MAAP
Mapping AMR & AMU Partnership

Annual Report

National situation of antimicrobial resistance and consumption
Analysis from 2016-2018

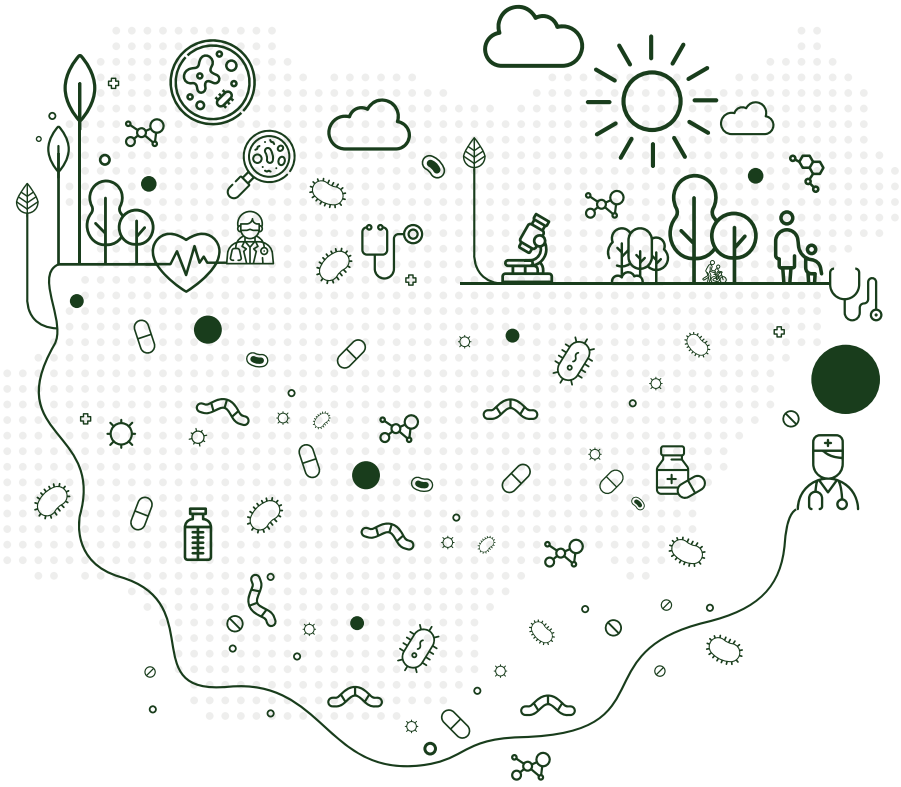
The Fleming Fund Regional Grants
UKaid from the British people
African Union
AFRICA CDC Centres for Disease Control and Prevention Safeguarding Africa's Health
ASLM African Society for Laboratory Medicine
ECOWAS
InSTEDD Innovative Support To Emergencies Diseases and Disasters
IQVIA
ONEHEALTH TRUST

Year: 2022

Nigeria (2016-2018)

NIGERIA

Fleming Fund Regional Grant (Round 1)



Mapping Antimicrobial Resistance and Antimicrobial Use Partnership

African Society for Laboratory Medicine
Africa CDC
WAHO
ECSA-HC
Center for Disease Dynamics, Economics and Policy
IQVIA
InSTEDD

The country report summarises the analysis of retrospective data on AMR and AMC commissioned in the context for Fleming Fund Regional Grant (Round 1) programme.

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Abbreviations

AMC	Antimicrobial Consumption
AMR	Antimicrobial Resistance
AMRCC	Antimicrobial Resistance Coordinating Committee
AMU	Antimicrobial Use
ASLM	African Society for Laboratory Medicine
ASP	Antimicrobial Stewardship Programme
ATC	Anatomical Therapeutic Chemical
AWaRe	Access, Watch, and Reserve
CDDEP	Center for Disease Dynamics, Economics and Policy
CI	Confidence Interval
CLSI	Clinical and Laboratory Standards Institute
CMS	Central Medical Store
CSF	Cerebrospinal Fluid
DDD	Defined Daily Dose
DID	DDD per 1 000 inhabitants per day
DRI	Drug Resistance Index
ECSA-HC	East, Central and Southern Africa Health Community
EML	Essential Medicines List
EQA	External Quality Assessment
EUCAST	European Committee on Antibiotic Susceptibility Testing
FDC	Fixed Dose Combinations
GLASS	Global Antimicrobial Resistance Surveillance System
HIS	Hospital Information System
InSTEDD	Innovative Support to Emergencies, Diseases and Disasters
KIIs	Key Informant Interviews
LIS	Laboratory Information System
LMIC	Low- or Middle-Income Country
LQMS	Laboratory Quality Management System
MAAP	Mapping Antimicrobial resistance and Antimicrobial Use Partnership
MoH	Ministry of Health
NEFDAC	National Agency for Food and Drug Administration and Control
NGO	Non-governmental Organisation
OR	Odds Ratio
QA	Quality Assessment
QC	Quality Control
QMS	Quality Management System
RSN	ResistanceMap Surveillance Network
SLIPTA	Stepwise Laboratory Improvement Process Towards Accreditation
SLMTA	Strengthening Laboratory Management Towards Accreditation
SOP	Standard Operating Procedure
STG	Standard Treatment Guidelines
WHO	World Health Organisation

Executive Summary

Antimicrobial resistance (AMR) is a major public health concern that needs to be urgently addressed to avoid needless suffering and the reversal of medical advancement in fighting infectious diseases. A clear link has been shown between the misuse of antimicrobials and the emergence of AMR. However, owing to the limited capacity of health systems and technological hurdles, the availability of comprehensive and robust AMR, antimicrobial use (AMU) and antimicrobial consumption (AMC) data in many low- and middle- income countries (LMICs), is generally lacking and there remains significant uncertainty as to the burden of drug resistance.

