae in 19% of the isolates, MRSA in 19% and carbapenem-resistant Enterobacteriaceae in 4% of the isolates. Multidrug resistant (MDR), extensively drug resistant (XDR), and pan drug resistant (PDR) isolates were also found in *S. aureus*, *E. coli*, and *K. pneumoniae*.

Peer-reviewed research between 2017 and 2023 reveals similar trends (See Annex 2 for details). The most frequently studied pathogens were *E. coli* (21 studies, 30.4%), followed by *Klebsiella* spp. (13 studies, 18.8%) and *S. aureus* (11 studies, 15.9%). The studies assessed resistance to 52 antibiotics, including gentamicin (8.8%), ciprofloxacin (8.0%), and ceftazidime (7.3%). Moderate to high levels of resistance to all antibiotics were observed, including compounds in the Watch category such as cefotaxime (5%–100%), cefixime (18%–100%), and meropenem (2%–79%), and those in the Reserve category such as ceftazidime and avibactam (59%) and linezolid (5%–36%). Of concern are high levels of resistance to Access and Watch antibiotics and MDR at the community level. Studies have also reported clarithromycin-resistance in Nigeria (a WHO high priority pathogen) ranging from 14.4.% in 2017, to 25% in 2020.[157-159] ARGs commonly identified include blaTEM, blaCTX-M, blaSHV, acc-3-lb, qnrA[154-156] (Annex 2).

Of the 46 studies reviewed, 16 (34.8%) were funded by international organisations, while 30 (65%) received no funding, highlighting the lack of dedicated domestic funding for AMR research in Nigeria.

2.2. Antimicrobial Use and Resistance in the Animal Health Sector

Antimicrobial Use in Animals

Antimicrobial use and consumption in food and agriculture systems is one of the key drivers of AMR. Weak regulation of access to and administration of these products facilitates overuse, misuse and abuse of antimicrobials, leading to resistance in animals, animal handlers, food products, and the environment.[140] Critically important antimicrobials for human medicine, such as fluoroquinolones, and potentially harmful antimicrobials banned for use in humans and animals, including furazolidones and chloramphenicol are reportedly used in food animals.[140,157-159]

Farmers across poultry, aquaculture, beef, and dairy value chains use antimicrobials for treatment, prophylaxis, and growth promotion. Most research on this use comes from the south-west and north-central zones, suggestive of the massive investment in animal production in these regions. In all studies, farmers reported procurement and administration of antimicrobials without consulting a veterinarian, in addition to poor knowledge of withdrawal periods and low awareness of residue testing.[160,161] Over 40 antimicrobials belonging to nine different classes were commonly used by farmers and herders, including aminoglycosides, cyclic polypeptides, oxytetracycline, macrolides, furaltadone, quinolones, sulphonamides, amphenicols and beta-lactams. The use of "cocktails" containing up to 6 different classes of antimicrobials at very high concentrations, some of which were not registered for use by WOAH, was also reported.[140,162] Poor biosecurity, hygiene, and waste management practices, poor knowledge of antimicrobial stewardship practices among farmers and animal health care workers, and weak enforcement of antimicrobial regulation laws/policies were identified as factors contributing to the overuse, misuse and abuse of antimicrobials.

Eleven classes of antimicrobials were imported for animal use in Nigeria between 2014 and 2017, with the highest import of antimicrobials taking place in 2015. The most frequently imported classes of antimicrobial agents were tetracyclines (629,236 kg), polypeptides (148,974 kg), and macrolides (132,712 kg) (Table 4 and Figure 6).

Regarding antimicrobial access in animals, many farmers choose and administer antibiotics to their animals without veterinary advice or prescription, based on factors such as cost, convenience of administration, and prior use. There is little use of antimicrobial susceptibility testing in choice of antibiotics by both farmers and veterinarians, partly due to poor access to laboratory services.[163] Although large farms are more likely to use antibiotics, small farmers are more likely to use them indiscriminately.[164]

Table 4: Antimicrobial imports for use in animal health in Nigeria 2014–2017

Antimicrobial agents	Quantity imported (kg)			
Years	**2014**	**2015**	**2016**	**2017**
Nitrofurantoin			243	
Pleuromutilins			2	
Glycopeptides	24	40		
Aminoglycosides	46	131	37,341	9,052
Penicillins	193		6,569	3,624
Amphenicols	268	658		
Polypeptides	459	142,333	4,290	1,892
Sulfonamides	1,060	687	6,635	11,592
Macrolides	3,349	9,798	107,775	11,790
Fluoroquinolones	5,115	3,146	13,520	3,152
Tetracyclines	8,147	168,880	154,433	297,776

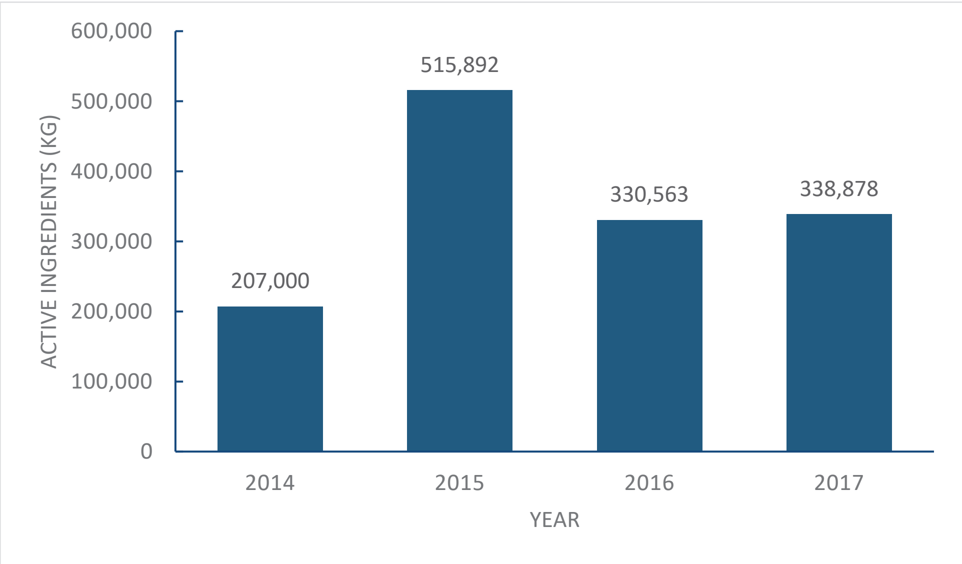

Figure 6: Quantities of antimicrobial agents imported for use in animal health 2014–2017

Antimicrobial Resistance in Animals

Antimicrobial overuse coupled with substandard quality antimicrobials are leading drivers for AMR emergence and spread in the agriculture sector.[166,167] Failure to observe withdrawal periods after treatment and before the sale of animal products also contributes to the high levels of antimicrobial residues in products for human consumption.[168] AMR in the Nigerian animal health sector is not restricted to livestock but extends to companion animals and wildlife. Companion animals are prone to spread infections, including MDR ones, due to their close interactions with humans.[169,170]

Most information on AMR in animals comes from research as there is little active surveillance on AMR in this sector. Genomic and phenotypic methods adopted in 59 studies evaluated bacterial resistance to more than 50 antimicrobials across Nigeria (Annex 4). The studies covered animal species, including livestock (cattle, sheep, goat, pigs, and poultry), food animal products and aquaculture. A wide range of resistant bacteria were reported, notably *Escherichia coli*, *Salmonella*, *Pseudomonas*, *Aeromonas*, *Staphylococcus species*, *Enterococcus*, Enterobacterales and *Campylobacter* in poultry and cattle, reflecting the priority list of pathogens for AMR surveillance in Nigeria. Two of the studies reported AMR in bats.[171,172] Only a few studies on aquaculture or abattoir effluent waste identified resistant *Vibrio* and *Listeria* species.[173] High levels of resistance were observed to aminoglycosides (gentamicin), macrolides (erythromycin), cephalosporins, quinolones and tetracyclines. A significant percentage (41%) of the studies involved international collaboration; 32% received overseas funding, while only 7% receiving domestic funding, from the Nigerian Government's Tertiary Education Fund (TETFUND). This illustrates the need to improve in-country diagnostic capacity and domestic research funding.

The fact that many of the studies focused on *Escherichia coli* may be because materials for isolation and identification are more accessible than for other priority bacterial species. There is need for closer coordination and cooperation between academia and the public veterinary services on surveillance of AMR in animals. Relatively few studies (19%) utilised mixed the sample approach, which gives insight into AMR in different animal species within the animal health sector. The distribution of studies shows a bias towards poultry (49%). Thus, more attention to other food animal species (pigs, ruminants, fish) is required. Over one-third (38.6%) of the studies investigated AMR genes (ARGs), with the most commonly identified ones being blaCTX-M, blaTEM, sul1 sul2,[174] along others listed in Annex 4.[161,171,175-181] Detection of ARGs provides information on the array of resistance genes that bacteria carry and their location on plasmids and other mobile genetic elements is indicative of their transferability to other susceptible bacteria of the same and different species. AMR in food animals is a major problem, efforts need to be made to ensure that the fifth pillar of the NAP, which is investment in research and development is given more attention. There is also a need for emphasis on awareness creation on AMR and AMU in this sector.

2.3. Antimicrobial Use and Resistance in the Environmental Health Sector

The environmental aspects of AMR are intricate and characterised by dynamic interactions involving climate change, pollution, food production, and clinical and agricultural use of antimicrobial agents.[182] The environment plays a critical role in the evolution and dissemination of antimicrobial resistance. Contamination of the environment by resistant bacteria from animal faeces, healthcare waste, or the use of abattoir or aquaculture effluent waste as sources of organic manure makes the environment the perfect hub for the circulation of resistant bacteria and ARGs in the environment. Data on AMR in the environment in Nigeria was available from 28 reviewed articles (Annex 5). The studies reported the occurrence of many bacteria, mostly members of the Enterobacteriaceae family, due to faecal contamination of soil, water, and effluents. Thus, the environment is a major contributor to AMR due to poor WASH infrastructure and habits. Other bacteria of clinical relevance isolated were *Aeromonas, Streptococcus, Staphylococcus, Bacillus subtilis* and *Vibrio*. One study also reported the occurrence of Aspergillus spp. at a meat market.[183] Ten papers investigated ARGs, with *mec*A, blaTEM, blaCTX-M, sul1, sul2 being the most commonly identified. These bacteria were tested against one hundred and six antibiotics representing 15 different classes of antimicrobials. High levels of resistance were observed, particularly to aminoglycosides, tetracyclines, and amphenicols.

Bacterial Resistance to Heavy Metals

Bacterial tolerance to heavy metals at concentrations above the maximum recommended limits has been reported in Nigeria. Notably, tolerance to copper, lead, cadmium, zinc, chromium, silver, and nickel was reported in *S. aureus, Streptococcus, Bacillus subtilis, Salmonella, Shigella, Vibrio, Citrobacter, E. coli, Pseudomonas*, and *Klebsiella*.[184-191] The studies covered samples collected from rivers, abattoir effluent, aquaculture sediment, soil, and fish across Nigeria. Resistance to heavy metals can co-occur with AMR through co-resistance (where genes responsible for different resistances are located close to each other, thus increasing the potential for co-transfer to other bacteria and cross-resistance) or cross-resistance (where a single mechanism confers resistance to more than one substance, such as antibiotics and heavy metals).[192]

Bacterial Resistance to Disinfectants

Resistance to commonly used disinfectants has also been recorded in bacteria of clinical relevance, such as *S. aureus, P. aeruginosa, B. subtilis, Enterococcus* spp., *Klebsiella, and E. coli*.[193-198] Resistance to disinfectants commonly used in hospital, farm, and food processing environments, such as saponated cresols, chloroxylenol, sodium hypochlorite, and chlorhexidines. One study reported the detection of disinfectant resistance genes *qac*E and *sit*ABCD in XDR *E. coli* strains isolated from chickens. These genes are known to confer resistance to quaternary ammonium compounds and hydrogen peroxides, respectively. It is therefore recommended to routinely monitor resistance to commonly used disinfectants.

Antimicrobial Use and Antimicrobial Resistance in Plant Health

The increased demand for food and other agricultural produce due to exponential population growth has placed a heavy burden on the use of agrochemicals. These pesticides, some of which contain antimicrobials, play a pivotal role in reducing losses due to bacteria, fungi, viruses, insects, and rodents.[199] Although the quantity of antimicrobials used in crops is considerably lower than that used in livestock,[200] the potential hazards of antimicrobial resistance should not be ignored. The residues of antimicrobial pesticides (fungicides and antibiotics) in crops can influence the evolution of resistant strains of bacteria and fungi in the environment and ultimately impede the exportation of crops with residues above the Maximum Residue Limits (MRL).[201]

Global pesticide consumption is estimated at 4 million tons, of which 50%, 30%, and 17% account for herbicides, insecticides, and fungicides. The African agrochemical market is valued at about 2.1 billion USD, with 0.4kg of pesticides used per hectare of cultivated land in Africa. This is projected to experience a significant increase, especially among the three largest agro-economic areas – Nigeria, Ghana, and Côte d'Ivoire.[201]

Nigeria is one of the largest importers of pesticides in Africa, with insecticides, fungicides, and rodenticides as the three most commonly used categories in crop value chains. Antimicrobials approved for use in the control of bacterial disease of plants include oxytetracycline, streptomycin, gentamicin, kasugamycin, and oxolinic acid. Oxytetracycline and streptomycin are the most widely used antibiotics.[202] These are already posing public health and environmental challenges due to their high usage. Up to half of the pesticides used in Nigeria are highly hazardous compounds banned in other parts of the world. Pesticide-associated poisonings from food consumption are a regular occurrence, but morbidity and mortality are not systematically reported. After a review and reclassification exercise in 2023, NAFDAC's Green Book product database lists 30 banned pesticides, only three of which are antimicrobial pesticides (fungicides) – Captafol (tetrahydrophthalimide, toluene, and chlorinated substances), Benapacryl (ester derivative of dinoseb) and Hexachlorobenzene (chlorinated hydrocarbon) (NAFDAC).

Unfortunately, weak regulation and porous borders mean that even banned pesticides still enter the country. Nigeria records losses of up to 362.5 million USD annually as it cannot export beans, fish, and honey, among other agricultural products, to the EU market[203] For example, beans were banned in 2015 because of dichlorvos pesticide residue of 0.3mg/kg – 4.6mg/kg, exceeding the maximum acceptable residue limit of 0.01mg/kg. Unfortunately, most studies on pesticide safety and residue limits focused on the herbicidal and insecticidal compounds, with no investigation of their antimicrobial activity. These agricultural pesticides persist in the environment and accumulate in tissues of plants and animals, contaminating foods and the environment.[204] Apart from antimicrobial use for plant health within Nigeria, there is a risk of antimicrobial residues in imported foods. Nigeria's major agricultural imports include wheat, sugar, fish, and milk.

3. Pillars of the National AMR Response

In 2017, the Nigerian Federal Ministries of Agriculture, Environment, and Health published the country's first National Action Plan on AMR (NAP 1.0), which described the national AMR situation; outlined strategic and operational plans to reduce, prevent, and slow the evolution of resistant organisms; identified specific objectives and strategic interventions; and described a monitoring and evaluation framework. The NAP 1.0, which covered the period between 2017 and 2022, was aligned with the five pillars of WHO's Global Action Plan on AMR and addressed AMR awareness, AMR surveillance, infection prevention control, access and appropriate use of antimicrobials, and research and development. It was created as a rapid response – despite limited resources – to prioritise urgent interventions needed to address AMR in the country. Implementation of this NAP has resulted in significant progress on AMR mitigation in Nigeria, including established structures for multisectoral collaboration, enhanced laboratory capacities for AMR surveillance, continuous development of human resources, and infection prevention and control programmes. This section will review progress made in the implementation of NAP 1.0 and recommendations for NAP 2.0 across AMR governance, as well as each of the five pillars.

3.1. Overview of NAP 1.0 implementation

The goal of NAP 1.0 was to reduce, prevent, and slow the evolution of resistant organisms and their impact on health care while ensuring optimal use and improved access to effective, safe, and quality-assured antimicrobials for continued successful management of infections. The plan incorporated the One Health approach and aimed to implement proposed actions by strengthening and utilising existing national systems or creating new structures where they did not exist.

Table 5: Number and status of activities by focus area

Focus area	Total no. activities	Completed	Ongoing	Not started
Increasing awareness and knowledge on AMR and related topics	6	17%	50%	33%
One health AMR surveillance and research	55	49%	31%	20%
Infection prevention and control	43	42%	14%	44%
Promote rational access to antibiotics and antimicrobial stewardship	31	35%	45%	20%
Invest in research to quantify the cost of resistance and develop new antimicrobials and diagnostics	15	7%	53%	40%
Total	**150**	**30%**	**39%**	**31%**

Several assessments have been carried out to track implementation and impact of NAP 1.0, including the quadripartite Tracking AMR Country Self-Assessment Survey (TrACSS), FAO progressive management pathway for AMR in Food and Agriculture sectors (FAO-PMP) and country-led evaluations.

The Tracking AMR Country Self-Assessment Survey (TrACSS) monitors the implementation of AMR national action plans on an annual basis, across the pillars of the Global Action Plan on AMR. Nigeria has a functioning multisectoral coordination mechanism for AMR, with participation from human, animal and environmental health sectors. NAP has a politically endorsed national action plan in place, being implemented and reviewed. However, there is no corresponding M&E framework, nor participation from food production, food safety or plant health sectors. Nationwide awareness campaigns and integrated surveillance of AMR are also lacking.

Between 2017 and 2022, the human health sector made progress on all TrACCS indicators, performing above the global average (C) on surveillance, at par for IPC but below the global average on training, monitoring of antimicrobial consumption and AWaRe classification for stewardship. In the animal health, food and agriculture sectors, Nigeria scores above the global average for training and biosecurity practices, at par for surveillance in terrestrial animals, below the global average for surveillance and laboratory integration in aquatic animals, food production and food safety, at par for terrestrial surveillance, and above average for training and biosecurity practices. In the environmental sector, significant progress has been made with Nigeria above the global average for residue risk assessment and legislation and at par for surveillance.

Nigeria's multisectoral One Health platform is led by the National One Health Steering Committee (NOHSC) comprising the Ministers of Health and Social Welfare, Agriculture and Food Security, Environment, Finance and Information. The steering committee provides overall policy and strategic direction to the One Health and AMR governance mechanisms. The Antimicrobial Resistance Coordinating Committee (AMRCC), with its secretariat at the Nigerian Centre for Disease Control and Prevention (NCDC), is responsible for overseeing and coordinating NAP implementation activities across the human, animal, and environmental health sectors in the country (Figure 7). The AMRCC is chaired by the NCDC with co-chairs from the animal and environmental health sectors. There is also a National Technical Working Group (TWG) on AMR which brings together stakeholders across the human, animal, and environmental health sectors from relevant government MDAs, civil society organisations, academic institutions and regulatory bodies. The human, animal, and environmental health sectors each have their own sub-TWGs. The One Health Technical Committee (NOHTC) and the National One Health Coordination Unit (NOHCU), also hosted at the NCDC, are not currently involved in AMR-related activities.

Despite challenges with funding reallocations and regularity in convening the group during the COVID-19 pandemic, the TWG is functional, meeting at least quarterly with additional ad hoc meetings scheduled as necessary to review ongoing AMR-related activities, to discuss and solve challenges, and plan future activities. Achievements include the technical review of the policy, legal and regulatory framework for

AMR; risk assessment for AMU and AMR, and review of the governance structure and manual. As NAP 1.0 did not include a full M&E framework, progress has been tracked through quarterly PowerPoint presentations and reports from TWG and AMRCC meetings. Annual planning of costed activities is done, but sources of funding are not clearly mapped out. Retrospective mapping of internal and external financial resources available to AMR is also done annually. Ongoing activities to address AMR in the country are summarised in newsletters published by the TWG. The human and animal health sub-TWGs are both functional and meet quarterly. The Federal Ministry of Environment (FMEnv) developed an AMR policy and five-year strategic plan in 2022 for the environmental sector. Efforts to establish state-level TWGs for AMR activities are at early stages, with TWGs in place in a few states.

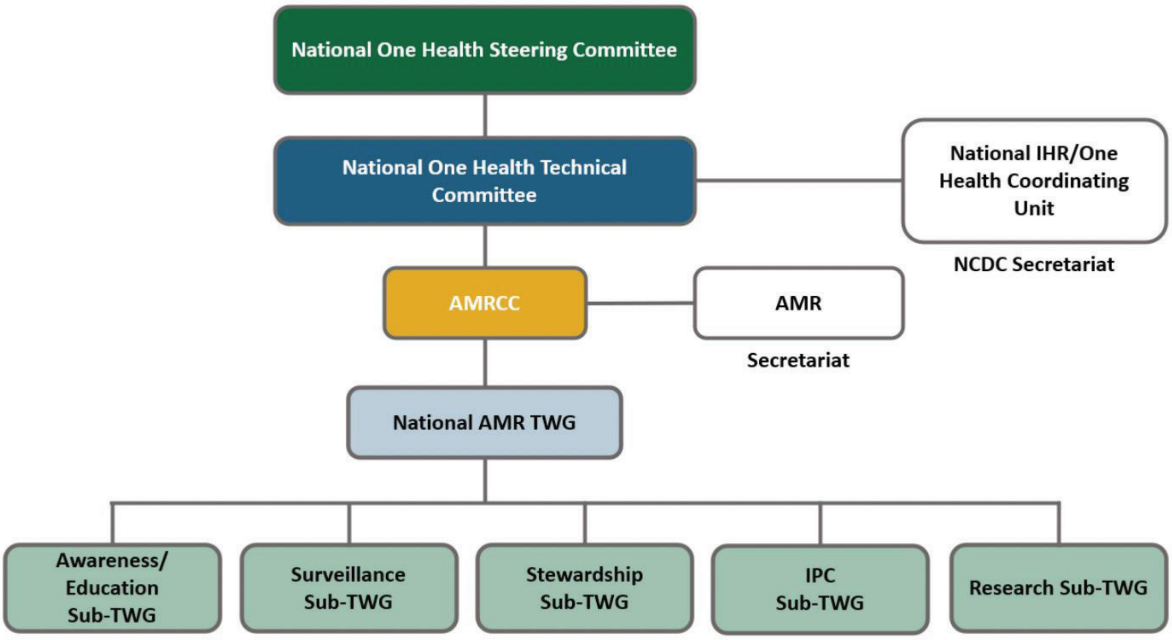

Figure 7: Organogram of the National AMR Prevention and Control Governance Structure

Source: NAP 1.0

The NAP on AMR calls for developing an additional coordinating body, a tripartite AMR National Behaviour Change Communication Consultative Group (NBCCCG), to oversee evidence-based communications programmes to improve awareness of AMR among the Nigerian population. This has not been done as its roles and responsibilities were determined to be duplicative of an existing body, the National Risk Communication TWG, hosted by the NCDC. The plant health, food production, and food safety sectors are not explicitly represented in the AMR governance and coordination structures, per the 2021 FAO progressive management pathway for AMR assessment (FAO-PMP) and the 2022 Tripartite AMR Country Self-assessment Survey (TrACSS)

Despite the One Health approach of the AMR governance and coordination structures, multisectoral collaboration remains challenging. The human health sector shows greater progress in NAP 1.0 implementation, followed by the animal health and the environmental health sectors respectively. This is partly driven by inequalities in domestic and donor funding, which focuses on investments in the human health sector in response to advocacy and resource mobilisation efforts. Other sectors will need to improve their engagement with policymakers, government representatives and key stakeholders to advocate for domestic budgetary allocation and donor funding for AMR. This is necessary to meet the clear need for additional funding and improvement of AMR infrastructure for animal and environmental sectors.

Improved engagement across all sectors in the early phases of the NAP 2.0 development could facilitate the inclusion of sector-specific targets and indicators necessary to drive AMR activities and monitor progress. Considering the cross-cutting nature of many AMR interventions, it would be beneficial to improve collaboration and joint resource mobilisation with other programmes such as WASH, IPC, UHC, annual vaccination programmes for animals and immunisation. At the core of policy development lies the utilisation of country-specific evidence. In this context, there is a need to utilise available AMR and related data at the national and sub-national levels to understand the AMR burden and inform appropriate interventions.

Key Recommendations for NAP 2.0 Development

- Define terms of reference and responsibilities for the functioning of the governing structures and technical working groups
- Ensure all relevant sectors and sub-sectors (including plant health, food production, and food safety) are represented in the appropriate governance structures
- Improve the governance structure for AMR in the environment sector
- Ensure that there are regular coordination meetings with rotating leadership from the human health, agricultural, and environmental sectors
- Consistently communicate relevant information (reports, agendas, meeting minutes) among all relevant group members and stakeholders
- Develop a framework for priority settings and decision-making, using existing evidence for decision-making
- Develop a monitoring and evaluation framework for NAP implementation
- Monitor progress through the development and dissemination of annual multisectoral reports
- Increase collaborations with state (Ministry of Finance, WASH, TB, Malaria and HIV control programmes) and non-state actors (academia, civil societies, and the private sector)

3.2. AMR Awareness and Knowledge

Table 6: 2023 Tripartite AMR Country Self-Assessment Survey (TrACCS) status for AMR awareness and knowledge

2023 Tripartite AMR Country Self-Assessment Survey (TrACCS) status	
TrACCS Indicator	**Status as of July 2023**
Raising awareness and understanding of AMR risks and response	Nationwide, government-supported antimicrobial resistance awareness-raising campaign targeting all or the majority of priority stakeholder groups, utilising targeted messaging accordingly within sectors
Youth education and AMR Do school-going children and youth (primary and secondary) receive education on antimicrobial resistance, as a long-term investment in mitigating AMR	Yes
Training and professional education on AMR in the human health sector	AMR is covered in 1) some pre-service training and in 2) some in-service training or other continuing professional development for human health workers
Training and professional education on AMR in the veterinary sector	Ad hoc AMR training courses available for veterinary related professionals
Training and professional education on AMR in the aquatic animal health sector	Ad hoc AMR training courses available for aquatic animal health professionals
Training and professional education on AMR provided to the agriculture (animal and plant), food production, food safety and the environment sectors	Tailored ad hoc AMR training courses available for at least two groups of key stakeholders

Despite existing communication strategies aligned with NAP 1.0 objectives and the One Health approach, implementation of other priorities and inadequate funding have hindered the scale and frequency of communication and awareness activities in Nigeria. The NBCCCG mentioned in the NAP on AMR has not been created, nor is there concrete engagement with the National Risk Communication TWG. Awareness activities are largely focused around WAAW. However, there are concerted efforts to expand AMR awareness activities in the three sectors by developing a community of practice for information sharing and dissemination.

Awareness Campaigns

Awareness campaigns have focused on the human and animal health sectors, with fewer activities focusing on food production and food safety stakeholders. Following stakeholder meetings during the National Antimicrobial Awareness Week (NAAW), social and behavioural change communication materials have been distributed in Abuja, Imo, and Akwa-Ibom during the 2019 NAAW. Prominent personalities instituted as AMR Champions include the Senate Committee Chairman on Health and Senate Chair on Agriculture and Productivity. To increase media awareness and appropriate reporting of AMR, stakeholders from media houses were trained by ReAct and FMAFS in 2019 and 2020. The importance of extending AMR awareness activities to the community-level is clearly emphasised. To achieve this, community leaders, vendors, and pharmacists have been engaged in collaboration.

WAAW activities in the animal health sector include seminars targeting cattle and poultry farmers, livestock marketers, and abattoir workers. These activities include discussions around AMR drivers, biosecurity, and alternatives to antimicrobials; engagement with media; and educational visits to secondary schools encouraging debates on AMR-related topics and support for AMR school clubs. Pre- and post-assessments in Ibadan (Oyo state) reveal positive impact and improvements in the knowledge and perception of AMR among participants following the awareness activities.

To address the lack of awareness of AMR and AMU – a critical barrier to political support and behavioural change among stakeholders in the aquaculture value chain – the FMAFS developed a national communication strategy for AMR/AMU for aquaculture along with information on appropriate communication tools, this document, emphasises awareness of AMR and offers suggestions for encouraging prudent AMU behaviour among aquaculture value chain actors.

In food and agriculture systems, there is a need for stakeholder mapping and KAP surveys to assess their level of AMR and AMU awareness and training needs. So far, there have been awareness assessments among poultry and pig farmers and veterinarians; however, this assessment needs to be extended to other stakeholders. Additionally, there are plans to develop an annual report on the evolution of AMU and AMR incidence in priority food and agriculture sectors based on monitoring and surveillance data to raise awareness among key stakeholders.

AMR in the Education Curriculum

According to TrACCS 2023, training and education on AMR are covered in core curricula in some pre-and in-service training and other continuing professional development for human health workers and are only available as ad hoc training courses in the veterinary and aquatic animal sectors. Inadequate funding and coordination gaps between governance and academic structures responsible for approving the curricula are critical barriers. According to the National Universities Commission of Nigeria, the updated Core Curriculum and Minimum Academic Standards (CCMAS) 2022 for Medicine and Dentistry, Veterinary Medicine, and Pharmaceutical Sciences include AMR in their curricula.

Adaptation and implementation of revised core curricula for undergraduate and graduate veterinarians and veterinary paraprofessionals and creation of an action plan to ensure coverage of AMR and prudent AMU in tertiary education and training programmes is ongoing in many institutions in Nigeria. Additionally, AMR and AMU are taught as part of existing courses such as Microbiology and One Health, but not as stand-alone courses in several institutions. Official discussions between the FMoH and the

Nigeria Institute of Food Science and Technology have taken place, but the revision of core curricula for food and agriculture professionals has not commenced yet.

Knowledge, Attitudes, and Practices Among Healthcare Workers – A Case Study

In 2021, the One Health Trust (OHT) and Africa CDC conducted a knowledge, attitudes, and practices (KAP) survey of 50 pharmaceutical healthcare providers. Results indicate poor knowledge of AMR, AMS, AWARE drug classification, and Nigeria's priority pathogens, despite 60% of respondents claiming to practice antimicrobial stewardship (Figures 8 and 9). These results indicate substantial knowledge gaps among the respondents regarding AMR and emphasise the need for targeted education and training on antimicrobial stewardship across all healthcare provider roles. Efforts to improve awareness of reserve drugs, critical priority pathogens, and the comprehensive implementation of antimicrobial stewardship practices should be prioritised. By addressing these knowledge gaps and advocating for best practices, healthcare providers can contribute to effectively controlling AMR and thus preserve antimicrobial effectiveness in Nigeria. Several peer-reviewed studies have also identified basic AMR and AMS knowledge gaps among pre-service and in-service HCWs.[205-207]

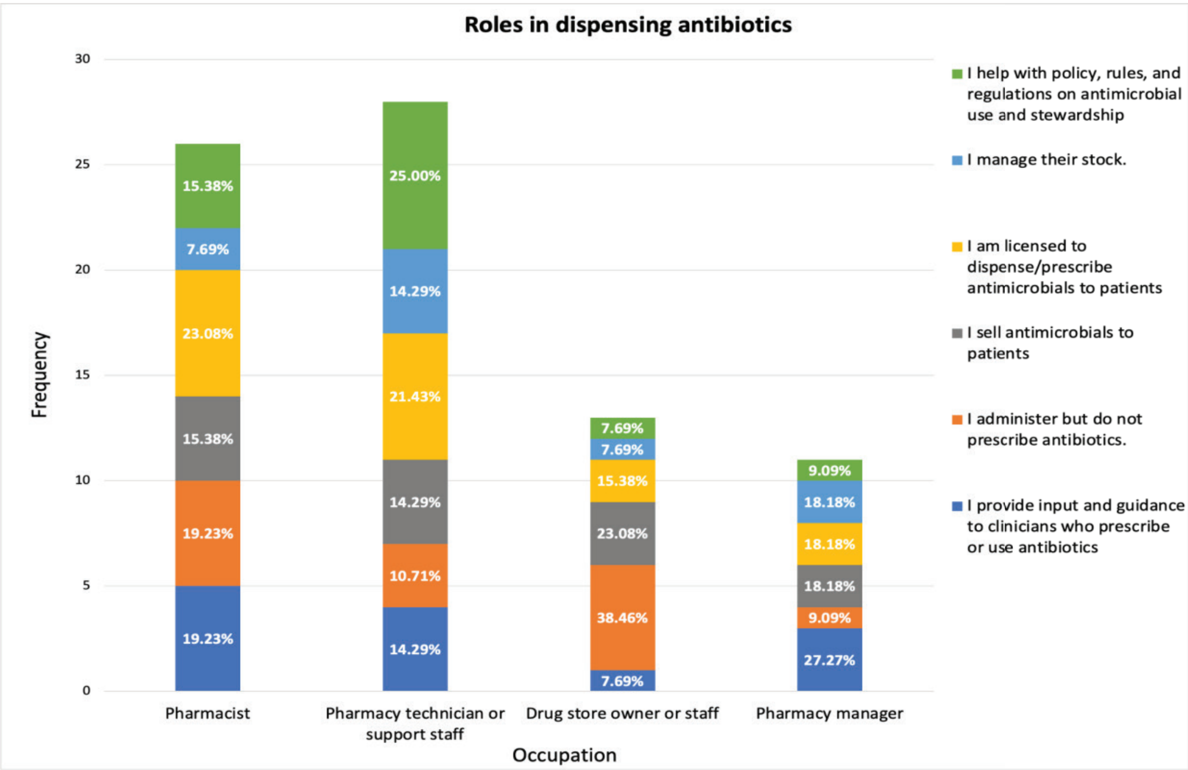

Figure 8: Distribution of respondents' roles in dispensing antibiotics (knowledge, attitudes, and practices among healthcare workers)

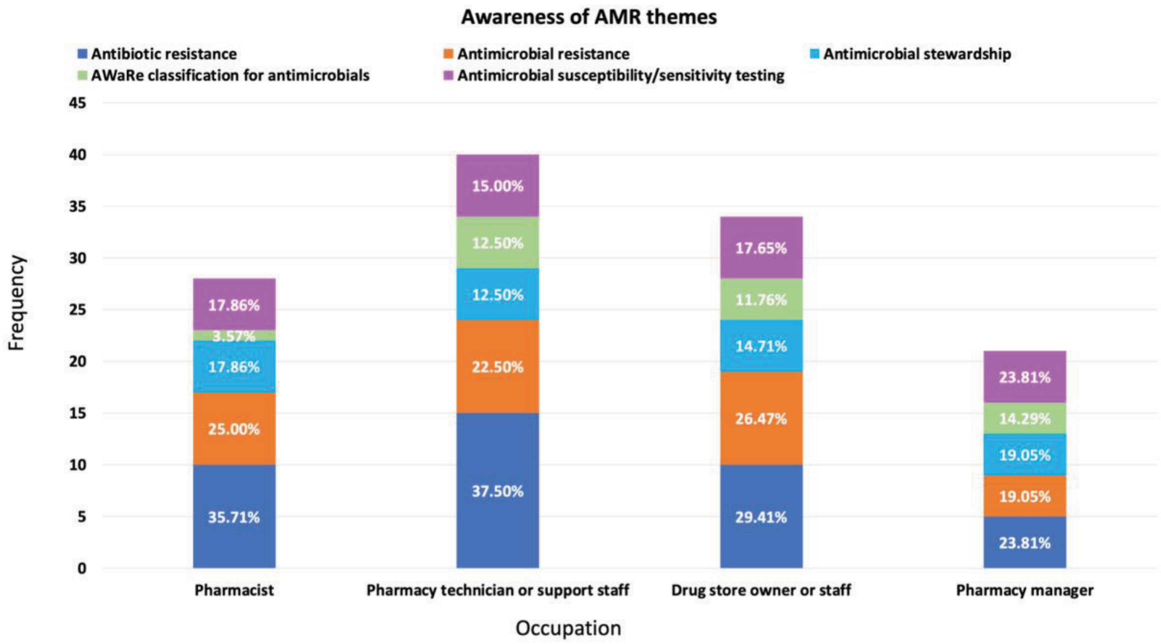

Figure 9: Distribution of respondents' awareness of AMR themes (knowledge, attitudes, and practices among healthcare workers)

In animal health, research shows significant gaps in knowledge and awareness of AMR, AMS, antibiotic use and withdrawal periods among animal farmers and healthcare providers.[143,163,165,167,208] Apart from these small-scale studies, no national KAP survey on diseases triggering high antimicrobial use have been done. Guidelines on the responsible use of antimicrobials in terrestrial and aquatic animals are available for healthcare workers, but they are not based on the evidence of KAP studies.

Impact of Civil Society Organisations

Non-governmental organisations play a vital role in conducting public engagement activities aimed at educating the public and fostering ownership of the AMR response. Below are a few examples that demonstrate the impact of civil service organisations.

Recognising the potential of the increasingly young population in the country, Ducit Blue Foundation has promoted AMR education and youth participation since 2020 through a pan-African One Health AMR Internship and Mentorship programme. In 2022, in partnership with the Alliance against Antimicrobial Resistance, Ducit Blue Foundation facilitated the translation of AMR-related materials into more than 53 African languages, including major Nigerian languages. These materials were transformed into information, education, and communication materials, disseminated across three geopolitical zones (Oyo, Borno, and Kwara states) in schools, marketplaces, farms, and public gatherings, and are still readily available for use. These campaigns have resulted in over 100,000 unique engagements.[209]

Using the youth engagement approach, DRASA Health Trust has implemented an AMR school programme since 2018, forming 320 DRASA Ambassadors and aiming to scale to 900 in 30 schools across Lagos and Osun States. These ambassadors, in spreading AMR awareness within their schools, have gone on to create comic illustrations of the resistance organisms termed 'supergerms'. Activities to further engage the ambassadors and educate peers about AMR have included a Spelling Bee and an interschool debate competition during the 2021 and 2022 WAAW, respectively.[210]

CFID is a community-based non-governmental organisation with significant contributions to the health system strengthening through AMS activities in Nigeria. In addition to AMS training in HCFs, CFID has conducted AMS activities among outpatients and community pharmacies and community sensitisation campaigns.

Key Recommendations for NAP 2.0 Development

- Increase AMR awareness activities and develop communication materials (policy briefs, slide decks) targeting policymakers and government officials to advocate for political commitment and support.
- Work with the National Risk Communication TWG to increase outreach to communities.
- Increase collaborations with existing health programmes (HIV, TB, malaria), civil society organisations, and community leaders to increase grassroots awareness of AMR and disseminate information to communities and the public.
- Conduct multisectoral stakeholder mapping to identify technical and non-technical target audiences in all sectors and sub-sectors.
- Improve AMR awareness among stakeholders in plant production and the environmental sector.
- Include AMR in the educational curricula of all relevant professions in the agriculture and environmental sectors.
- Measure impact of awareness activities using pre- and post-tests.

3.3. Surveillance, Laboratory and Diagnostic Capacity

Table 7: 2023 Tripartite AMR Country Self-Assessment Survey (TrACCS) status for surveillance, laboratory and diagnostic capacity

2023 Tripartite AMR Country Self-Assessment Survey (TrACCS) status	
TrACCS Indicator	**Status as of July 2023**
Is data for the indicators as defined in the monitoring and evaluation plan for the national AMR action plan collected regularly across all relevant sectors?	No
Do you have adequate technical capacity, resources and established systems in the country to collect data across all relevant sectors?	No
Is the data analysed and used by the AMR multisector coordination mechanism for decision making across all	No

relevant sectors and to advocate for policy changes and allocation of adequate resources?	
Is the country using relevant antimicrobial resistance surveillance data to inform operational decision making and amend policies?	Yes for human health
Has the country established or starting the implementation of an Integrated Surveillance System for Antimicrobial Resistance	No
National surveillance system for antimicrobial resistance (AMR) in humans	There is a standardised national AMR surveillance system collecting data on common bacterial infections in hospitalised and community patients, with established network of surveillance sites, designated national reference laboratory for AMR, and a national coordinating centre producing reports on AMR
Does the country have one or more reference lab/s performing AST/susceptibility testing for all the bacteria listed below Acinetobacter baumannii, Pseudomonas aeruginosa, Enterobacteriaceae E.coli, Klebsiella, Proteus Enterococcus faecium, Staphylococcus aureus, Campylobacter spp., Salmonellae, Neisseria gonorrhoeae, Streptococcus pneumoniae, Haemophilus influenzae, Shigella spp.	Yes, the country has one or more reference lab/s performing susceptibility testing for some of the bacteria listed
Does the country have one or more National Mycology Reference Laboratory designated by ministry of health to perform identification AND susceptibility testing of Candida and Aspergillus?	No
Is there a mechanism in place to report stock-outs of reagents/consumables for the diagnosis of bacterial infections and AST in clinical bacteriology laboratories in the public health sector?	No, each bacteriology laboratory manages stockout without compulsory reporting
Are standardised national or international AST guidelines used by the National Reference Bacteriology/AST Laboratory (NRBL) and by clinical bacteriology laboratories at all levels of the public health system?	The NBRL and some clinical bacteriology laboratories use standardised AST guidelines
Does the country have an external quality assurance EQA programme and to what extent it is implemented?	A national external quality assurance (EQA) system is compulsory and/or implemented in some bacteriology labs in the country, including the National Bacteriology Reference Laboratory (e.g. those enrolled in the national AMR surveillance system)
Does the country have developed a national list of essential in vitro diagnostics that includes all essential AMR diagnostics?	The country has developed the national list of essential in vitro diagnostics, but it does not include all essential AMR diagnostics

National surveillance system for antimicrobial resistance (AMR) in live terrestrial animals	Some AMR data is collected at local levels but a nationally standardised approach is not used. National coordination and/or quality management is lacking
National surveillance system for antimicrobial resistance (AMR) in live aquatic animals	National plan for AMR surveillance in place but laboratory and epidemiology capacities for generating, analysing and reporting data are lacking
National monitoring system for antimicrobial-pesticide use in plant production including bactericides and fungicides	National plan or system under development for monitoring amount of pesticides used including antimicrobial pesticides applied such as bactericides and fungicides
National surveillance system for antimicrobial resistance (AMR) in food (terrestrial and aquatic animal and plant origin)	Some AMR data is collected – but a standardised approach is not used. National coordination and/or quality management is lacking
Effective integration of laboratories in the AMR surveillance in the animal health and food safety sectors	Laboratories perform antimicrobial susceptibility testing (AST) for own purposes and are not included in the national AMR surveillance system
Level of the standardisation and harmonisation of procedures among laboratories included in the AMR surveillance system in the animal health and food safety sectors	Between 30% to 79% of laboratories follow the same AST guidelines
Relevance of diagnostic (bacteriology) techniques used by laboratories included in the AMR surveillance system in the animal health and food safety sectors	AST, bacterial isolation and identification protocols are perfectly suited to the national AMR surveillance objectives
Technical level of data management of the laboratory network in the AMR surveillance system in the animal health and food safety sectors	AST data are handled manually, or AST data management is not computerised in all laboratories of the network and/or there are problems in the recording of the samples and their traceability along the analysis chain
Is there a system for regular monitoring (passive surveillance) of antimicrobial compounds and their metabolites (or residues) and resistant bacteria or antimicrobial resistance genes (ARGs) in water quality	No

Human Health

Before NAP 1.0 development, Nigeria did not have a national AMR surveillance system for human health. There are currently 12 sentinel laboratories contributing to the national AMR surveillance system for human health:

1. University College Hospital, Ibadan – Reference laboratory
2. NCDC National Reference Laboratory, Gaduwa – Reference laboratory
3. Lagos University Teaching Hospital
4. Aminu Kano Teaching Hospital, Kano
5. National Hospital, Abuja

6 Obafemi Awolowo University Teaching Hospital, Ife
7 University of Ilorin Teaching Hospital
8 University of Calabar Teaching Hospital
9 University of Nigeria Teaching Hospital, Nsukka
10 Federal Medical Centre, Jalingo
11 Ladoke Akintola University Teaching Hospital, Osogbo
12 Babcock University, Ilishan Remo

However, not all of the aforementioned laboratories consistently report data to NCDC for further analysis and onward submission to GLASS. The national reference laboratory at University College Health Ibadan is the only one capable of conducting genomic analyses. The surveillance system covers GLASS priority pathogens (*Acinetobacter* spp., *E. coli*, *K. pneumoniae*, *N. gonorrhoeae*, *Salmonella* spp., *Shigella* spp., *S. aureus*, and *S. pneumoniae).* Surveillance data is analysed and stored using the national AMR Information system (AMRIS). The national AMR surveillance network has submitted data to GLASS from six of its sentinel sites between 2017 and 2022. Of 12,251 samples, 5,601 returned bacterial isolates, with high resistance levels of most isolates to most antibiotics tested. The most prevalent resistant profiles were ESBL-producing Enterobacteriaceae in 19% of the isolates, MRSA in 19%, and carbapenem-resistant Enterobacteriaceae in 4%. MDT, XDR, and PDR isolates were also found in *S. aureus, E. coli*, and *K. pneumoniae.*

Nigeria has benefited from the Fleming Fund's support in its AMR response, including in the set-up of the AMR governance and surveillance systems. Field epidemiologists trained under the Nigeria Field Epidemiology Training Programme (NFETP), were coopted to launch the AMR surveillance activities. Additional training was provided for sentinel and reference laboratory scientists, both in bacteriology methods and using the data collection system WHONET. The UK Health Security Agency's International Health Regulations Strengthening Project supported the training by providing courses on enteric bacteriology for sentinel laboratories, the NRL, and the NCDC laboratories. A sample referral network is in place to transfer isolates from sentinel sites to the reference laboratory.[211] However, better data storage and reporting systems are required to facilitate information flow and a transparent overview of contributions from each sentinel site.

Regarding quality control and accreditation, some laboratories conduct external quality assessments provided by the African Society for Laboratory Medicine (ASLM) and One World Accuracy. According to KIs, there are ongoing efforts to expand the national surveillance system and also include laboratories from the private sector. The NRLs have not been ISO 15189 or ISO 17025 accredited; however, the NLR University College Ibadan is working towards obtaining accreditation.

The NRL Ibadan has partial electronic record keeping and biorisk management and is working towards improving them. However, the laboratory has good specimen collection, transport, and processing, and access to equipment, reagents, reference materials, and consumables. The NRL Ibadan collaborates well with the referral laboratories and has good internal and external quality control procedures and data information management. Additionally, the genome-wide sequencing (GWS) capacity has enabled the NRL to conduct subtyping and validate findings from sentinel sites. The GWS capacity at NRL Ibadan, initially established through extramural funding, has had a tremendous impact in enabling AMR surveillance amid limited resources and undeveloped infrastructure. Additionally, NRL Ibadan has mentorship systems to enable sentinel laboratories to achieve Stepwise Laboratory Quality Improvement Process Towards Accreditation (SLIPTA) by the African Society for Laboratory Medicine (ASLM) through the External Quality Assessment for Africa (EQuAFRICA) consortium. A coordinating unit oversees the quality assurance of AMR tests. However, the absence of equipment for anaerobic culture processing at NRL Ibadan prevents the culture *Clostridioides difficile.* In addition, it has no capacity to perform therapeutic drug monitoring for patients receiving vancomycin and linezolid, nor does it have the capacity to assess biomarkers such as procalcitonin and C-reactive protein.

Other surveillance laboratories in Nigeria could be adapted to monitor the emergence and spread of drug-resistant microbes, as in the case of monitoring influenza and COVID-19,[158] and can add significant value to AMR preparedness and control. The Central Public Health Laboratory, one of the laboratories under the NCDC laboratory network for the surveillance of Measles and Rubella has recently been given full WHO accreditation.[212] Other sentinel laboratories in four hospitals have been leveraged for the influenza response.[213]

The MAAP consortium has shed some light on AMR surveillance capacities in Nigeria and AMR trends in recent years. The project identified 34,423 laboratories in the national laboratory network, 264 of which reported having the capacity for bacteriology testing. Among the 73 laboratories surveyed by the MAAP consortium, the laboratory readiness score describing core capacities for bacteriology and antimicrobial susceptibility testing varied widely, ranging from 13.2% to 84.2%. Many laboratories reported gaps in infrastructure, quality management systems, human resources, and data storage. Of the 73 surveyed laboratories, 72.6% reported access to regular power supplies, 82.2 % reported access to continuous water supplies, and only 35.6% reported access to certified functional biosafety cabinets. Furthermore, 68.5% had quality management systems, 35.6% were accredited, and 86.3% had at least one qualified microbiologist. While most laboratories had a database for storing patient data, 73.8% were paper-based, and only 15 laboratories reported having both paper and electronic systems for patient data storage.

In collaboration with the Robert Koch-Insitut (RKI), the NCDC implemented one of the sub-projects of the Capacity Development for Preparedness and Response for Infectious Diseases (NiCaDe) project, the NiCaDe-AMR project.[214] The project aimed to support the national implementation of AMR surveillance and improve diagnostic stewardship with a focus on secondary HCFs. In 2020, NCDC and RKI developed a study protocol to evaluate diagnostic stewardship interventions in selected hospitals. In the baseline study, a cross-sectional online survey was carried out in 25 public secondary HCFs in Abuja, FCT, and Lagos State to evaluate their capacities for pathogen identification using blood culture analysis and AST.[215] Electronic medical records of 2,924 patients with suspected sepsis were collected between October 2020 and May 2021 to assess practices on sepsis diagnosis. The survey showed that 32% of facilities performed blood cultures on only 2.7% of patients, mainly from the paediatrics department. Similar findings came from a study in north-central Nigeria where blood cultures informed antibiotic therapy in only 12.5% of the patients.[216] According to the previous AMR situational analysis, limited use of appropriate diagnostic mechanisms and poor quality assurance of laboratories were critical factors that contributed to ineffective pathogen identification and AST.[217]

Animal Health

To establish AMR surveillance in the animal health sector, seven laboratories across geopolitical zones have been selected as sentinel surveillance sites, including the NRL at the National Veterinary Research Institute (NVRI):

1. AMR National Reference Laboratory, National Veterinary Research Institute, Vom
2. Microbiology Laboratory, Animal Health Antimicrobial Resistance Surveillance Sentinel Site, Veterinary Teaching Hospital, University of Ilorin
3. Microbiology Laboratory, Animal Health Antimicrobial Resistance Surveillance Sentinel Site, Veterinary Teaching Hospital, University of Nigeria, Nnsukka
4. Microbiology Laboratory, Animal Health Antimicrobial Resistance Surveillance Sentinel Site, Veterinary Teaching Hospital, Ahmadu Bello University, Zaria
5. Microbiology Laboratory, Animal Health Antimicrobial Resistance Surveillance Sentinel Site, Veterinary Teaching Hospital, Usmanu Danfodio University, Sokoto
6. Microbiology Laboratory, Animal Health Antimicrobial Resistance Surveillance Sentinel Site, Veterinary Teaching Hospital, University of Ibadan
7. Federal Fisheries Laboratory, Animal Health Antimicrobial Resistance Surveillance Sentinel Site.

The laboratories were selected based on their capacity to conduct AST and were renovated and equipped for AMR surveillance through the support of a Fleming Fund Country Grant. Sentinel laboratories have the capacity to conduct basic AMR tests and are expected to send MDR samples for further testing by the NRL. Priority microorganisms for AMR surveillance in animal health include *E. coli*, Salmonella spp., *Enterococcus faecalis* and *Campylobacter* spp. for across food animals species, with additional priority pathogens of *Listeria monocytogenes* and *S. aureus* for ruminants; *Vibrio* and *Aeromonas* for aquaculture.

With regards to antimicrobial residue monitoring in food animal products, the Department of Veterinary and Pest Control Services has developed a draft residue monitoring plan. Furthermore, with the support of the REDISSE project it has identified laboratories and supported capacity building of field epidemiology staff using a One Health approach for residue monitoring to test antimicrobial and pesticide residue in milk, meat, honey, and eggs. In addition, there is an existing programme for residue monitoring in animal feeds, and several studies have investigated residues in aquaculture, poultry, and other animal feed. However, there is a need to compile the findings from these studies to identify common trends and inform priority actions.

With support from Fleming Fund country grants, FMAFS has developed tools and guidelines to support AMR surveillance in the animal health sector in Nigeria, including a manual for the management of an animal biorepository; a biosafety manual for AMR surveillance in surveillance sites; standard operating procedures for biological safety cabinets and guidelines for their maintenance; guidelines on biological spill management in surveillance laboratories; SOPs for handwashing and use of personal protective equipment; and standard guidelines for waste management in the laboratory.

Acknowledging the need for active surveillance in the animal health sector (only a small portion of sick animals may access the veterinary clinics), FMAFS created an expanded AMR surveillance strategy for food animals (cattle, goats, sheep, pigs, and aquaculture) outlining guidelines for active surveillance which can also be adapted for passive surveillance. FMAFS, with support from the Fleming Fund Country Grant, has also developed an active surveillance protocol for the monitoring of AMR in poultry.

To inform the development of AMR surveillance strategies in aquatic species in Nigeria, FMAFS , with support from the Fleming Fund Country Grant, developed a political economic analysis (PEA) framework which assessed the capacity and needs for the prevention and control of AMR in the aquaculture sector, with a focus on farmed aquatic species. The PEA revealed an indiscriminate overuse of antibiotics in aquaculture practices mainly driven by economic incentives and easy access to antimicrobials and associated with several sociodemographic factors. The analysis informed a recommendation report for establishing an aquatic species AMR surveillance system.

AMR surveillance in plant health, although included in NAP 1.0, was not implemented.

The Environment

There is currently no national surveillance system to monitor AMR in the environment, and the two NESREA environmental laboratories, in Kano and Rivers states, do not have the capacity for AST. A 2020 assessment of 177 stakeholders from the government, industries, waste management facilities, livestock farms, and crop cultivation revealed the need to develop surveillance capacity in the environmental sector and to improve the capacity of the two environmental laboratories. The survey revealed that existing structures for environmental surveillance monitor physical, chemical, and biological parameters but not the presence of antibiotic-resistant bacteria, ARGs, or antimicrobial residues. However, three industrial facilities and two wastewater treatment plants analysed effluent for AMR-related parameters.

Recognising the importance of environmental surveillance of AMR and related parameters, the FMEnv conducted a situational analysis which informed the development of a National Strategic Plan on Antimicrobial Resistance for the Environment sector spanning 2023 to 2028. The NAP on AMR for the environment contains four main objectives: 1) to create an AMR surveillance system, 2) to regulate the discharge and distribution of antimicrobials into the environment, 3) to improve public knowledge and awareness on AMR and antimicrobial discharge into the environment, and 4) to establish standard parameters for the monitoring and control of antimicrobials in the environment. These objectives are developed to address critical gaps such as a lack of AMR awareness among politicians and a resulting lack of political and financial support for AMR activities in the environment, lack of laboratory infrastructure and human resources for AMR testing in the environment, and lack of standard guidelines and SOPs to support AMR surveillance. Finally, there is an opportunity to support AMR surveillance in the environment sector through the newly established Integrated National Environmental Health Surveillance System hosted at the FMEnv.

The Tricycle Project – a pilot surveillance project monitoring rates of ESBL-EC in the three sectors – has provided a framework for integrated surveillance and One Health collaborations. According to a KI, this pilot project in Nigeria has led to the development of a national protocol that has highlighted and addressed some gaps in surveillance in three sectors.

Key Recommendations for NAP 2.0 Development

- Strengthen and expand AMR surveillance capacity to address geographical disparities within the six geopolitical zones in Nigeria.
- Increase participation of private laboratories in the national surveillance networks.
- Map laboratory capacity for AMR and AMR-related indicator surveillance (resistant pathogens, antimicrobial resistance genes, antimicrobial residues) and utilise findings from previous projects
- Develop guidelines and standard operating procedures for AMR data collection in all sectors (leverage methodologies and best practices from the Tricycle Project to inform standardised AMR surveillance guidelines).
- Develop systems for standardised data entry and reporting.
- Develop frameworks for data analysis and dissemination.
- Strengthen AMR laboratory capacity for the environment and establish a national AMR surveillance network.
- Include AMR-related indicators in existing environmental surveillance structures, including the Integrated National Environmental Health Surveillance System.
- Monitor antimicrobial resistance and antimicrobial residues in wastewater from hospitals, agricultural farms, and pharmaceutical industries.

3.4. IPC, WASH, and Immunisation

Table 8: 2023 Tripartite AMR Country Self-Assessment Survey (TrACCS) status for IPC, WASH and immunisation

2023 Tripartite AMR Country Self-Assessment Survey (TrACCS) status	
TrACCS Indicator	**Status as of July 2023**
Infection Prevention and Control (IPC) in human health care	A national IPC programme and operational plan are available and national guidelines for health care IPC are available and disseminated. Selected health facilities are implementing the guidelines, with monitoring and feedback in place
Biosecurity and good animal husbandry practices to reduce the use of antimicrobials and minimise development and transmission of AMR in terrestrial animal production	The national plan agreed to ensure good animal husbandry and biosecurity practices in line with international standards (e.g. WOAH Terrestrial Codes, Codex Alimentarius). Nationally agreed guidance for good practices developed, adapted for implementation at local farm and food production level
Biosecurity and good animal husbandry practices to reduce the use of antimicrobials and minimise development and transmission of AMR in aquatic animal production	The national plan agreed to ensure good animal husbandry and biosecurity practices in line with international standards (e.g. WOAH Aquatic Code, Codex Alimentarius). Nationally agreed guidance for good practices developed, adapted for implementation at local farm and food production level
Good manufacturing and hygiene practices to reduce the development and transmission of AMR in food processing	The national plan agreed to ensure good manufacturing (GMP) and hygiene practices (GHP) in line with international standards (e.g. Codex Alimentarius). Nationally agreed guidance for good practices developed, and adapted for implementation according to local food processing approaches

Infection Prevention Control

Infection prevention and control (IPC), water, sanitation, and hygiene (WASH), and immunisation are pivotal to AMR prevention and control. Since the development of NAP on AMR, efforts have been made to bolster the national IPC programme with an emphasis on the One Health approach. The multisectoral AMR TWG on IPC in Nigeria coordinates IPC activities in the country to prevent HAIs, train HCWs on IPC, implement IPC programmes in HCF at the state level, and link them to relevant AMS programmes. variety of policy documents have been developed, including a national IPC manual (2021), disease-specific IPC guidelines for outbreaks (viral haemorrhagic fevers, COVID, monkeypox, and diphtheria), national WASH guidelines, and an action framework for vaccines. These policies aim to reduce the risk of drug-resistant infections and improve health outcomes. NCDC and NPHCDA collaborated with partner organisations to conduct a budget landscape analysis and develop a Budgetary Advocacy Plan to guide resource mobilisation efforts for IPC from the Federal government. NCDC continues to work with relevant stakeholders at all levels to provide technical guidance, resources, and policy coordination to enable them to become IPC centres of excellence. Stakeholders involved in the programme implementation include the Department of Hospital Services of the FMoH, the National Primary Health Care Development Agency (NPHCDA), the National Agency for the Control of AIDS (NACA), focal persons in the 36 states and the FCT, and external partners such as the United States Center for Disease Control and Prevention (US CDC), WHO, and Africa CDC.

There have been several initiatives to strengthen IPC capacity in Nigeria (Table 9) , including the Nigeria Centre for Disease Control: Capacity Development for Preparedness and Response for Infectious Diseases – IPC (NiCaDe-IPC) the MAURICE project Koch Institute and DRASA's IPC training programme and the Presidential Task Force on COVID-19.[214,218,219] A recent report from the Presidential Task Force on COVID-19). Table 9 outlines the significant strides Nigeria has made to build IPC capacity.

Despite these successes, IPC assessments in the country have indicated major gaps in implementation. the IPC TWG experiences some challenges to its optimal functioning, such as a lack of sufficient funding to hold regular quarterly meetings, high staff turnover, poor communication among sectors, and competing demands among members, especially during concurrent disease outbreak responses. Furthermore, there are gaps in human resources to drive the implementation of the IPC activities at the health facility level due to IPC focal persons holding other primary roles and positions. Geographical disparities in IPC capacity persist across the country (Figure 10).

The domestic budget for IPC activities in the human health sector is inadequate due to poor political recognition and dedicated funding and is therefore heavily reliant on donors. To expand and ensure the sustainability of the IPC activities, there is a need for dedicated government funding. To improve IPC standards in the practice context of hospitals, the actors need to develop social competencies and attitudes such as teamwork and interprofessional collaboration and a systemic understanding of IPC in the health facility and build skills to design locally significant processes to improve the IPC infrastructure at the health facility level. These enabling skills, as well as the focus on organisational improvement, are in line with WHO recommendations but have rarely been the subject of nationwide IPC training.

Table 9: IPC strengthening projects in Nigeria

Project	Partners	Objectives	Achievements
Nigeria Centre for Disease Control: Capacity Development for Preparedness and Response for Infectious Diseases (NiCaDe-IPC)	Robert Koch Institute (RKI) German Ministry of Health	To build up training capacities for infection prevention and control in hospitals at national and state level.	92 Change Agents trained in 23 healthcare facilities from four geopolitical zones of the country (South East, South-south, South West and North Central)
Manual on Universal and Outbreak infection Prevention and Control (MAURICE)	Robert Koch Institute (RKI) GIZ (Gesellschaft fur Internationale Zusammenarbeit)	To improve patient and health care workers' safety during outbreaks of epidemic-prone diseases.	IPC curriculum for HCWs developed
Dr. Ameyo Stella Adadevoh Health Trust (DRASA's) IPC Training Program	WHO	To develop a network of health champions preventing disease and saving lives through education and training, community engagement, emergency planning and policy change	1,400 AMR ambassadors trained in 32 schools across Lagos and Osun States demonstrated 161% increase in knowledge of AMR
The Turn Nigeria Orange Project	Infection Control Africa Network (ICAN), Nigeria Society for Infection Control, DRASA, Africa CDC, WHO	To strengthen the culture of hand hygiene and Infection Prevention and Control (IPC) in healthcare institutions across the country.	245 healthcare professionals have been trained in IPC from 41 tertiary HCFs in all the 36 states and FCTand 81 secondary health facilities in 11 states (Ogun, Osun, Ekiti, Oyo, Ondo, Plateau, Benue, Kebbi, Enugu, Nasarawa and the FCT)
Presidential Task Force on COVID-19			35,000 HCW trained in IPC

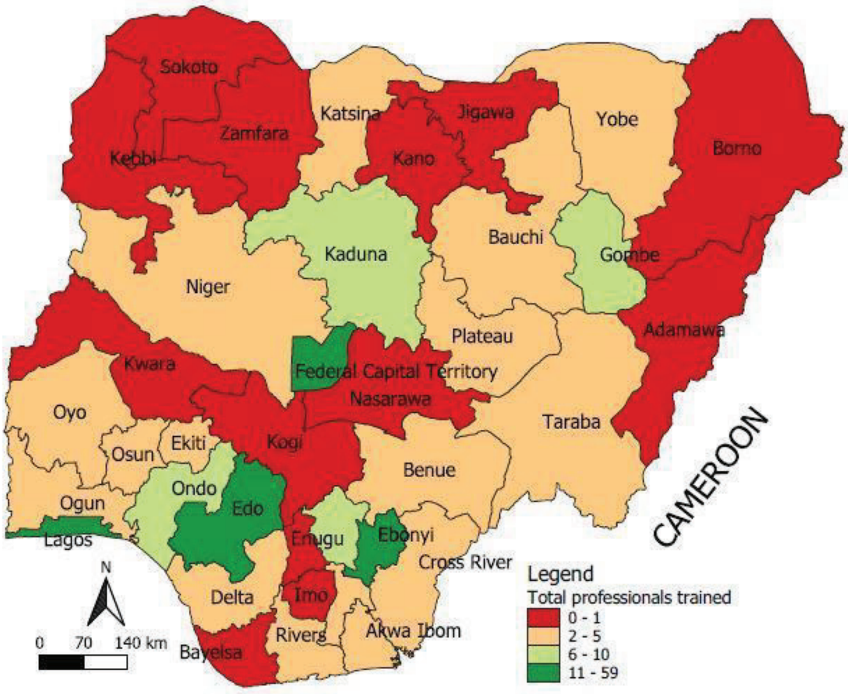

Figure 10: Distribution of IPC-trained professionals per state in Nigeria between 2021 and 2022

Source: NCDC

Table 10: Facilities undergoing infection prevention control evaluations in Nigeria between 2021 and 2022

Facility type	Number of facilities per IPC level (%)				Total
	Inadequate	Basic	Intermediate	Advanced	
Primary	1 (14.3)	1 (14.3)	4 (57.1)	1 (14.3)	7
Secondary	32 (27.4)	48 (41)	31 (26.5)	6 (5.1)	117
Tertiary	2 (3.2)	26 (41.3)	27 (42.9)	8 (12.7)	63
Totals	35 (18.7)	75 (40.1)	62 (32.1)	15 (8.0)	187

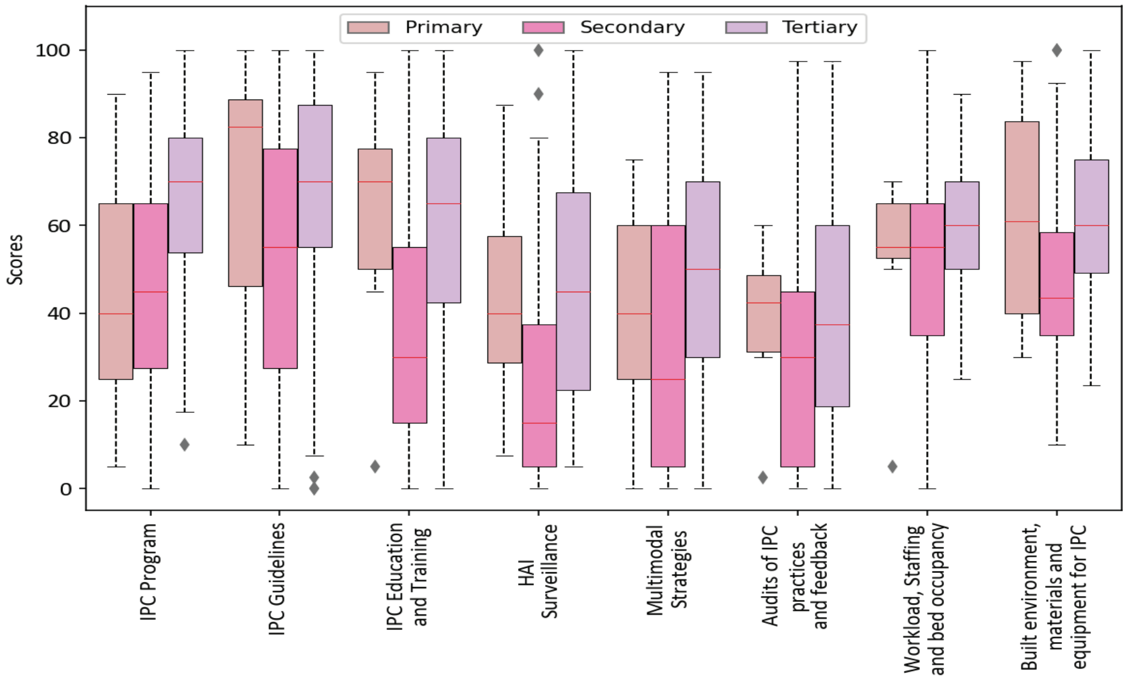

Figure 11: Variations in the IPC indicator percentage scores within primary, secondary, and tertiary facilities between 2021 and 2022

Source: NCDC

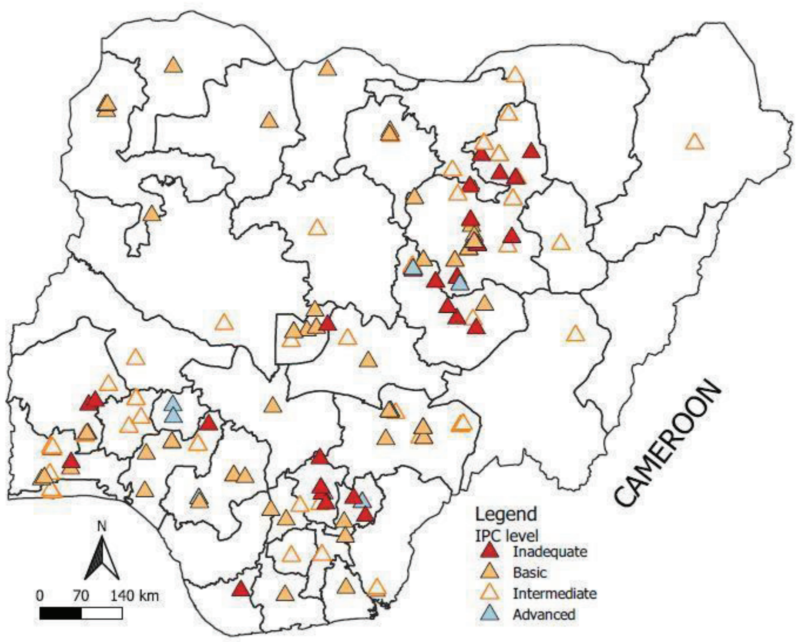

Figure 12: Geographical distribution of the assessed facilities and their IPC levels across Nigerian states between 2021 and 2022

Source: NCDC

Water Sanitation and Hygiene

The water sanitation and hygiene (WASH) sector is intrinsically connected to the incidence and spread of infectious diseases, and as such, it plays a critical role in AMR mitigation. Recent estimates report only Modest progress in improving WASH infrastructure in Nigeria, with 67% of Nigerians using basic drinking water services, 46% using basic sanitation services, 17% households using basic hygiene services and only 10% having access to all three combined.[220] An additional 2 million people gained access to wash services between 2019 and 2021, while the population grew by 5 million in the same period. Thus, the significant gain in number of people with access to WASH registers as just 1% increase. Over half of HCFs have access to basic water supply services, but only 30% have access to basic hand hygiene services and 12% have access to basic sanitation services. Just 6% have access to all three. More than half HCFs were rated low for WASH standards,[221] with primary and secondary HCFs at a significant disadvantage compared to tertiary HCFs as shown in Table 9 and Figurers 11 and 12. Geographical and socioeconomic disparities exist, with those in hand hygiene matching the disparities noted in IPC above (Figures 13 and 14).

Table 11: Distribution of facilities across healthcare levels and hand hygiene standards, 2020–2021

Facility	Number of facilities (%)				Total
	Inadequate	Basic	Intermediate	Advanced	
Secondary	28 (35.4)	28 (35.4)	13 (16.5)	10 (12.7)	79
Tertiary	12 (24.5)	21 (42.9)	13 (26.5)	3 (6.1)	49
Total	40 (31.3)	49 (38.3)	26 (20.3)	13 (10.2)	128

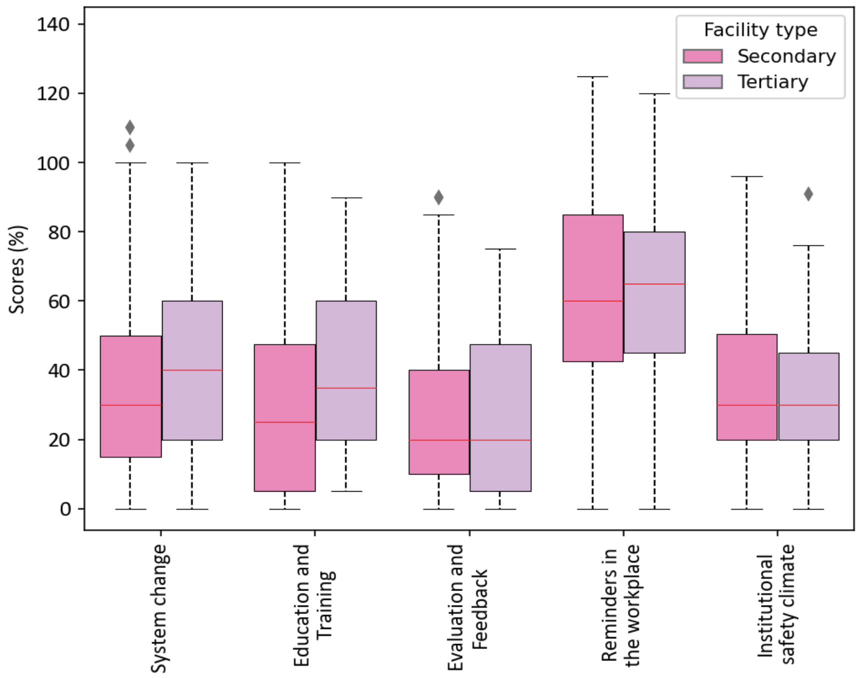

Figure 13: Variations in the percentage scores distributed across the five metrics of hand hygiene assessment between 2021 and 2022

Source: NCDC

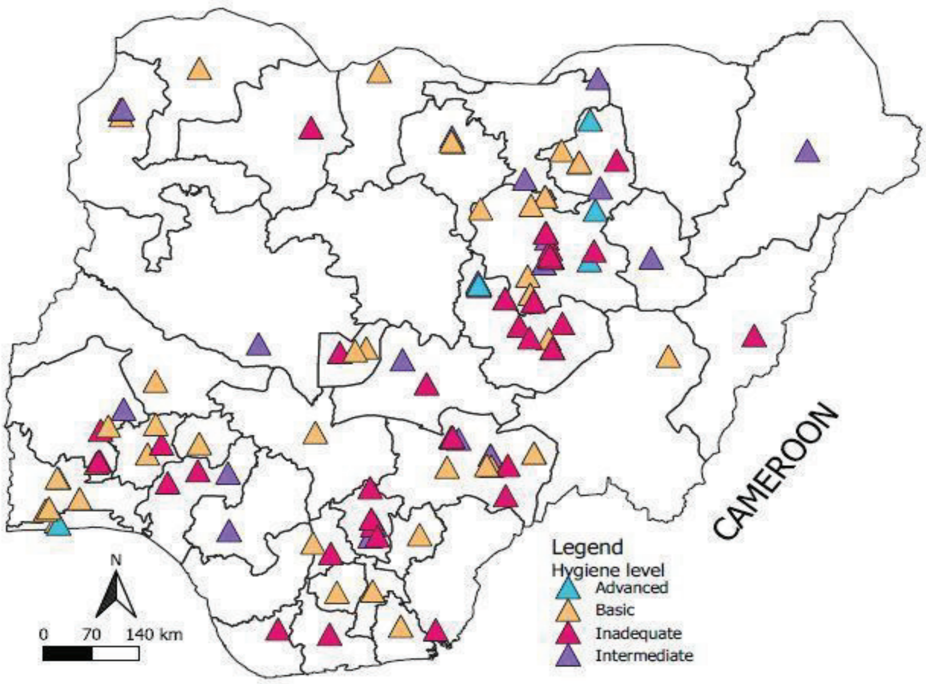

Figure 14: Hand hygiene assessments in primary and secondary healthcare facilities in Nigeria, between 2021 and 2022

Source: NCDC

Proper waste management is an important part of infection prevention and control. While all three tiers of government play a role in waste management, low capacity at the local government level is a major contributor to disparities in waste management systems across Nigeria. Of special concern is the waste management situation in abattoirs and hospitals, where poor standards, practices and enforcement create a significant risk for the emergence and spread of infectious diseases and AMR. Collaborative research from all One Health sectors to assess the situation and provide sector-specific and cross-cutting recommendations. Overall, the creation of a legal framework for IPC, WASH and biosecurity, could address some of the human resource gaps and improve issues with operationalisation, monitoring, and enforcement of regulations across all sectors.

Immunisation

Vaccines can prevent infections (both susceptible and drug resistant), lower the incidence of secondary infections and the need for antimicrobial use, thereby addressing several AMR drivers simultaneously. Despite this potential to significantly slow the emergence and transmission of AMR their role in AMR mitigation is not properly addressed in many NAPs.[222] To address this, WHO has developed an action framework to articulate the role of vaccines against AMR, a technical annex to the Immunisation Agenda 2030. It recommends increased uptake of vaccines targeting drug-resistant pathogens such as the *Haemophilus influenzae* type B (Hib) vaccine, the influenza vaccine, the measles-containing vaccine, the pneumococcal conjugate vaccine (PCV), the rotavirus vaccine, and typhoid conjugate vaccine.

In Nigeria, vaccines are expected to have high impact on AMR. Disease-specific models predict prevention of up to 62% of MDR typhoid cases, 11% antibiotic-treated cases of rotavirus.[223,224] Vaccines in development for MDR-TB and malaria are also expected to have significant impact on the high disease burden in Nigeria.[225,226] However, vaccine coverage with potential impact on AMR have plateaued since 2016 and are below the international targets of the 90% (Figure 15). Considering this evidence, advocacy to increase existing vaccine coverage levels and introduce new vaccines to the immunisation programme is essential to reduce infectious disease and AMR burdens in the country (Figure 16).

Barriers to increasing vaccine coverage are complex. Although there have been issues with vaccine hesitancy, the Nigerian population is generally receptive to vaccines, and hesitancy issues have been addressed through communication strategies and engagement with traditional leaders. Current challenges include insufficient financial and human resources for service delivery, especially in hard-to-reach areas; lack of human resources to deliver the vaccines (70% are volunteers); and coordination and accountability challenges between state and local governments. These hinder vaccine delivery and uptake even when vaccines are available, as well as causing disruptions in the supply chain.

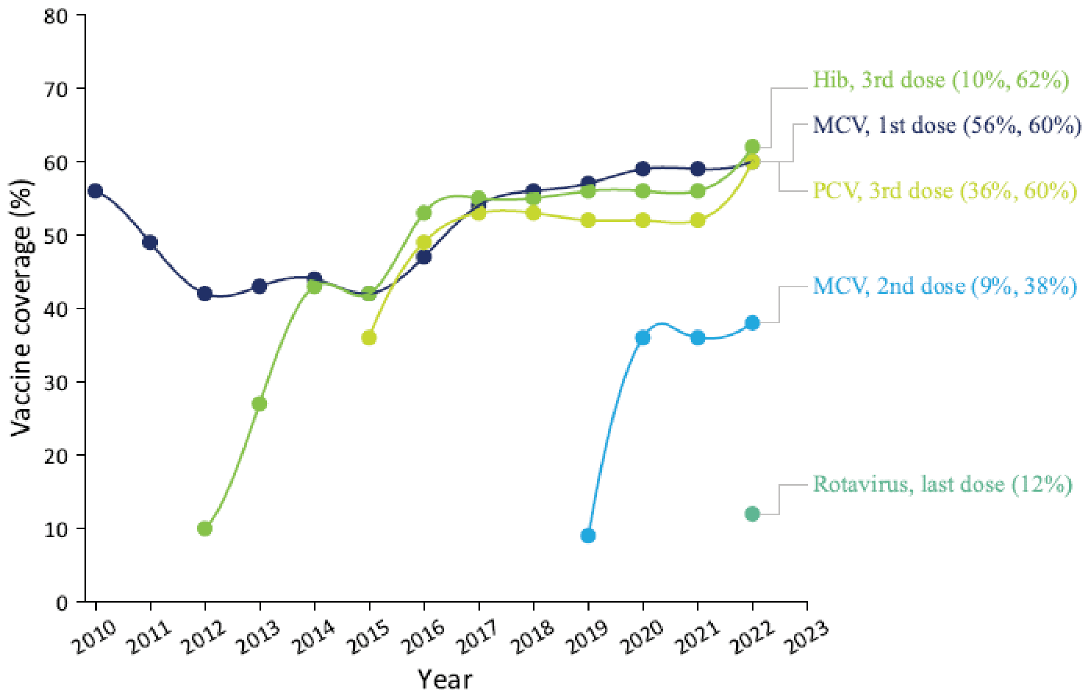

Figure 15: Immunisation coverage of vaccines which can target AMR

Source: WUENIC database

Vaccine	Target	Estimated impact of vaccine		
Ensure and maintain universal uptake				
PCV (per-year)	**Pneumococcal ARI in children** (24-59 months old)	**13%** cases		Of **antibiotic-treated respiratory tract infections** prevented
RotaC (per-year)	**Rotavirus diarrheal cases in children** (under two years old)	**11%** cases		Of **antibiotic-treated diarrhea** prevented
Include vaccines relevant to public health and AMR into the routine immunization program				
TCV (Over 10 years)	**Typhoid fever cases in infants** (from 9 months old)	**62%** cases	**62%** deaths	Of **multidrug resistant typhoid fever** prevented
Malaria (Over 5 years)	**Malaria** (in children and adults)	**228,000** cases	**107,000** deaths	Of **drug-resistant malaria** prevented

PCV= Pneumococcal conjugate vaccine, TCV = Typhoid conjugate vaccine, RotaC = Rotavirus vaccine, ARI= Acute respiratory tract infection

Figure 16: Recommendations to avert infectious diseases and reduce AMR in Nigeria

Data source[223-226]

Animal health

Biosecurity is a very important component of AMR control in the animal health sector. Although national guidelines on IPC and biosecurity for the entirety of the animal health sector are yet to be developed, FMAFS has developed guides on biosecurity and the use of disinfectants for farmers. These have been deployed in one-off training farmers on effective biosecurity measures in all 774 local government areas. Small-scale training and coaching programmes are widely available across the country, but there are no national programmes. The absence of monitoring and evaluation framework for these activities makes it difficult to assess their impact. Unfortunately, NAP 1.0 did not include or prioritise these key activities to reduce the need for antimicrobials in the animal health sector.

Key Recommendations for NAP 2.0 Development

- Create a legal framework for IPC and biosecurity to increase human resource capacities.
- Advocate for political and financial support to improve IPC and WASH infrastructure in Nigeria by highlighting the extensive health and economic burden from infectious diseases driven largely by the current poor infrastructure.
- Expand IPC capacity assessments to address disparities in assessments of gaps and needs across the 36 states in Nigeria.
- Address geographical disparities in capacity-building IPC interventions (education and training).
- Establish closer collaborations with Immunisation and WASH groups to increase AMR visibility in these programmes.
- Increase collaborations with WASH programmes to advocate for dedicated funding to reduce the incidence of hospital-acquired infections and AMR prevalence in healthcare facilities.
- Include measurable IPC, Immunisation, and WASH objectives as interventions that address AMR.

3.5. Access and Optimal Use of Antimicrobials

Table 12: 2023 Tripartite AMR Country Self-Assessment Survey (TrACCS) status for access and optimal use of antimicrobials

2023 Tripartite AMR Country Self-Assessment Survey (TrACCS) status	
TrACCS Indicator	**Status as of July 2023**
Country has laws or regulations on prescription and sale of antimicrobials, for human use	Yes
Country has laws or regulations on prescription and sale of antimicrobials for terrestrial animal use	Yes
Country has laws or regulations on prescription and sale of antimicrobials for aquatic animals	Yes
Country has laws or regulations on prescription and sale of medicated feed	Yes, for both terrestrial and aquatic animals
Country has laws or regulations that prohibits the use of antibiotics for growth promotion in terrestrial animals in the absence of risk analysis	No
Country has legislation on the registration and use of applicable pesticides with antimicrobial effects, such as bactericides and fungicides used in plant production	Yes
Is the country using relevant antimicrobial consumption/use data to inform operational decision making and amend policies?	Yes, for human health and terrestrial animal health
National monitoring system for consumption and rational use of antimicrobials in human health	Total sales of antimicrobials are monitored at national level and/or some monitoring of antibiotic use at sub-national level
Optimising antimicrobial use in human health	National guidelines for appropriate use of antimicrobials are available and antimicrobial stewardship programmes are being implemented in some healthcare facilities
Adoption of AWaRe classification of antibiotics in the National Essential Medicines List	Country has adopted the AWaRe classification of antibiotics in their National Essential Medicines List
Do you have a national plan or system in place for monitoring sales/use of antimicrobials in animals?	Yes, terrestrial animals only
Do you submit AMU data to the WOAH Database on Antimicrobial agents intended for use in animals?	Yes
Optimising antimicrobial use in terrestrial animal health	National legislation covers all aspects of national manufacture, import, marketing authorisation, control of

	safety, quality and efficacy and distribution of antimicrobial products
Optimising antimicrobial use in aquatic animal health	National legislation covers all aspects of national manufacture, import, marketing authorisation, control of safety, quality and efficacy and distribution of antimicrobial products

Antimicrobial Consumption

Most data on antimicrobial consumption in humans are derived from peer-reviewed studies, indicating persisting poor knowledge, attitudes and practices regarding antimicrobial use and unregulated access to antimicrobials from pharmacies and patent and proprietary medicine vendors,[227-229] Antimicrobial consumption data is available at the national level, and an antimicrobial consumption surveillance pilot began in 2023.

Information on antimicrobial consumption in animals is based on annual import data reported to the OIE. However, there is little information on the flow of antimicrobial use between import and distribution, highlighting the need for surveillance of antimicrobial sales and dispensing networks. Import of nitrofurans and amphenicols was banned in 2016, but these compounds still find their way into the country and are being used in food animals.

To ensure prudent use of antimicrobial agents, FMAFS, with support from FAO-ECTAD, developed a treatment guideline for using antimicrobial drugs in animals in line with WOAH's Classification of antimicrobial agents. Additionally, the Veterinary Council of Nigeria developed and reviewed the veterinary formulary, which comprises all drugs used in animals, including antimicrobials.

Antimicrobial Stewardship

Antimicrobial stewardship guidelines are under development in the human health sector, and NCDC has supported the establishment of AMS programmes in 35 public hospitals. In addition, point prevalence surveys before and after AMS interventions have been conducted in several hospitals. In the past, most healthcare facilities had active drug and therapeutics committees, but gradually these committees became inactive, resulting in poor stewardship structures across the country. There have been continuous efforts to improve judicial antimicrobial use by promoting the essential medicines list and standard treatment guidelines. However, these are hampered by insufficient government funding for AMS and reliance on donor funding, including those mentioned below. The Commonwealth Partnerships for Antimicrobial Stewardship (CwPAMS) programme aims to leverage the expertise of UK health institutions and technical experts to strengthen the capacity of the health workforce in three tertiary facilities: Lagos University Teaching Hospital, University College Hospital, Ibadan and Babcock University Teaching Hospital. United States Agency for International Development-Medicines, Technologies, and Pharmaceutical Services (USAID-MTaPS) supports AMS programmes in hospitals in Enugu and Kebbi states. The Centre for Initiative and Development (CFID) conducted AMS education and training in 48 communities and 63 schools in Taraba state, reaching 252 in-school AMR peer educators and 4,080 AMS champions. The CFID programme also established AMR radio and television AMR awareness campaigns, capacity building among pharmacists and patent and proprietary medicine vendors in five states and seven hospitals, training over 1,000 HCWs (Figure 17). A mobile application containing EML, STG, and IPC guidelines was developed with the support of the Commonwealth Pharmacists Association team. However, although these guidelines are now more widely available, there are no incentives or penalties to drive compliance among healthcare workers. The Federal Ministry of Health is working to integrate antimicrobial AwaRe categorisation into the essential medicines list.

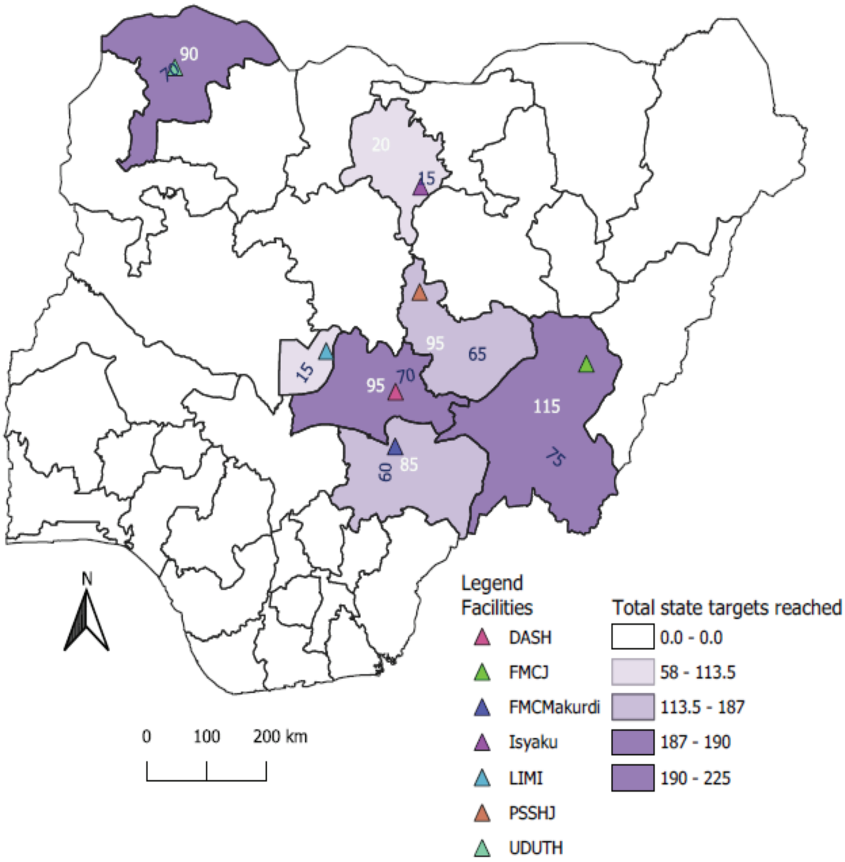

Figure 17: Paediatric antimicrobial stewardship training in HCFs in Nigeria conducted by CFID Taraba

Numerical values show the number of nurses (white) and doctors (blue) trained in each facility. In addition to doctors and nurses, total state targets reached include medical laboratory scientists, public health officers, and pharmacists.

Access to Antimicrobials

The NAP on AMR 1.0 states that all medical products meant for human and animal use must be registered with the National Agency for Food and Drug Administration and Control (NAFDAC) to ensure monitoring of quality, safety, and efficacy. However, the circulation of counterfeit and substandard medical products is rampant. Antimicrobials, classified as prescription-only medicines, can easily be obtained without a prescription in pharmacies and patent medicine stores. Contributing factors include poor health insurance coverage of the population and high out-of-pocket expenses associated with antibiotic purchases, hospital consultation fees, and diagnostic tests. The signing of the National Health Insurance Authority (NHIA) bill in 2022 is expected to play a significant role in encouraging rational antibiotic use and should be included in strategic AMR plans.

AMS activities by NCDC target patients, proprietary vendors, community pharmacists, and traditional leaders to create awareness of antimicrobial use and quality. Community pharmacies are encouraged to procure antimicrobials from reliable sources and conform to NAFDAC regulations on storage conditions.

The inadequate capacity of Nigerian pharmaceutical industries affects AMR and AMU in Nigeria. Despite the considerable capacity of Nigerian pharmaceutical companies drive pharmaceutical manufacture, distribution, and sales in sub-Saharan Africa, many quality-related challenges persist, together with the dominance of multinational companies, unfavourable government policies, and inadequate investment in research and development. As such, only a handful of companies are involved in the domestic manufacture of active pharmaceutical products and excipients, with a heavy reliance on imports from India and China.[230] Approximately 70% of antimicrobial agents are imported, with local manufacturers producing mainly antifungals and anthelmintics for veterinary use. To encourage local production of antimicrobial agents and diagnostics for human and animal use, the government is reducing taxes on raw materials used in manufacturing. Such interventions are much needed, as importing medicines is currently cheaper than local manufacture.

Access to quality antimicrobials can also be improved by increasing coverage of the national health insurance scheme. Out-of-pocket medical expenditure can be as high as 75%, but this could be higher for more expensive treatments. Another factor contributing to disparities in healthcare access and quality antimicrobials is related to legislation; regulation of drugs and pharmaceuticals is on the exclusive (Federal) legislative list, but healthcare is on the concurrent list, governed by the policies at all three tiers of government. Therefore, there are discrepancies in the standard of public healthcare, with higher quality at the federal level, but declining quality at the state and local government levels. There are significant gaps in infrastructure and human resources at primary healthcare facilities which serve most communities. Nigerians face several barriers to accessing both basic and advanced healthcare services which are critical to access to medicines.

Key Recommendations for NAP 2.0 Development

- Incorporate the AwaRe classification in standard treatment guidelines.
- Develop antimicrobial stewardship guidelines and a toolbox to facilitate their implementation in facilities with different capacities.
- Support the expansion of AMS committees in healthcare facilities nationwide.
- Increase awareness activities on antimicrobial quality and judicious use at the community level.

- Utilise data from point prevalence surveys to inform future AMS strategies.
- Advocate for increasing coverage of Universal Healthcare Coverage to increase access to appropriate diagnostics and medicines.
- Improve the pathways and processes for registration, procuring, and distribution of antibiotics.
- Advocate for an increase in the domestic production of pharmaceuticals to overcome issues with access to quality antimicrobials.
- Support the enforcement of regulations around antimicrobial procurement, dispensing, and use.

3.6. Research and Development

There is no coordinated national plan or strategy for AMR research in Nigeria, which is needed to drive intentional collaboration with research institutions to meet the targets of this pillar. A national research agenda exists, but AMR and AMU are not clearly stated as a priority or specific thematic area. Academic and operational research in Nigeria is very active in assessing the state of AMR and AMU across sectors. As shown throughout this situational analysis, peer-reviewed articles have studied pathogen resistance profiles, identified MDR lineages circulating in Nigeria, and measured awareness, knowledge attitudes and practices about AMR and AMU. However, disparities in data collection and analysis methods, geographical distribution, and other aspects give an incomplete picture of the true burden imposed by AMR.

A critical barrier to AMR-related research and development in Nigeria is the limited diagnostic and laboratory infrastructure. In 2017, only 6% of public health facilities in Nigeria had an attached laboratory, restricting the country's capacity to detect emerging and existing infectious disease threats and implement preventative public health measures.[217] A study assessing Nigeria's laboratories' capacity as NRLs meeting enrolment status for WHO's GLASS-AMR, showed that although five of the tested laboratories satisfactorily identified pathogen species and performed antimicrobial susceptibility testing, all eight were unable to proficiently subtype antimicrobial-resistant bacteria using whole genome sequencing (WGS).[214] However, whole genome surveillance (WGS)-based subtyping at an academic laboratory at the University of Ibadan enabled the University College Hospital (UCH) to serve as an interim NRL.

While Nigeria has significant domestic pharmaceutical capacity, it uses less than 30% of these facilities, and approximately 70% of drugs distributed in the country are imported, according to Nigeria's National Drug Policy, revised in 2021.[231] Data on the activity of pharmaceutical facilities in Nigeria presents a serious knowledge gap, as the most recent study was published in 2001; the study found that only 60 out of over 130 pharmaceutical manufacturers were active, despite the industry's ability to meet 50 to 75% of the country's drug needs at the time.[232] Up-to-date data is needed to accurately evaluate Nigeria's pharmaceutical capacity and availability to sufficiently produce and distribute medicines to the country's population.

Nigeria's National Drug Policy was formulated by the FMoH in 1990 when domestic drug manufacturing was inadequate and unable to meet the needs of the country's population. The policy was revised in 2005 to restate the importance of local manufacturing and to address existing gaps in drug production, distribution, and access, including the realisation of self-sufficiency regarding local drug production, the establishment of a drug procurement system, and commitment to judicious drug use in healthcare settings.[233] One of the targets in the third edition of the brief, published in 2021, is to achieve a 70% increase for local production capacity and utilisation of essential medicines by 31st December 2025.[243] The policy authors call for establishing a One Health AMR committee, including members across the Ministries of Health, Agriculture, and Environment, to ensure the pharmaceutical industry's commitment to preserving safe and effective antimicrobial agents for Nigeria's population. The African Medicines Agency (AMA) treaty which entered into force in 2021 is expected to make a significant impact on regulatory harmonisation in the region, ultimately improving access to medicines. However, as of 2022, Nigeria has not signed the treaty.[234]

Nigeria was the first African country to develop a National Essential Diagnostics List (NEDL), which was published in 2022 with the support of the World Health Organization and Global Fund. The NEDL names 145 diagnostic test categories, including 65 general in vitro diagnostics (IVDs), and is predicted to help expand Nigeria's domestic diagnostic capacity, increase access to testing, and strengthen laboratory and surveillance data collection.[235]

Key Recommendations for NAP 2.0 Development

- Support Fleming Fund Fellows to analyse and disseminate research findings.
- Conduct scoping analyses and systematic reviews to synthesise existing evidence and identify research gaps.
- Identify AMR research priorities in Nigeria based on current evidence and needs. Create a research agenda to coordinate AMR research in Nigeria.
- Conduct AMR research (resistance trends, antimicrobial consumption, and use, and laboratory capacity assessments) in areas with significant AMR surveillance gaps to get a better understanding of sub-national AMR epidemiology and capacity for surveillance.
- Conduct knowledge, attitude, and practice surveys to inform knowledge gaps and training needs among relevant stakeholders.
- Conduct stakeholder mapping to identify target audiences for awareness activities.
- Promote research into antimicrobial alternatives.
- There is a need to investigate the impact of flooding which is linked to climate change and is a major, underappreciated contributor to shifts in health landscape in Nigeria, including AMR.

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Annex 1: AMR Stakeholders

Stakeholder Group	Sectors	Pillar 1: Awareness	Pillar 2: Surveillance	Pillar 3: IPC	Pillar 4: Stewardship	Pillar 5: Research and Development	Governance/Resource Mobilisation
Federal Ministry of Health (FMoH)	MDA	x	x	x	x	x	x
Federal Ministry of Agriculture and Food Security (FMAFS)	MDA	x	x	x	x	x	x
Federal Ministry of Environment (FMEnv)	MDA	x	x	x	x	x	x
Federal Ministry of Water Resources (FMWRS)	MDA			x			x
Federal Ministry of Finance (FMF)	MDA						x
Nigeria Centre for Disease Control (NCDC)	MDA	x	x	x	x		x
Leads of TWGs							x
National Agency for Food and Drug Administration and Control (NAFDAC)	MDA	x	x		x	x	x
National Veterinary Research Institute (NVRI)	MDA		x	x	x	x	x
National Agency for the Control of AIDS (NACA)	MDA	x	x		x		x
National Tuberculosis and Leprosy Control Programme (NTBLCP)	MDA	x	x		x		x
National Malaria Elimination Programme (NMEP)	MDA	x	x		x		x

Institute of Human Virology Nigeria (IHVN)	MDA		x			x	x
Veterinary Council of Nigeria (VCN)	MDA	x	x	x	x	x	x
Medical and Dental Council of Nigeria (MDCN)	MDA	x	x	x	x	x	x
Africa Centres for Disease Control and Prevention (ACDC)	INGO						x
Nursing and Midwifery Council of Nigeria	MDA	x		x			x
Pharmacy Council of Nigeria (PCN)	MDA	x			x		x
Medical Laboratory Scientist Council of Nigeria	MDA	x			x		x
House Committee on Health (Legislature)	MDA						x
Media		x					x
Nigeria Medical Association (NMA)	MDA		x	x	x		x
National Association of Nigeria Nurses and Midwives	MDA		x	x	x		x
Pharmaceutical Society of Nigeria (PSN)	MDA		x	x	x		x
Society for Public Health Physicians of Nigeria	MDA		x	x	x		x
Nigerian Veterinary Medical Association	PRIVATE		x	x	x		x
Association of Medical Laboratory Scientists of Nigeria	MDA		x	x	x		x
Tertiary Education Trust Fund (TETFund)	ACADEMIA					x	x

Food and Agriculture Organization of the United Nations (FAO)	UN	x	x	x	x		x
United Nations Environment Programme (UNEP)	UN	x	x	x	x	x	x
United Nations International Children's Emergency Fund (UNICEF)	UN			x			x
World Health Organisation (WHO)	UN	x	x	x	x	x	x
World Organisation for Animal Health (WOAH)	INGO	x	x	x	x	x	x
Medicines, Technologies, and Pharmaceutical Services / Management Sciences for Health (MTaPS)	INGO	x		x	x		x
Medicines, Technologies, and Pharmaceutical Services / Management Sciences for Health (MTaPS)	NGO	x		x	x		x
Management Sciences for Health (MSH)	INGO	x		x	x		x
African Field Epidemiology Network (AFENET)	INGO		x			x	x
Clinton Health Access Initiative (CHAI)	INGO	x			x		x
National Council on Health	MDA	x	x	x	x	x	x
Association of General and Private Medical Practitioners of Nigeria (AGPMPN)	MDA	x	x	x	x	x	x
Universities and Academic institutions	ACADEMIA		x			x	
WaterAid	INGO	x		x			

Private veterinary clinics	PRIVATE	x	x	x	x	x	
Ducit Blue Solutions / Foundation	NGO	x		x	x		
Dr. Ameyo Stella Adadevoh (DRASA) Health Trust	NGO	x		x	x		
International Rescue Committee (IRC)	INGO	x	x	x	x		
Center for Initiative and Development (CFID)	NGO	x			x		
Environmental NGOs	NGO	x	x		x	x	
UK Health Security Agency (UKHSA)	INGO		x				
Nigerian Institute of Medical Research (NIMR)	MDA	x	x		x	x	x
National Environmental Standards and Regulations Enforcement Agency (NESREA)	MDA	x	x				x
National Primary Health Care Development Agency (NPHCDA)	MDA		x	x	x		x
National Institute for Pharmaceutical Research and Development (NIPRD)	MDA		x		x	x	
Private laboratories	PRIVATE		x				
State Ministries of Health	MDA	x	x	x	x	x	x
State Ministries of Environment	MDA	x	x	x	x	x	x
State Ministry of Agriculture, livestock, fisheries	MDA	x	x	x	x	x	x
State Primary Healthcare Boards	MDA	x	x	x	x		x

Consumer and Patient Organisations	NGO	x					
Patient Safety Africa	NGO	x	x				
Agricultural associations	PRIVATE/NGO	x		x			
Ministry of Information and Communication	MDA	x					x
Federal Ministry of Education	MDA	x			x	x	x
Poultry Association of Nigeria	PRIVATE/NGO		x	x			
Sheep and Goat Association of Nigeria	PRIVATE	x	x	x	x		
Environmental Health Council of Nigeria	MDA	x		x			
Miyetti Allah Cattle Breeders Association of Nigeria (MACBAN)	PRIVATE/NGO	x	x	x	x		
Fish Farmers Association of Nigeria	PRIVATE/NGO	x	x	x	x		
Pig Farmers Association of Nigeria	PRIVATE/NGO	x	x	x	x		
Rabbit Farmers Association of Nigeria	PRIVATE/NGO	x	x	x	x		
National Biosafety Management Agency	MDA			x			x
Veterinary Teaching Hospitals	ACADEMIA	x	x	x	x	x	
Animal Science Association of Nigeria	PRIVATE/NGO	x	x	x	x	x	
Pharmaceutical Manufacturers Group of Manufacturer Association of Nigeria (PMG MAN)	PRIVATE/NGO				x		

National Animal Health Technologist Association	PRIVATE/NGO	x	x	x	x	x	x
National Park Services and Zoological Gardens	MDA	x	x				
Forestry Research Institute of Nigeria	ACADEMIA					x	
Butchers Associations	PRIVATE/NGO	x	x	x			
Agricultural Research Council of Nigeria	ACADEMIA	x	x			x	x
Association of Pharmaceutical Importers of Nigeria	PRIVATE/NGO						
Feed Millers Association	PRIVATE/NGO	x					
Nigeria Agricultural Quarantine Services	MDA		x				x
International Federation Against Infectious Diseases in Nigeria	NGO		x				
Life Stock Management Services Ltd	PRIVATE			x			
Nigeria Governor's Forum	MDA	x					x
National Health Insurance Authority	MDA		x		x		x
Standards Organisation of Nigeria (SON)	MDA				x		
Nigeria Customs Service	MDA				x		
Guild of Medical Directors	MDA	x	x	x	x		
Association of Community Pharmacists	PRIVATE/NGO				x		

Association of Local Government of Nigeria (ALGON)	MDA	x					x
Society for Animal Production	NGO		x	x	x		
Health Commissioners Forum	MDA	x					x
Global Fund	INGO						x
World Bank	INGO						x
GAVI	INGO			x			x
Law Enforcement Agencies	MDA				x		
Small Animal Veterinary Association of Nigeria (SAVAN)	PRIVATE/NGO	x	x	x	x		
Environment Health Officers Association of Nigeria	PRIVATE/NGO		x	x			
House Committee on Agriculture	MDA						x
House Committee on Environment	MDA						x
Senate Committee on Health	MDA						x
Senate Committee on Agric	MDA						x
Senate Committee on Environment	MDA						x
National Council on Agric	MDA						x
Manufacturers/Distributors of Diagnostics	PRIVATE		x				

Nigerian Society for Microbiology	NGO		x	x	x		
Maternal and Child Health stakeholders	NGO	x	x	x	x	x	x
Nigerian Academy of Science	ACADEMIA					x	
WASH stakeholders	NGO	x	x	x	x	x	x
National Universities Commission (NUC)	MDA		x		x	x	
Traditional Medicine Practitioners	PRIVATE	x			x	x	
Robert Koch Institute	INGO	x	x	x	x	x	
Fleming Fund	INGO		x	x	x	x	
National EML Committee	MDA		x		x		
Animal and Plant Health Agency UK	INGO		x			x	
ASLM – The African Society for Laboratory Medicine	INGO		x				
State Ministries of Budget and Planning	MDA						x
NARD – National Association of Resident Doctors	NGO	x					
HMB – Hospital Management Board	MDA		x	x	x		
Federal teaching Hospitals	ACADEMIA		x	x	x		
Private hospitals/tertiary hospitals	PRIVATE		x	x	x		
Pharmaceutical companies	PRIVATE	x			x	x	

Pediatric association of Nigeria	NGO	x				x	
National Association of Pediatric Infectious Diseases Specialists	NGO	x				x	
Christian Health Association of Nigeria (CHAN)	NGO		x	x	x		
Nigerian Prison Services – Custodial Services	MDA	x	x	x	x		
US CDC	INGO					x	x
Humanitarian Response Agencies	INGO	x					x
Agric Commissioners Forum	MDA						x
Environmental Health Commissioners Forum	MDA						x
Private Veterinary Labs	PRIVATE		x			x	
Nigeria Immunization Technical Advisory Group (NITAG)	MDA			x			
Food Safety stakeholders	MDA	x	x	x	x	x	
TrACSS focal points	MDA		x				x
West African Health Organization (WAHO/RAHC ECOWAS)	INGO						x
State Ministries of Education	MDA	x			x		x
Guild of Medical Laboratory Directors	MDA		x			x	
National Association of Animal Health and Husbandry Technologists	MDA	x					

Annex 2. Antimicrobial Resistance Studies in Human Health

Geographical location	Facility	Sample size	Age group	Sample type	Bacteria isolated	Antimicrobial resistance % (Antibiotic)	Reference	Funding
Kano State	Tertiary hospital	192	Children under 5	Blood and CSF	*Streptococcus pneumoniae*	52% (penicillin), 2% (erythromycin), 44% (MDR)	Lo et al.[236]	BMG, Wellcome trust, US CDC
Benue State	Tertiary hospital	180		Faeces	*Enterococci faecalis*, *Enterococcus faecium*	5% (linezolid)	Ngbede et al.[237]	Cooperation Visits Programme of The World Academy of Sciences and Deutsche Forschungsgemeinschaft
Osun State		5	Children under 15	Isolates from previous study	*Escherichia coli* *Enterobacter* spp., *Klebsiella pneumonia*	80% (cefotaxime) 40% (ceftriaxone) 60% (ceftazidime) 60% (tetracycline) 100% (ciprofloxacin) 60% (chloramphenicol) 80% (gentamicin) 80% (trimethoprim/ sulfamethoxazole)	Uwanibe et al.[238]	NIH-H3Africa, World Bank Grant
Edo State	Tertiary education institution	180	University students	Urine and nasal swabs	*Escherichia coli* *Klebsiella* spp.	100% (cefepime)	Jesumirhewe et al.[239]	Austrian Agency for Health and Food Safety (AGES)

						100% (cefuroxime) 100% (cefotaxime) 100% (gentamicin) 100% (amoxicillin-clavulanic acid) 100% (cefuroxime) 100% (cefotaxime)		
Ebonyi State	Tertiary hospital	1	Adult male	Urine	*Enterobacter cloacae*	100% (ceftriaxone) 100% (cefotaxime) 100% (cefepime) 100% (ampicillin) 100% (ciprofloxacin) 100% (levofloxacin) 100% (fosfomycin)	David et al.[240]	International Centre for Genetic Engineering and Molecular Biology (ICGEB)
Kano State and Federal Capital Territory	Hospitals – tertiary and children's hospitals	49		Blood, urine, and wound swabs	*Klebsiella* spp. *Enterobacter* spp. *Escherichia* spp. *Serratia* spp. *Citrobacter* spp.	28.6% (amikacin) 85.7% (gentamicin) 81.6% (aztreonam) 100% (ampicillin sulbactam) 79.6% (piperacillin-tazobactam) 95.9% (cefotaxime) 89.8% (cefepime) 91.8% (ceftriaxone) 89.8% (ceftazidime) 59.2% (ceftazidime avibactam) 80.9% (ceftolozane tazobactam)	Medugu et al.[241]	National Institute of Allergy and Infectious Diseases of the National Institutes of Health, Bill & Melinda Gates Foundation

						65.3% (meropenem) 89.8% (trimethoprim/ sulfamethoxazole)		
Lagos, Osun, Oyo, Kwara, Ogun states	Tertiary hospitals and private diagnostic laboratories	125		Blood, cerebrospinal fluid, rectal swab	*Acinetobacter baumannii*	93.1% (cefepime) 90.1% (ceftazidime) 91.8%(ciprofloxacin) 79.9% (doripenem) 91.4% (gentamicin) 73.5% (imipenem) 91.8% (levofloxacin) 79.1%(meropenem) 26.2% (tigecycline) 33.6%(minocycline) 92% (piperacillin-tazobactam)	Odih et al.[242]	National Institute of Health Research, University of Copenhagen
Southwest	Tertiary hospitals	420		Urine, blood, sputum, wound swabs, high vaginal swabs, pus, stool, tracheal aspirate, and semen	*Klebsiella pneumoniae*	67.2% (tetracycline) 61.7% (oxacillin) 60.2% (ampicillin) 58.6%(ciprofloxacin) 56.3% (chloramphenicol) 43.0% (meropenem) 53.9% (ceftriaxone) 51.6% (cefotaxime) 53.9% (gentamicin) 53.1% (ceftazidime)	Odewale et al.[243]	Alexander von Humboldt Foundation

Federal Capital Territory and Nasarawa State	Hospitals	4163	Children	blood cultures	*Salmonella enterica*	78.3% (ampicillin) 78.3% (trimethoprim-sulfamethoxazole) 46.7% (chloramphenicol) 41.4% (tetracycline) 33.9% (piperacillin) 25.3% (amoxicillin-clavulanic acid) 25.3% (streptomycin) 22.9% (cephalothin)	Uzairue et al.[156]	No funding
Lagos State	Hospitals	123	Adults (20 to 85 years)	Wound, urine, sputum/tracheotomy aspirates, ear, and vaginal swabs	*Pseudomonas aeruginosa*	62% (piperacillin) 52% (ceftazidime) 45% (cefepime) 39% (imipenem) 44% (meropenem) 59% (gentamicin) 55% (tobramycin) 71% (ciprofloxacin) 74% (levofloxacin)	Olalekan et al.[244]	German Academic Exchange Service (DAAD), German Research Foundation (DFG)
Lagos State	Secondary and private hospitals	508		Blood, stool	*Salmonella sp.*	75% (cefpodoxime) 50% (ofloxacin) 37.5% (ciprofloxacin) 50% (amikacin) 37.5% (gentamicin) 100% (ceftazidime) 100% (cefotaxime) 100% (cefoxitin)	Fakorede et al.[245]	No funding

						100% (amoxicillin-clavulanic acid) 100% (ampicillin) 100% (ertapenem) 100% (doripenem) 100% (MDR)		
Southwest	Tertiary hospitals	68	1 day to 71 years	Blood	*Escherichia coli*	100% (trimethoprim) 92.5% (ampicillin) 79.1% (ciprofloxacin) 55.2% (aminoglycosides) 91% (MDR)	Afolayan et al.[246]	National Institute of Health Research, Wellcome Trust grant
Lagos State	Secondary hospitals	499	1 to 89 years	Sputum, urine, stool, and swabs from wounds, vagina, cervix, ear, eye, and throat	*Staphylococcus aureus* *Escherichia coli* *Staphylococcus* spp. *Enterococcus* spp. *Klebsiella pneumoniae*	79.3 (MDR) 87.5% (cefotaxime)	Chukwu et al.[247]	No funding
Federal Capital Territory (Abuja)	Tertiary hospitals	107		Urine, blood culture, cerebrospinal fluid, and endo-cervical swabs	*Escherichia coli*	94.3% (ampicillin) 88.8% (trimethoprim/ sulfamethoxazole) 80.4% (ceftriaxone) 56.1% (gentamicin) 7.5% (meropenem) 95.3% (MDR)	Medugu et al.[155]	No funding

Rivers State	Tertiary hospital	104	0 to 70 years	Blood, urine, tracheal aspirate, cerebrospinal fluid (CSF), wound swabs, high vaginal swabs, eye, and ear exudates	*Pseudomonas aeruginosa*	73.1% (ceftazidime) 61.5% (piperacillin-tazobactam) 61% (MDR) 5% (XDR)	Awanye et al.[248]	No funding
Ekiti State	Tertiary hospital	177	4 days to 87 years	Blood culture	*Escherichia coli* *Klebsiella aerogenes* *Staphylococcus aureus*	14.7% (ceftazidime) 2.9% (imipenem) 20.6% (ciprofloxacin) 20.6% (ofloxacin) 23.5% (gentamicin)	Oyekale et al.[249]	No funding
Anambra State	Tertiary hospital	363		Urine	*Escherichia coli*	76.88% (ceftazidime) 77.5%% (cefuroxime) 61.88% (cefixime) 6.25% (gentamicin) 6.88% (ofloxacin) 32.5% (amoxicillin-clavulanic acid) 34.38% (ciprofloxacin)	Nwokolo et al.[250]	
Osun State	Tertiary hospital	172		Urine, swab, aspirate, sputum, stool, and blood	*Klebsiella pneumoniae*	87.8% (ampicillin) 34.8% (amoxicillin-clavulanic acid) 52.3% (cefoxitin) 61.1% (cefotaxime) 51.2% (cefepime) 37.8% (chloramphenicol)	Ajimuda et al.[251]	No funding

						50.6% (nalidixic acid) 58.1% (levofloxacin) 62.8% (ciprofloxacin) 52.3% (gentamicin) 2.3% (meropenem)		
Kano State	Tertiary and secondary hospitals	214	0 to 14 years	Nasal swab	*Staphylococcus aureus*	92.5% (penicillin) 20% (ciprofloxacin) 7.5% (gentamicin) 2.5% (mupirocin) 82.5% (trimethoprim/ sulfamethoxazole)	Sadauki et al.[252]	No funding
Borno State	Tertiary hospital	100		Nasal swab	*Staphylococcus aureus*	100% (oxacillin) 100% (cefoxitin) 100% (oxytetracycline) 100% (cephazolin) 100% (cephazolin) 100% (penicillin G) 84% (sulfamethoxazole/ trimethoprim)	Jauro et al.[253]	
Southwest	Tertiary hospital	200		Urine	*Escherichia coli*	100% (MDR)	Ajala et al.[254]	No funding
Plateau State	Secondary hospital	568		Stool	*Campylobacter* spp.	13% (MDR)	Audu et al. Audu, 2022 #357	Elphinstone Scholarship from the University of Aberdeen, Scotland

Rivers State	Tertiary hospital	185	Pregnant women	Vaginal and rectal swabs	*Streptococcus agalactiae*	30.3%(erythromycin) 24.2% (clindamycin) 24.2% (chloramphenicol) 27.3% (levofloxacin) 100% (tetracycline)	Bob-Manuel et al.[255]	CDC
Edo State	Secondary hospitals	284		Surgical wound swabs	*Pseudomonas* spp. Isolates from Central Hospital Benin (CHB) Isolates from University of Benin Teaching Hospital (UBTH)	63.0% (MDR) 85.2% (ceftazidime) 70.4% (cefuroxime) 81.5% (cefixime) 63.0% (amoxicillin-clavulanic acid) 70.4% (gentamycin) 66.7% (nitrofurantoin) 59.3% (ofloxacin) 48.1% (ciprofloxacin) 57.1% (MDR) 77.1% (nitrofurantoin) 68.6% (gentamycin) 62.9% (amoxicillin-clavulanic acid) 68.6% (gentamicin) 60% (ceftazidime) 57.1% (cefuroxime) 57.1% (cefixime) 51.4% (ofloxacin) 37.1% (ciprofloxacin)	Eremwanarue et al.[256]	No funding
Edo State	Tertiary hospital	3,247		Blood, ear swab, endo-cervical swab,	*Escherichia coli*	93.1% (co-trimoxazole)	Tobin et al.[257]	European and Developing Countries Clinical Trials

				high vaginal swab, pus aspirate, seminal fluid, urethral swab, and wound swab	*Staphylococcus aureus* *Streptococcus pneumoniae* Resistance to gram-positive pathogens Resistance to gram-negative pathogens	86.4% (tetracycline) 72.5% (cloxacillin) 68.1% (erythromycin) 28.0% (cefixime) 35.8% (ceftazidime) 24.5% (ceftriaxone) 30.6% (chloramphenicol) 100% (amoxicillin) 96.9% (cloxacillin) 95.6% (erythromycin) 88.3% (tetracycline) 96.9% (amoxicillin-clavulanic acid) 93,2% (co-trimoxazole) 23.2% (nitrofurantoin) 17.5% (cefixime)		Partnership (EDCTP2) programme
Osun State	Tertiary hospital	150	Less 10 to 60 years	Wound swab, urine, blood, ear swab, pus, eye swab, aspirate, urethral swab, pleural fluid, catheter tip, sputum, high vaginal swab	*Pseudomonas* spp.	35% (gentamicin) 13% (amikacin) 29% (ciprofloxacin) 28% (levofloxacin) 17% (piperacillin) 6% (piperacillin-tazobactam) 7% (imipenem) 11% (meropenem) 12.7% (MDR)	Adejobi et al.[258]	No funding

Kogi State	Private hospitals	200	17 to 72 years	Urine	*Escherichia coli* *Klebsiella pneumoniae*	100% (cefotaxime) 83.3% (amoxicillin-clavulanic acid) 83.3% (ciprofloxacin) 79.6% (ceftazidime) 100% (cefotaxime) 75% (ciprofloxacin) 83.3% (amoxicillin-clavulanic acid) 62.5% (cefoxitin) 66.7% (gentamicin)	Mofolorunsho et al.[259]	
Ogun State	Tertiary hospital	50		Urine, pus, sputum, catheter tip, eye, wound, and ear swabs	*Pseudomonas aeruginosa*	100% (ceftazidime) 100% (cefuroxime) 100% (amoxicillin-clavulanate) 97% (cefixime) 97% (ofloxacin) 97% (ciprofloxacin) 92% (nitrofurantoin) 25.6% (imipenem) 51.2% (gentamicin) 28% (cefepime) 23% (aztreonam)	Ugwuanyi et al.[260]	No funding
Gombe State	Community	262	15 to 62 years	Nasal swabs	*Staphylococcus aureus*	100% (amoxicillin) 50% (erythromycin) 43.5% (co-trimoxazole) 15.2% (amoxicillin-clavulanic acid)	Onanuga et al.[261]	

						26.1% (cefoxitine) 28.3% (doxycycline) 19.6% (ciprofloxacin) 17.4% (linezoid) 4.3% (gentamicin)		
Delta State	Rural communities	312		Hand swabs, fomites, carcass	*Escherichia coli*	100% (ceftazidime) 100% (cefotaxime) 100% (amoxicillin-clavulanic acid) 4.8% (nitrofurantoin) 90% (MDR)	Egbule et al.[262]	No funding
Kano State	Secondary hospitals	296	Younger than 5 years	Rectal swab	*Escherichia coli* ESBLs Phenotypic ESBLs Genotypic	71.1% (cefuroxime) 73.7% (cefotaxime) 73.7% (amoxicillin-clavulanic acid) 68.4% (ceftazidime) 34.2% (ciprofloxacin) 23.7% (gentamycin) 92.1% (co-trimoxazole) 94.7% (tetracycline) 78.9% (MDR) 73.3% (cefuroxime) 73.3% (cefotaxime) 80.0% (amoxicillin-clavulanic acid) 73.3% (ceftazidime) 36.7% (ciprofloxacin) 26.7% (gentamycin)	Saka et al.[263]	No funding

						90.0% (co-trimoxazole) 100% (tetracycline) 90.0% (MDR)		
Sokoto State	Secondary hospitals	756	≤20 to ≥41 years	Nasal swab	*Staphylococcus aureus*	54.5% (cefoxitin) 36.4% (linezolid) 33.3% (erythromycin) 42.4% (clindamycin) 60.6% (ceftazidime) 18.2% (gentamicin) 12.1% (levofloxacin) 18.2% (trimethoprim/sulfamethoxazole) 15.2% (chloramphenicol) 39.4% (tetracycline) 52.6% (MDR) 42.1% (XDR) 5.3% (PDR)	Adeiza et al.[264]	
Lagos, Ogun and Oyo States	Live bird markets	311		Nasal swab	*Staphylococcus aureus*	5.6% (tetracycline) 5.6% (sulfamethoxazole/trimethoprim) 94.4% (ciprofloxacin) 88.9% (gentamicin) 83.3% (erythromycin) 68.0% (MDR)	Ogundipe et al.[265]	Alexander von Humboldt Foundation

Lagos State	Tertiary hospital	18		Urine, blood, sputum	*Klebsiella* spp.	100% (cefuroxime) 100% (cefixime) 100% (amoxicillin-clavulanic acid) 100% (ampicillin + cloxacillin) 100% (cefotaxime) 100% (imipenem) 94.4% (ofloxacin) 88.9% (nalidixic acid) 88.9% (gentamicin) 88.9% (levofloxacin)	Akinpelu et al.[266]	
Oyo State	Tertiary hospital	98		Blood	Escherichia coli *Klebsiella* spp.	96% (cloxacillin) 96% (oxacillin) 92% (colistin) 98% (streptomycin) 93.75% (cefotaxime) 91.67% (cloxacillin) 91.67% (oxacillin) 91.67% (colistin sulfate)	Ayandele et al.[267]	
Osun State	Tertiary hospital	77		Urine	*Escherichia coli* *Salmonella* spp.	83.3% (ceftazidime) 91.6% (cefuroxime) 58.3% (gentamicin) 62.5% (ceftriaxone) 100% (erythromycin) 45.8% (ofloxacin) 95.8% (amoxicillin-clavulanic acid)	Kayode et al.[268]	No funding

						100% (ceftazidime) 91.7% (cefuroxime) 41.7% (gentamicin) 100% (ceftriaxone) 75% (erythromycin) 16.7% (ofloxacin) 100% (amoxicillin-clavulanate)		
Anambra State	Tertiary hospital	100		Urine	*Escherichia coli*	60.34% (cefpodoxime) 1.72% (aztreonam) 13.79% (cefotaxime) 1.72% (ceftazidime) 15.52%(meropenem) 5.17% (cefoxitin) 6.9% (ofloxacin) 6.9% (ciprofloxacin) 8.62% (norfloxacin) 6.9% (levofloxacin) 50% (co-trimoxazole) 10.34% (gentamicin) 27.59% (amoxicillin)	Ugwu et al.[269]	
Enugu	Tertiary hospital	200		Urine, pleural and peritoneal aspirate, blood, wound swab, cerebrospinal fluid	*Escherichia coli*	45.43% (amikacin) 100% (ampicillin) 54.29% (amoxicillin–clavulanic acid) 95.71% (aztreonam) 82.86% (ceftriaxone) 90% (ceftazidime)	Nwafia et al.[270]	

						100% (chloramphenicol) 74.29% (ciprofloxacin) 7.14% (ertapenem) 64.29% (gentamicin) 1.43% (imipenem) 4.29% (meropenem) 38.57% (nitrofurantoin) 62.86% (ofloxacin) 34.29% (piperacillin/ tazobactam 100% (tetracycline)		
Federal Capital Territory (Abuja)	Farms	122	18 years and above	Stool	*Escherichia coli*	83.3% (tetracycline) 79.2% (sulfamethoxazole-trimethoprim) 77.1% (ampicillin) 72.9% (streptomycin) 50% (nalidixic acid) 41.7% (gentamicin) 31.3% (chloramphenicol) 27.1% (cephalothin) 10.4% (nitrofurantoin) 6.3% (imipenem) 79.2% (MDR)	Aworh et al.[271]	No funding

Enugu State	Tertiary hospital	422	0 to 15 years	Urine and stool	*Klebsiella* spp. *Escherichia coli*	100% (sulfamethoxazole/ trimethoprim) 100% (tetracycline) 96.9% (kanamycin) 84.4% (nitrofurantoin) 68.6% (ciprofloxacin) 62.5% (chloramphenicol)	Oli et al.[272]	No funding
Oyo State	Primary, secondary, and tertiary hospitals	682	1 to 60 years	Blood	*Staphylococcus aureus*	92.8% (ampicillin) 44.6% (amoxicillin-clavulanic acid) 37.7% (cefoxitin) 7.1% (gentamicin) 11.8% (ciprofloxacin) 10.4% (clindamycin) 34.8% (erythromycin) 20.3% (chloramphenicol) 58.8% (tetracycline)	Popoola et al.[273]	Bill & Melinda Gates Foundation
Enugu State	Tertiary hospital	810	Less than 20 to 60 years	Stool, urine, and blood	*Salmonella* spp.	93.9% (ampicillin) 78.1% (amoxicillin-clavulanic acid) 4.4% (ceftriaxone) 22.8% (ceftazidime) 66.7% (cefuroxime) 12.3% (ofloxacin) 43.0% (chloramphenicol)	Ohanu et al.[274]	No funding

						71.9% (tetracycline) 66.7% (co-trimoxazole) 100% (erythromycin)		
Oyo State	Tertiary hospital	152	8 to 85 years	Blood, urine, tracheal aspirate, and wound biopsies	*Klebsiella* spp. *Escherichia coli*	72.7% (amoxicillin-clavulanic acid) 100% (cefuroxime) 66.7% (ceftazidime) 92.3% (ceftriaxone) 69.2% (ciprofloxacin) 71.4% (pefloxacin) 83.3% (gentamycin) 38.5% (amikacin) 16.3% (meropenem) 70.8% (MDR) 80.0% (amoxicillin-clavulanic acid) 100% (cefuroxime) 83.3% (ceftazidime) 80.0% (ceftriaxone) 75.0% (ciprofloxacin) 75.0% (perfloxacin) 100% (gentamycin) 71,4% (MDR)	Makanjuola et al.[275]	
Osun State	Tertiary hospital	80	1 month to 78 years	Wound swab	*Pseudomonas aeruginosa* *Staphylococcus aureus*	19.2% (imipenem) 57.7% (ceftriaxone) 73.1% (ofloxacin) 65,4% (ciprofloxacin) 100% (cefuroxime)	Omoyibo et al.[276]	No funding

						100% (ceftazidime) 100% (ampicillin) 92.3% (nitrofurantoin) 100% (amoxicillin-clavulanic acid) 13% (imipenem) 39.1% (ceftriaxone) 73.9% (ciprofloxacin) 78.3% (gentamicin) 82.6% (erythromycin) 100% (cloxacillin) 100% (c0-trimoxazole) 43.5% (chloramphenicol) 95.7% (tetracycline) 78.3% (streptomycin) 100% (amoxicillin-clavulanic acid)		
Bayelsa State	Secondary and primary hospitals	201	16 to 45 years	Urine	*Klebsiella pneumoniae* *Pseudomonas aeruginosa*	80.0% (amoxicillin-clavulanic acid) 82.2% (cefuroxime) 66.7% (ceftazidime) 82.2% (cefotaxime) 55.6% (gentamicin) 51.1% (ciprofloxacin) 93.3% (co-trimoxazole) 93.3% (tetracycline)	Onanuga et al.[277]	

						80.6% (amoxicillin-clavulanic acid) 86.3% (cefuroxime) 58.3% (ceftazidime) 75.0% (cefotaxime) 58.3% (gentamicin) 44.4% (ciprofloxacin) 94.4% (co-trimoxazole) 100% (tetracycline)		
Osun State	Secondary hospital	268	0 to 60 months, 15 to 46years	Stool	*Escherichia coli*	95.8% (streptomycin) 94.2% (sulphonamide) 92.5% (ampicillin) 93.3% (tetracycline) 85.9% (trimethoprim) 8.4% (ciprofloxacin)	Odetoyin et al.[278]	Branco Weiss Fellowship from the Society-in-Science, ETHZ, Switzerland INO

Annex 3. Antimicrobial-Resistant Trends Among Relevant Pathogens in Nigeria

Methicillin-resistant *Staphylococcus aureus* (MRSA)

A meta-analysis estimating the prevalence of *S. aureus* in Nigeria, showed prevalence rates ranging from 13.0% to 82.0%.[279] Resistance trends were assessed for methicillin (46.0%), penicillin G (82.0%), cloxacillin (77.0%), amoxicillin (74.0%), cefuroxime (69.0%), and ampicillin (68.0%). However, there are regional variations for the trends of methicillin-resistant *S. aureus* (MRSA) infections. A systematic review showed that overall, the prevalence of MRSA in Nigeria rose from 18.3% to 42.3% between 2009 and 2013.[280] According to this review, there was a decline in the prevalence of MRSA in the north-east (from 12.5% to 8.0%) between 2007 and 2012. In contrast, there has been an increase in MRSA prevalence in the south-west from 20.2% to 47.4% between 2006 and 2010. In the northwest, 50% to 75% of *S. aureus* isolates from surgical sites and hospital beds of hospitalised patients were MRSA.[281] Additionally, a 46.9% MRSA prevalence was detected among participants across three study centres in the same region.[279] In the south-south, 42.0% of isolates from Benin city study were MRSA.[282] In a southwestern study, a lower MRSA prevalence of 9.43% was identified in 700 healthy volunteers[283] In the southeast, the prevalence rate of MRSA in clinical and community samples was 22.6% and 20.8%, respectively. All the clinical isolates were resistant to ceftazidime, tetracycline, and penicillin.[284] The prevalence of MRSA in another group of study subjects within the south-east was 22.6%.[285]

Multidrug-resistant Tuberculosis

One of the most urgent and difficult challenges facing global TB control is the emergence and spread of MDR-TB. As Nigeria has the second highest HIV burden globally, MDR-TB continues to threaten the control of both diseases. A systematic literature review revealed that among 8002 adult TB patients, MDR among new and old cases was 6.05% and 32%, similar to WHO estimates of 4.05 and 25%, respectively. Stratified based on geography, rates were lower in the north than in the south region of Nigeria. Among new patients, the resistance rate to any of the TB drugs was 21% and 36% in the north and south, respectively. Among previously treated patients, resistance rates were 36% and 62% in the north and south, respectively.[286] In the southeast, MDR-TB has been identified in 3.1% of isolates, while 35.1% was recorded in the southwest.[287,288] The south-south region has also recorded resistance to streptomycin (27.6%), isoniazid (6%), rifampicin (19%), and ethambutol (17.2%), with total MDR-TB rate being 5.2% among newly diagnosed patients.[268,289] The same region has also documented a 42% resistance rate to at least one anti-TB medication.[290]

Fluoroquinolone and Third-generation Cephalosporin-resistant *Escherichia coli*

There is widespread existence of multidrug-resistant *E. coli* in Nigeria which threatens the effective treatment of enteric infections. The organism is normally susceptible to most clinically relevant antimicrobial agents, but their intrinsic capacity to develop resistance is attributed to a horizontal gene transfer mechanism of resistance.[291] In a southeastern study, isolation and susceptibility testing of 206 *E. coli-positive* clinical specimens showed that 14.6% were fluoroquinolone-resistant.[292] Individual resistance rates were determined for pefloxacin (80.0%), ciprofloxacin (86.7%), sparfloxacin (86.7%), levofloxacin (100%), nalidixic acid (100%0), ofloxacin (86.7%,) and moxifloxacin (93.3%).

Among slaughterhouse workers in Abuja (north-central) and Lagos (south-west), stool samples contained *E. coli* isolates that were multidrug resistant.[293] The isolates showed resistance to Ciprofloxacin and nalidixic acid at 81.0% and 57.3% respectively. For the third-generation cephalosporins, isolates showed 25.3% and 13.3% resistance to cefotaxime and ceftazidime respectively. In Abuja, 80.4% of isolates from urine, blood cultures, endo-cervical swabs, and cerebrospinal fluids were resistant to ceftriaxone.[155] In the south-south of Nigeria, isolates from the urinary tract samples were resistant to nalidixic acid (68%), ciprofloxacin (60%), and cefotaxime (20%).[282]

Carbapenem-resistant *A. baumanni* and *K. pneumoniae*

Carbapenems are one of the most effective and last-line antibiotics for treatment of multidrug-resistant gram-negative bacteria. A systematic review determined the prevalence of carbapenem resistance in Nigeria to be 21.3%, with southern and northern Nigeria documenting 22.0% and 20.9% prevalence rates, respectively. Carbapenem resistance prevalence was 25.4%, 24.3% and 14.7% in south-east, south-west and south-south respectively and 7.5%, 31.2% and 19.2% in the north-east, north-west, and north-central respectively.[294]

The emergence of carbapenem-resistant *K. pneumoniae* in Nigeria would impact clinically and economically the management of associated infections. The same systematic review gave a mean prevalence of *K. pneumoniae* carbapenem resistance to be 26.3%. *K. pneumoniae* isolates closely related to the high-priority globally resistant strain have been obtained in a phylogenetic analysis in Nigeria from clinical samples in three AMR surveillance sites in the southwest. The ESBL gene was found in 72% of *K. pneumoniae* genomes, while only 8% carried a carbapenem-inhibiting enzyme.[295] In another southwestern study involving six states, sample isolates obtained from seven tertiary hospitals had a *K. pneumoniae* prevalence of 30.5% and were resistant to tetracycline (67.2%), oxacillin (61.7%), ampicillin (60.2%), ciprofloxacin (58.6%), and chloramphenicol (56.3%), imipenem (48.4%), cefepime (44.5%), and meropenem (43.0%). Carbapenem-resistant and ESBL genes were also found in some of the clinical isolates.[140] In the same region, 43 strains of *K. pneumoniae* were resistant to third-generation cephalosporins (ceftazidime 46.5%; cefixime 35%) and carbapenems (7.0%).[294]

In the south-east, Carbapenem-resistant *K. pneumoniae* was found in 4.0% of isolates and resistance to third-generation cephalosporins occurred in 60–100% of isolates.[296,297] In the north-west, out of 292 clinical isolates of *Enterobacteriaceae* from 2 leading hospitals in Sokoto State, 44.2% and 6.5% were resistant to carbapenems and third-generation cephalosporin, respectively.[297]

Infections from A. *baumannii* account for 15.3% of healthcare-associated infections globally and are associated with poor health outcomes because they are usually resistant to antibiotics in the WHO Access and Watch list.[298] Strain isolates from hospitals in the southwest which were submitted to Nigeria's AMR surveillance laboratory between 2016 and 2020, highlighted an increase in carbapenem-resistant genes in the majority of isolates[242] In isolates obtained from southwestern and north-central regions, genes for carbapenem resistance were also prevalent.[299] Another southwestern study recorded a 5.3% prevalence.[309,295] In Yola (north-east), antimicrobial susceptibility testing revealed carbapenem resistance in 6.8% of *A. baumannii* isolates. Of this, 88.2% were resistant to imipenem and meropenem.[300] There is a paucity of data for other geographical regions.

Like carbapenem, colistin is a last resort drug for gram-negative Enterobacteriaceae, but a study in Benue State (south-south) investigating carbapenem and colistin resistance in *Enterobacteriaceae* isolates from humans, animals and the environment reported 9.1% concurrent carbapenem-colistin resistance.[301]

Extended-Spectrum Beta-lactamase (EBSL) Producing *Enterobacteriaceae*

Extended-spectrum beta-lactamase-producing *Enterobacteriaceae* are responsible for many drug-resistant bloodstream infections. Their mechanism of resistance involves hydrolysing the extended-spectrum cephalosporins, penicillins, and aztreonam but not carbapenems. ESBL prevalence and antibiotic resistance has been reported in Nigeria. In a teaching hospital in southwest Nigeria, enteric isolates obtained from the urinary tract of 61 patients from February 2017 to October 2018 showed high resistance to amoxicillin-clavulanate (98%), cefuroxime (92%), erythromycin (90%) and ceftazidime (84%).[268]

Of 413 *Enterobacteriaceae* isolates obtained from children's samples in seven hospitals in Federal Capital Territory (north-central) and three hospitals in Kano (north-west), ESBL-producing strains were found in 160 isolates. Resistance was recorded for ceftriaxone (92.3%), aztreonam (96.8%), cefpodoxime (96.3%), cefotaxime (98.8%), and trimethoprim/sulfamethoxazole (90%).[302]

In Edo state (south-south), ESBL strains obtained from clinical *Enterobacteriaceae* isolates were resistant to ceftazidime (88.9%), cefotaxime (93.7%), cefepime (82.5%) and aztreonam (90.5%).[303]

In Kogi State (north central), ESBL production was found in 69% of *E. coli* and 31% of *K. pneumoniae* isolates. *E. coli* and *K. pneumoniae* showed 100% resistance to ceftriaxone. Resistance to ampicillin-clavulanic acid (83.3%), ciprofloxacin (83.3%) and ceftazidime (79.6%) occurred in 54 isolates of ESBL-EC.

ESBL *K. pneumoniae* isolates were resistant to ciprofloxacin (75%) and amoxicillin-clavulanic acid (83.3%).[259]

Another study involving clinical isolates collected from general hospitals in Lagos State (southwest, Nigeria) between August 2020 and March 2021 showed a high prevalence of resistance to several antibiotics.[104] Among all isolates, 22.8% were identified as *S. aureus*, 16.4% *E. coli*, and 15.9% *Staphylococcus* spp. The study authors also observed that a large proportion of the collected isolates (79.3%) were multidrug resistant.

Isolates of *E. coli*, *K. pneumoniae*, *P. aeruginosa* obtained from three tertiary hospitals in Ibadan, Ogbomoso and Osogbo in southwest Nigeria showed susceptibility patterns as follows:[304]

	E. coli	*K. pneumonia*	*P. aeuruginosa*
Ceftriaxone	94.7%	95.0%	100%
Ceftazidime	78.9%	100%	100%
Amoxycillin-clavulanic	100%	100%	100%

Annex 4. Antimicrobial Resistance Studies in Animal Health

Table A4.1: Studies assessing antimicrobial resistance in food and agriculture systems

Location	No. of samples	Animal species	Sample type	Bacteria isolated	% of resistant isolates	ARGs detected	External funding	Reference
Oyo	100	Animals (goats, pigs, poultry, cattle, sheep)	Faecal samples	*Escherichia coli*	89%	–	Yes (DAAD)	Olowe et al.[305]
Oyo	80	Animal products (milk, cheese, beef, chicken, yoghurt)	Food products	*Escherichia coli*	38.8%	–	Yes (DAAD)	Olowe et al.[305]
Kwara	354	Chickens	Caecal samples	*Escherichia coli*	10.5%	blaTEM, blaOXA-1, and blaCTX-M-1	Yes	Al-Mustapha et al.[161]
Kwara	181	Chickens	Caecal samples	*Escherichia coli*	40%	BlaAMPC,blaESBL,blaTEM-1b,blaTEM-106, blaTEM126,blaCTX-M-14,blaCTX-M-55, fosA3,qnrS1, qnrB19, Sul1, Sul2, Sul3,mef(B)	No	Al-Mustapha et al.[181]

Abeokuta	200	Chickens	cloacal/rectal swab	*Escherichia coli*	16%	–	No	Adebowale et al.[38]
Enugu	340	Chickens	Eggs	*Escherichia coli*	10.9%	–	Yes (Tetfund)	Okorie-kanu et al.[306]
Southeastern Nigeria	785	Chickens	Faecall and cloacal swab	*Enterobacterales*	5.7%	mcr-1 and mcr-1.22	No	Anyanwu et al.[180]
Zaria	105	Chickens	cloacal swab	*Escherichia coli*	20%	–	No	Ejeh et al.[307]
Ado Ekiti	350	Pig and Cattle	Faecal samples	*Escherichia coli*	63.2%	BlaTEM, blaCTX-M	No	Olowe et al.[176]
Southeastern Nigeria	180	Bat, Frugivorous	Liver, Spleen and Intestines of bats	*Escherichia coli*	8.3%	BlaCTX-M-15, blaTEM, tetA, int1	Yes (U la Roja)	Obodoechi et al.[171]
Southeastern Nigeria	180	Bat, Insectivorous	Liver, Spleen and Intestines of bats	*Escherichia coli*	11.1%	BlaCTX-M-15, blaTEM, tetA, int1	Yes (U la Roja)	Obodoechi et al.[171]
Abeokuta	153	wildlife	Faeces	*Escherichia coli*	83%	–	No	Ojo et al.[172]
Southeastern Nigeria	975	Livestock and humans	Faecal and hand swabs	Cephalosporin-resistant *E. coli*	41.2%	BlaCTX-M(blaCTX-M-15,blaCTX-M-55, blaCTX-M-64 and blaCTX-M-65), sul1, qnrS1,strB, blaTEM-1b,	Yes	Olorunleke et al.[308]

						tetA-V2 and drfA14		
Southeastern Nigeria	1,846	Livestock and humans	Faecal and hand swabs	Cefotaxime-resistant *Enterobacteriaceae*	84%	–	No	Olorunleke et al.[309]
Enugu	388	Chicken, Cattle and Pig	Faecal samples	*E. coli* O157	13.4%	–	Yes (Tetfund)	Anyanwu et al.[310]
Kwara	1,225	Dairy farm	Raw milk	*E. coli* and *E. coli* O157	48.9% and 2.3%	–	No	Ghali-Mohammed et al.[311]
Oyo	360	Layer farm	Table eggs	*E. coli* O157	9.8%	–	No	Atoyebi et al.[312]
Oyo	108	Milk samples	Powdered milk	*E. coli* O157	2.7%	–	No	Adedeji and Adetunji[313]
Oyo	150	Dairy herds	Raw Milk samples	*E. coli* O26	13.3%	–	No	Faroyin et al.[314]
Oyo	1,000	Chickens	Chicken meats	*E. coli* O157 and *Salmonella*	2.7%	–	No	Ajulo et al.[315]
Ogun	100	Chickens	Faeces	*Salmonella*	22%	blaTEM	No	Shittu et al.[316]
Nasarawa	900	Chickens	droppings, flesh and feed samples	*Salmonella* spp.	10.1%	–	No	Ibrahim et al.[317]

Enugu	340	Chickens	Eggs	*Salmonella* spp.	2.5%	–	Yes (Tetfund)	Okorie-kanu et al.[306]
Benin	250	Chickens	Poultry Meat	*Salmonella* spp.	41.2%	Sul1, Sul2, floR, blaCTX-M, blaTEM, strA	Yes (SA)	Igbinosa et al.[318]
Kwara	900	Chickens	Environment	*Salmonella* spp.	6.4%	–	No	Ahmed et al.[319]
Zaria	105	Chickens	cloacal/rectal swab	*Salmonella* spp.	11.4%	–	No	Ejeh et al.[307]
Delta and Edo	1,440	Shrimp	Whole shrimp	*Salmonella*	14.5%	Class I and II integrase, sul2, catB3, flor, tmp, blaTEM, strB, dfr1 and tetC	Yes (TWAS)	Beshiru et al.[320]
Sokoto	300	Chicken Hatchling	Faecal samples	*Salmonella* spp.	10.7%	Sul1, sul2, sul 3, tetA, fosA7, fosB, OptrA	Yes, UK MRC and DFID	Jibril et al.[321]
Kwara	1,500	Chickens and Pigs	Faecal sample	*Salmonella* spp.	6.6%	QnrB19 and tetA	Yes	Raufu et al.[322]
Twelve States (Ogun, Imo, Edo, Lagos, Rivers, Enugu in the Southern part of Nigeria and Plateau, Kaduna, Kano,	2,615	Chickens	Litter, faeces, dust, water and feed w	*Salmonella* spp.	14%	–	Yes	Fagbamila et al.[323]

Katsina, Gombe and Bauchi in the North)								
Lagos	306	Food animals	Faecal sample	*Salmonella* spp.	23.2%	tetA, blaTEM, qnrB, qnrS	Yes (DTU)	Ajayi et al.[178]
Enugu	400	Chicken, cattle and pigs	Fecal samples	*Ochrobactrum* spp., s *Alcaligenes faecalis* and *Pseudochrobactru m assacharolyticum*	6.5%	Ochrobactrum anthropi ampC gene (blaOCH)	Yes (Agencia Estatal de Investigacion (AEI) of Spain, and the Fondo Europeo de Desarrollo Regional (FEDER))	Alonso et al.[324]
Abia and Imo States	40	Chickens	Chicken samples	*Salmonella Pullorum* and *Salmonella gallinarum*	100	dfrA,dfrG,acc(3)-II	No	Nwiyi et al.[325]
Zaria	390	Chickens and cattle	cloacal swab, Manure	*Enterococcus* spp.	42.8%	TetL, M, K, O and ermB	No	Ngbede et al.[326]
Ibadan	108	Chickens	Poultry droppings	*Pseudomonas* spp.	53.7%	–	No	Falodun and Ikusika[327]
Ibadan	144	Cattle	Faeces	*Pseudomonas* spp.	45%	–	No	Falodun and Musa[328]

Southwestern Nigeria	51	Pig, Cattle, sheep, and Aquaculture	Fecal and aquaculture wastewater	*Pseudomonas* spp.	100%	AmpC, blaTEM, AmpC, blaSHV	No	Falodun et al.[179]
Ibadan	108	Pigs	Faeces	*Pseudomonas* spp.	47.6%	–	No	Falodun and Ikusika[327]
Ibadan	94	Environment	Aquaculture Wastewater	*Pseudomonas* spp.	100%	–	No	Falodun and Ikusika[327]
Benin	144	Environment	Abattoir Wastewater	*Aeromonas* spp.	22.2%	Pse, class 1 integron, blaTEM	Yes (TWAS)	Igbinosa et al.[177]
Benin	144	Environment	Aquaculture Wastewater	*Aeromonas* spp.	18.1%		Yes (TWAS)	Igbinosa et al.[177]
Southeast	129	Fish skin scrapping	Aquaculture	*Aeromonas* spp.	67%	–	No	Anyanwu et al.[329]
Benin	334	Environment	Wastewater	*Vibrio* spp.	50%	–	Yes (TWAS)	Igbinosa et al.[173]
Osun	98	Environment	Fishpond sediments	*E. coli*	100%	–	No	Ajewolo et al.[189]
Osun	40	Environment	Aquaculture Wastewater	*Staphylococcus aureus* and *Enterobacteriaceae*	80%	–	No	Fakorede et al.[330]
Ebonyi	50	Environment	Abattoir effluent waste	*Salmonella* and *Shigella*	100%	–	No	Onuoha et al.[331]

Ebonyi	50	Environment	Aquaculture effluent waste	*E. coli* and *Salmonella*	100%	–	No	Onuoha et al.[332]
Borno	100	Chickens	Tracheal swabs	*Staphylococcus aureus*	54%	–	No	Suleiman et al.[333]
Borno	100	Sheep	Nasal swabs	MRSA	26%	–	No	Jauro et al.[253]
Oyo	18	Animals, humans and Environment	Swabs	MRSA	100%	SCCmecIVa, SCCmecV	Yes	Odetokun et al.[334]
Enugu	291	Pigs	Ear and Nasal swab	Non-aureus *Staphylococcus*	21.9%	–	Yes	Ugwu et al.[335]
Enugu	1,290	Chicken, Pigs and Humans	Carcass swab and Nasal swabs	*S. aureus*	4.1%	mecA	Yes	Okorie-Kanu et al.[336]
Enugu	255	Ready to eat pork, beef, and chicken	Meat sample	*Staphylococcus* spp.	9.4%	–	No	Okoli et al.[337]
Nsukka	108	Chickens	liver, kidney, and muscle	Gentamicin Residue		–	Yes (Tetfund)	Onyeanu et al.[338]
Anambra	400	Pigs	Fecal samples	*Escherichia coli, Klebsiella pneumoniae, Citrobacter freundi, Salmonella enterica, Enterobacter*	75%	blaCTX-M	No	Ada et al.[339]

				cloacae and *Proteus vulgaris*				
Oyo	168	Dairy herd	Non-duplicate milk samples	*Escherichia coli, Enterobacter amnigenus* and *Pseudomonas aeruginosa*	23.8%	blaCTX-M(blaCTX-M-15), blaTEM	No	Amosun et al.[340]
Lagos	238	Cattle, chicken and swine	Faecal samples	*Escherichia coli*	58.8% 39.8% and 34.1%	–	Yes	Adenipekun et al.[341]
Oyo	1,135	Chicken and environment	Biological samples from broiler products and environment	*Salmonella*	23%	–	Yes	Oloso et al.[342]
South-west	36	Environment(poultry farms)	Waste, litter, soil and water	*Escherichia coli*	94%	–	No	Adelowo et al.[343]
Oyo	360	Environment	Table scrapings and swabs of environment	*Aspergillus* spp.	4.46 + 0.24 log C'FUml" 1	–	No	Ogundijo and Adetunji[183]
Total	**23,230**			**Total**			**41.2%**	

Table A4.2: List of antimicrobials tested in the reviewed studies

Antimicrobial class/sub-class tested	Antibiotic agents tested	% of antibiotics
Aminoglycosides	Gentamicin	7.5
	Streptomycin	3.4
	Neomycin	1.3
	Kanamycin	1.3
	Amikacin	0.3
	Tobramycin	0.3
	Spectinomycin	0.6
Ansamycins	Rifampicin	0.3
1st Generation cephalosporins	Cephalothin	0.3
	Cephalexin	0.6
2nd Generation cephalosporins	Cefuroxime	2.5
	Cefoxitin	1.6
3rd Generation cephalosporins	Ceftriaxone	1.6
	Cefotaxime	4.1
	Cefexime	0.6
	Ceftazidime	5.0
	Cefpodoxime	0.3
	Cefepime	1.3
	Cephazolin	0.6
	Ceftiofur	0.3
Macrolides	Erythromycin	3.4
	Azithromycin	0.9
Aminopenicillins	Amoxicillin	0.3

	Ampicillins	6.3
Aminopenicillins + beta-lactamase inhibitors	Amoxicillin-Clavulanic acid	5.3
Penicillins	Penicillins	2.8
	Piperacillin	0.9
	Oxacillin	1.6
	Cloxacillins	0.3
Phosphonic acids	Fosfamycin	0.3
Cyclic polypeptides	Colistin	1.6
First Generation quinolones	Nalidixic acid	3.1
	Flumequin	0.3
Second Generation quinolones	Ciprofloxacin	7.2
	Perfloxacin	0.3
	Levofloxacin	0.3
	Ofloxacin	1.3
	Norfloxacin	0.9
	Enrofloxacin	0.3
Sulphonamides + Diaminopyramides	Sulphonamide + Trimethoprim	6.9
Tetracyclines	Tetracycline	7.2
	Doxycycline	0.9
	Oxytetracycline	0.6
Monobactams	Aztreonam	0.9
Oxazolidinones	Linezolid	0.3
Carbapenem	Meropenem	3.1
	Ertapenem	0.6

Lincosamides	Clindamycin	0.6
Amphenicols	Chloramphenicol*	4.7
	Florphenicol	0.3
Nitrofuran derivatives	Nitrofurantoin*	1.3
Glycylcyclines	Tigecycline	0.3
Glycopeptides	Vancomycin	0.9

* Banned for use in animals

Annex 5. Antimicrobial Resistance Studies in Environmental Health

Figure A5.1: Antimicrobial resistance in environmental health

S/N	Location	Sample type	Bacteria isolated	AMR	ARG	Reference
1	Imo	Rivers and aquaculture wastewater	*Vibrio*	Mezlocillin, Doxycycline, Tetracycline, Carbenicillin and Ampicillin, Kanamycin	–	Chikwendu et al.[344]
2	Ondo	River water	*Bacillus, Micrococcus, Streptococcus, Pseudomonas, Proteus,* and *Staphylococcus* species	Ciprofloxacin, Chloramphenicol, Amoxicillin, Streptomycin, Erythromycin, Co-trimoxazole, Pefloxacin, Ceftriaxone, Nitrofurantoin, Tetracylcine, Ofloxacin	–	Ayandiran et al.[345]
3	Southwestern Nigeria	Wetlands	*Enterobacteriaceae*	Cephalosporins	–	Adelowo et al.[346]
4	Rivers	Pond water	*E. coli, Staphylococcus* spp., *Shigella* spp., *Klebsiella* spp., *Vibrio* spp., *Salmonella* spp.	Lincocin, Rifampicin, Augmentin, Chloramphenicol, Erythromycin, Co-trimoxazole, Streptomycin,	–	Abu and Wondikom[347]

				Pefloxacin, Gentamycin Norfloxacin, Ofloxacin Ciprofloxacin		
5	Ibadan	Hospital wastewater	Coagulase Negative *Staphylococcus* species	Oxacillin, Tetracycline, Erythromycin, Vancomycin, Ciprofloxacin, Sulfamethoxazole-Trimethoprim, Linezolid, Clindamycin, and Chloramphenicol	mecA	Adekanbi et al.[348]
6	Ogun and Benue	Hospital wastewater, rivers and aquaculture effluent waste	*E. coli*, *Proteus mirabilis*, *Stenotrophomonas maltophilia*	Ceftazidime, Tetracycline, Ciprofloxacin, and Sulphamethoxazole-trimethoprim	bla SHV, bla CTX-M-15 bla TEM	Adelowo et al.[175]
7	Ibadan	Hospital untreated wastewater	MDR *Proteus mirabilis*	Ciprofloxacin	qnrD and COL3 M Plasmid	Ajayi-Odoko et al.[349]
8	Southwestern Nigeria	Hospital wastewater, borehole and well water	*Serratia fonticola*, *Enterobacter cloacae* and *Pantoea agglomerans*	Ampicillin, Ceftazidime, Amoxicillin-clavulanic, Trimethoprim &Sulfamethoxazole, Gentamicin, Cefotaxime, Cefpodoxime, Ceftriaxone, Ciprofloxacin, and Tetracycline	–	Banjo et al.[350]
9	Yobe	Sewage from Government hospital	*Escherichia coli*, *Salmonella enteric*,	–	–	Mustapha[351]

			Pseudomonas aeruginosa, *Proteus mirabilis*, *Klebsiella pneumoniea*, *Vibrio cholerae*, *Morganella morganii*, *Shigella* spp., *Citrobacter fruendii* and *Moraxella catarrhalis*			
10	Osun	Well water	*E. coli*	–	–	Odetoyin et al.[334]
11	Osun	Drinking water distribution systems	*Aeromonas*, *Alcaligenes*, *Bacillus*, *Klebsiella*, *Leucobacter*, *Morganella*, *Proteus*	Tetracycline	tetA, tetE and tetM	Adesoji et al.[174,176]
12	Ondo	Drinking water distribution systems	*Pseudomonas*	Gentamicin, Streptomycin, Tetracycline, Ceftiofur, and Sulphamethoxazole	tetA, sul1, blaTEM, aph(3"), Class 1 integron carrying (aminoglycosides (aadA2, aadA1), trimethoprim (dfrA15, dfr7) and sulphonamide (sul1) while the plasmid ranged between 22 and 130 kb)	Adesoji et al.[352]
13	Southwestern Nigeria	Treated and untreated water	*Alcaligenes*, *Acinetobacter*, *Aeromonas*, *Bordetella*, *Brevundimonas*, *Chromobacterium*, *Klebsiella*, *Leucobacter*, *Morganella*, *Pantoae*, *Proteus*, *Providencia*,	Aminoglycosides	(aph(3″)c and aph(6)-1dd	Adesoji et al.[353]

			Psychrobacter and *Serratia*			
14	Southwestern Nigeria	Drinking water distribution system	*Pseudomonas* spp., *Serratia* spp., *Proteus* spp., *Acinetobacter* spp., and *Providencia rettgeri*	Florfenicol	floR	Adesoji and Call[354]
15	Southwestern Nigeria	Sewage sludge samples	–	Chloramphenicol, Erythromycin, sulphamethoxazole residue	–	Olarinmoye et al.[355]
16	Oyo	Soil and Manure	*Klebsiella*, *Escherichia*, *Citrobacter*, *Staphylococcus* and *Shigella*	–	–	Ayandele et al.[356]
17	Southwestern Nigeria (Lagos and Ogun)	Pharmaceutical effluent	*Acinetobacter*, *Proteus mirabilis*, *Klebsiella pneumonia*, *Bacillus* and *Enterobacter*	Augmentin, Nalidixic acid, Ofloxacin, Gentamicin, Nitrofurantoin, Co-trimoxazole, and Tetracycline	Sul1, Sul2, and Class 1 Integron	Obayiuwana et al.[357]
18	South-South Nigeria (Delta)	Soil sediments	*Klebsiella spp.*, *Escherichia coli*, *Staphylococcus spp.*, *Streptococcus spp.*, *Pseudomonas aeroginosa*, *Bacillus subtilis* and *Micrococcus* spp.	Septrin, Chloramphenicol, Sparfloxacin, Ciprofloxacin, Amoxicillin, Augmentin, Gentamycin, Pefloxacin, Ofloxacin, Streptomycin	–	Eghomwanre et al.[358]

19	South-South	Soil	Alpha proteobacteria, Betaproteobacteria, Gamma proteobacteria, Deltaproteobacteria, and the Firmicutes (*Clostridia*)	–	AmpC	Edet et al.[359]
20	South-South (Delta)	Soil	*Escherichia*, *Proteus*, *Pseudomonas*, *Bacillus*, *Micrococcus*, *Staphylococcus*, *Streptococcus* and *Neisseria* spp.	Chloramphenicol, Sparfloxacin, Gentamicin, Pefloxacin, Ofloxacin, Streptomycin, Amoxicillin, Ciprofloxacin, and Amoxicillin-clavulanic	–	Odum et al.[360]
21	South-South (Rivers)	Soil	*Bacillus* spp., *Micrococcus*, *Staphylococcus*, *Pseudomonas*, *Proteus*, *Serratia*, *Escherichia coli*, *Salmonella* and *Klebsiella* spp.	Cefuroxime, Ceftazidime, Cefixime, Cloxacillin	CTX-M, mecA	Chilaka et al.[361]
22	Cross River	Soil and Effluents	*Staphylococcus aureus*, *Escherichia coli*, *Pseudomonas aeruginosa*, *Streptococcus* spp., *Salmonella* spp, *Klebsiella pneumonia*, *Providencia* spp., *Enterobacter aerogenes*, *Proteus* spp., *Chryseobacterium* spp., *Bacillus cereus* and *Serratia marcescens*	Imipenem; Cefuroxime, Augmentin, Levofloxacin, Gentamicin, Ramicef, Cefoxitin, Graxone, Vancomycin and Ofloxacin	–	Andy and Okpo[362]

23	Imo	Effluent and waste dump soils of hospitals	*Klebsiella* spp., *Pseudomonas* spp., *E. coli*, *S. aureus*, Coagulase negative *Staphylococcus* spp., *Streptococcus* spp., *Salmonella* spp., *Proteus* spp., *Citrobacter* and *Enterobacter* spp.	Amoxicillin, Gentamicin, Tetracycline, Erythromycin, and Chloramphenicol	–	Adieze et al.[363]
24	Plateau	Wastewater and Soil	*Escherichia coli*, *Klebsiella* spp., *Proteus*	Ceftazidime, Ampicillin, Augmentin, Cefuroxime, Nitrofurantoin, Ofloxacin, Ciprofloxacin and Gentamicin.	–	Ngene et al.[364]
25	Kaduna	Soil	*Salmonella*	Ampicillin, Tetracycline, Sulphamethoxazole-trimethoprim, and Amoxicillin-clavulanic acid, Chloramphenicol and Gentamicin	–	Nyandjou et al.[365]
26	Benin city	Effluent	*Pseudomonas aeruginosa*	Cefuroxime Amoxillicin Nalidixic acid	–	Isichei-Ukeh and Enabulele[366]
27	Southwest Nigeria	Pond sediment	*Escherichia coli*	–	–	Ajewole et al.[189]
28	Zaria	Effluents	*Escherichia coli* *Klebsiella ozaenae*, *Hapnea alvei* and *Morganella morganii*	Ampicillin Tetracyclin and Cephalothin	–	Yusuf et al.[367]

Table A5.2: Antimicrobials and antimicrobial classes detected in the environment

Class	Antimicrobials	% of antimicrobial resistance reported in the Environment
Aminoglycosides	Gentamicin	8.5
	Kanamycin	1.9
	Streptomycin	4.7
Ansamycins	Rifampicin	0.9
1st Generation cephalosporins	Cefoxitin	0.9
2nd Generation cephalosporins	Cefuroxime	1.9
3rd Generation cephalosporiins	Ceftriaxone	1.9
	Cefpodoxime	0.9
	Cefixime	1.9
	Ceftiofur	0.9
Macrolides	Erythromycin	4.7
Aminopenicillins	Amoxicillin	2.8
	Ampicillin	4.7
Aminopenicillins + beta-lactamase inhibitors	AMC/Augmentin	3.8
Penicillins	Oxacillin	0.9
	Cloxacillin	0.9
	Carbenicillin	0.9
	Mezlocillin	0.9
First Generation quinolones	NA	0.9
Second Generationa quinolones	Ciprofloxacin	5.7
	Levofloxacin	0.9
	Perfloxacin	3.8

	Ofloxacin	6.6
	Norfloxacin	0.9
	Sparfloxacin	0.9
Sulphonamides + Diaminopyramides	Sulphonamide + Trimethoprim	5.7
	Co-trimoxazole	2.8
	Septrin	0.9
Tetracycline	Tetracycline	9.4
	Doxycycline	0.9
Oxazolidinones	Linezolid	0.9
Carbapenem	Imipenem	0.9
Lincosamide	Clindamycin	0.9
	Lincocin	0.9
Amphenicols	Chloramphenicol	6.6
	Florfenicol	0.9
Nitrofuran derivatives	Nitrofurantoin	2.8
Glycopeptides	Vancomycin	1.9

Annex 6. Status of NAP Version 1 Strategic Interventions

NAP 2017–2022 Strategic Intervention	Progress as of August 2023
AMR Awareness and Knowledge	
Establish an evidence-based public communication programme targeting the public and audiences in human, animal and environmental health under the leadership of a tripartite AMR National Behaviour Change Communication Consultative Group (NBCCCG)	Limited progress The NBCCCG has not been formally created A document outlining a communication strategy has been developed; however, funding is a challenge for its implementation
Conduct high-level advocacy visits to policymakers and relevant stakeholders to create budget lines and source for required financial and technical support for AMR awareness programmes in the 36 States, FCT and at the Federal level	Not completed
Implement communication campaigns to increase awareness of appropriate antimicrobial use and the adoption of infection prevention measures among the public, policymakers, human, animal and environmental professionals and other relevant stakeholders in communities, schools, workplaces and health facilities	Limited progress There are limited awareness activities in the human and animal health sectors; awareness campaigns are typically centred around World Antimicrobial Awareness Week
Augment the knowledge and understanding of AMR, IPC, biosecurity and antimicrobial stewardship among human, animal, and environmental health care and allied professionals	Limited progress
Surveillance, Laboratory and Diagnostic Capacity	
Establish a national coordination structure for surveillance of AMR	Completed in human health A national surveillance network has been completed in human health; however, the number of participating facilities needs to be expanded.
Develop a multisectoral surveillance implementation plan	Not started
Develop sector-specific surveillance protocols to detect emerging, re-emerging and changing trends in AMR	Not completed
Prepare and implement a Human Resource Development Plan for AMR Surveillance	Not started

Set up an NCDC National Reference Laboratory	Completed
Standardise laboratory capacity for monitoring AMR (Human, Terrestrial and Aquatic Animal, Food and Environment)	Not completed
Enrol in GLASS	Completed
Contribute National Surveillance data to GLASS	Completed
Capacity Building of AMR Researchers	Limited Fleming Fund Fellowship programmes have supported AMR researchers and their projects.
Periodically identify and articulate surveillance gaps and AMR burden estimation needs	Not completed Some assessments have been conducted, but a more systematic approach needs to be adopted, and findings must be disseminated to understand progress.
Secure funding from relevant public and private sources	Limited progress Funding supports comes primarily form donors and international partners, resulting in disparate funding opportunities across the sectors.
IPC, WASH, Biosecurity and Immunisation	
Establish a National Infection Prevention and Control Programme	Completed
Strengthen IPC practices	Not completed Limited government funding is a barrier to assessing and increasing IPC capacity through education and training.
Improve IPC education and training	Not completed Limited government funding is a barrier to expanding IPC capacity building through education and training.
Introduce IPC programme into veterinary practice and aquatic and terrestrial animal husbandry	Not completed
Improve IPC and farm biosecurity practices	Not completed
Include hygiene and infection prevention and control as core (mandatory) content in training and education of veterinary professionals and animal health practitioners	Not completed
Improve IPC education and training for veterinary practice and aquatic and terrestrial animal husbandry	Not completed

Support implementation of food safety guidelines at the community level	Not completed
Improve access to potable water in communities and within healthcare facilities	Not completed
Ensure water quality standard	Not completed
Improve waste management practices	Not started
Support safe disposal and management of sewage and faecal matter	Not started
Promote hand hygiene at the community level and in schools	Limited progress
Scale up immunisation coverage in human and animal health sectors	Not completed
Increase range of available vaccines in–country for both human and animal health	Not completed
Support surveillance of vaccination programmes in human and animal health to enable appropriate vaccination	
Access and Optimal Use of Antimicrobials	
Strengthen regulatory systems to promote rational antimicrobial use, infection prevention and antimicrobial stewardship among human health, animal health, environment and allied professionals	Limited progress
Promote optimal procurement and distribution of quality antimicrobials and diagnostics for human and animal use	Limited progress
Enhance local production of quality antimicrobial agents and diagnostics for human and animal use	
Expand NHIS coverage to include more enrollees	Limited progress
Promote the use of up-to-date treatment guidelines and ensure prudent use in humans and animals	Not completed
Promote optimal prescribing and dispensing of antimicrobials in humans and animals	Not completed
Strengthen the capacity of regulatory agencies across ‘One Health’ sectors (i.e. human, animals, food products and environment)	

Enhance intersectoral coordination and collaboration between/among regulatory agencies	
Research and Development	
Commission researchers and research institutions to undertake research in identified gaps	
Assess available AMR funding mechanisms	

Annex 7. Interviews with Key Informants from One Health Sectors

One Health Trust interviewed key 33 informants from diverse fields directly or indirectly related to mitigating AMR in Nigeria. The interviews, conducted between March 23 and May 31, 2023, included the following respondents:

- Experts from One Health sectors: human health (five), animal health (five), and environmental health (four)
- Six experts whose job designation or description directly mentions AMR, such as the AMRCC Chair and AMR Surveillance Fellow
- Four experts from the World Health Organization (one expert each from animal and environmental health sectors, and two from human health)
- Three representatives from NGOs primarily focused on human health, including both social and medical aspects of human health.
- Two academic experts
- One representative from NAFDAC overseeing human and veterinary medicines.

The qualitative interviews consisted of open-ended questions about several aspects of AMR surveillance, AMU, current and future policies, mitigation strategies, and respondents' own professional work experiences. The following word clouds were created using the answers given during the interviews. Despite their limitation in providing a comprehensive snapshot of the responses, the word clouds identified words such as *funds*, *sector*, *surveillance*, *environmental*, *and vaccines* among others in two main categories: challenges and recommendations (Figures 15 and 16).

Figure A7.1: Key informant interviews – words most commonly associated with challenges

Figure A7.2: Key informant interviews – words most commonly associated with recommendations

The following factors were cited most frequently, both among challenges faced in the current set-up and among recommendations for future action and policy:

Funding

Challenges with funding were the most cited among all factors of concern. Beyond a general lack of sufficient funding to carry out AMR activities — including AMR awareness, laboratory infrastructure, AMR surveillance, and vaccine delivery, among others — other funding strategy issues were also highlighted, such as the lack of a multisectoral AMR fund and the high out-of-pocket expenditure for healthcare seekers in the absence of a stronger national health insurance scheme.

Recommendations included making funds available to lower levels of health administration to carry out AMR-related activities, channelling taxes collected from the pharmaceutical industry into AMR activities, and allocating a budget for antimicrobial stewardship and public health education.

> *For human health, we need to improve health insurance and funding. Without health insurance, it is difficult to capture a real picture of AMR in the communities, so improving access to health through health financing is necessary. Microbiology tests also need to be subsidised because many people cannot afford the culturing tests. Financing for AMR is mainly by partner and donor agencies. The government has not put sufficient funds into it.*
>
> – An AMR programme manager

Awareness or Communication

Lack of awareness around AMR was cited as a major challenge in multiple contexts and population groups, such as farmers, health professionals, policymakers, and the general public. Raising awareness around AMR at all levels, but especially in the community, was the most cited recommendation for the future.

> *We need to focus a lot on awareness and outreach. For instance, if there is awareness among the public, they can demand stewardship from their doctors, government, and other stakeholders, which will bring a great behavioural change.*

– An NGO representative

Disparities Between Sectors

Several respondents commented that the three sectors — human health, animal health, and environmental health — were unequal in many aspects, such as capacity, funding, and progress made in AMR activities. While the human health sector is seen to be the most dominant in terms of diagnostic capacity and funding resources through sponsors, the environmental health sector is seen to be the most lacking on the same terms. The AMR Secretariat being placed in the premises of the NCDC is also seen by some respondents as potentially disadvantageous to the animal and environmental health sectors.

> *In the environmental sector, there is low awareness about AMR, they also lack structures, protocols, and surveillance data to know the true extent of the AMR problem in the environment. They also have a challenge with funding because they don't have those kinds of partnerships with the donors.*

– A member of the technical working group for the planning of NAP 2.0

Multisectoral Coordination

Despite progress since the development of the NAP on AMR, many respondents commented on insufficient communication across sectors as a critical barrier to achieving AMR mitigation goals using the One Health approach. Challenges include the lack of participation in projects hosted by other sectors, lack of feedback or response from specific sector representatives, and conflicting priorities among sectors. Bridging the communication gap and improving collaboration and commitment across sectors was seen as important by several respondents, who suggested a better AMR governance structure that engages all sectors equally and uses their diverse resources better.

> *There is a need to move from one sector driving the whole process to a more integrated One Health approach, with a neutral One Health secretariat (hosted under the presidency) to help the One Health approach and reduce bottlenecks.*

– A programme manager

Diagnostic Capacity

Inadequate microbiology diagnostics capacity was seen as a barrier to achieving AMR mitigation goals like comprehensive AMR surveillance. Respondents cited challenges with a lack of diagnostic equipment and resources, a lack of access to diagnostic facilities for farmers and hatcheries, and a lack of trained staff to conduct tests. Expanding laboratory capacity across the country for all sectors was recommended, along with strengthening current diagnostic capacity.

> *Consumables were an issue because, after data collection, there would still be no consumables (tools) to process samples. Some equipment was provided to labs, but it wasn't enough to conduct the surveillance.*
>
> – An AMR Surveillance Fellow

Beyond the above summary of the main challenges and recommendations mentioned in the key informant interviews, respondents also touched upon other factors such as the lack of enforcement of AMR regulations, the importance of building political visibility and advocacy to advance the AMR cause, and the need for conducting more AMR research in Nigeria to develop policies tailored to the Nigerian context.

FEDERAL MINISTRIES OF AGRICULTURE AND FOOD SECURITY; ENVIRONMENT; AND HEALTH AND SOCIAL WELFARE

National Action Plan (NAP) on Antimicrobial Resistance: Situational Analysis and Key Recommendations for the Development of NAP 2.0

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