The Fleming Fund, a 265-million-pound United Kingdom aid, supports a range of initiatives to increase the quantity and quality of AMR data in LMICs. The Regional Grant (Round 1) activities in Africa are led by The African Society for Laboratory Medicine (ASLM) and implemented by the 'Mapping Antimicrobial resistance and Antimicrobial use Partnership' (MAAP) consortium. This report summarises the activities undertaken by MAAP during implementation of the Regional Grant, and aims to determine national AMR, AMC and AMU surveillance capacity, resistance rates and trends as well as assess the antimicrobial flow in Nigeria during 2016-2018.

Nigeria had approximately 34 423 laboratories in the national laboratory network during the study period, of which 264 were reported to have capacity for bacteriology testing. Based on self-reported information from 73 laboratories, functioning and quality compliance were assessed to understand the laboratory preparedness for AMR surveillance.

AMR rates presented are based on the analysis of antimicrobial susceptibility results 0f 23 963 positive cultures obtained from 25 laboratories. High AMR rates were noted for third-generation cephalosporin-resistant Enterobacterales (67-73%) and methicillin-resistant Staphylococcus aureus (MRSA) (58-82%). Moderate to high levels of resistance were noted for carbapenem-resistant Pseudomonas aeruginosa (30-53%) and fluoroquinolone-resistant Salmonella species (46-75%). There was no significant association between the available patient variable and AMR. All results should be interpreted with caution as the participating laboratories were at different levels of service and had variable testing capacity.

AMC is measured as the quantity of antimicrobials sold or dispensed, whereas AMU reviews whether antimicrobials are used appropriately based on additional data such as clinical indicators. Only AMC data were retrievable at selected sentinel pharmacies as AMU data were not obtained due to a lack of a unique patient identifier and tracking systems across hospital departments. The collected national AMC data from National Agency for Food and Drug Administration and Control (NAFDAC) was not analysed as the datasets missed key essential pack size information, therefore MAAP was unable to calculate DDDs consumed (primary requirement for AMC analysis). The analysed AMC data in this report presents results from aggregated pharmacy-level AMC datasets. The average total AMC consumption levels in the sampled pharmacies between 2016-2018 was 4 479 320.2 defined daily doses (DDDs), ranging from 4 507 217.7 in 2016; 4 446 350.0 in 2017 and 4 484 392.9 in 2018. Antimicrobial utilisation by the World Health Organisation (WHO) Anatomical Therapeutic Chemical (ATC) classification was highest for combinations of penicillins, including beta-lactamase inhibitors (range 14.9% to 16.8%), followed by nitroimidazole derivatives (range 12.2% to 18.3% in 2017) and finally, fluoroquinolones (range 11.3% to 16.9%). The top five most consumed antimicrobials were Metronidazole, Amoxicillin/Clavulanic acid, Cefuroxime, Ciprofloxacin and Amoxicillin. Together, they account for >55% of the total consumption share thus, suggesting lack a of variation. This consumption trend could potentially increase AMR.

The total AMC came from 54.2% 'Access', 45.8% of 'Watch' and <0.1% of 'Reserve' antibiotics. This data indicated a relatively high consumption of 'Watch' category antibiotics at the possible expense of utilisation of 'Access' category antibiotics. This finding led to the sampled pharmacies, on average, failing to meet the WHO minimum recommended consumption threshold of 60% and it was identified that the public hospitals were responsible for <60% 'Access' category consumption. Consumption of only one antibiotic, Tigecycline, from the 'Reserve' category of antibiotics was observed. Thirteen combinations of two or more broad-spectrum fixed-dose combinations (FDC) of antimicrobials were identified that were not recommended for clinical utility but were nevertheless consumed in the pharmacies. Of those, Ampicillin/Cloxacillin was most consumed (mean DDD of 157 091.4).

The drug resistance index (DRI) is a simple metric based on aggregate rates of resistance and measured on a scale of 0-100, where 0 indicates fully susceptible while 100 indicates fully resistant. The DRI estimate was found to be high at 66% (95% CI, 59.9-72.0%) thus implying low antibiotic effectiveness, which is a threat to effective infectious disease management and calls for urgent policy intervention.

The following recommendations should be noted by policy makers and healthcare providers to further strengthen AMR and AMC surveillance, for AMR mitigation in the country.

- To strengthen the delivery of services by the laboratories, we recommend that all laboratories are mapped across a range of indicators, including population coverage, infectious disease burden, testing capabilities, and quality compliance. This would inform decision makers on unmet needs and decide a way forward for expansion of the laboratory network.
- For high-quality microbiology testing and reporting, staff training on laboratory standards, ability to identify common pathogens and data management skills are essential. Capacity building of staff may be completed through in-house expertise or outsourced to external organisations or tertiary facilities.
- To strengthen AMR surveillance, it is essential to curate the right data and generate evidence. We recommend data collection through standardised formats at all levels (laboratories, clinics and pharmacies) as well as the use of automation for data analyses. We also recommend establishing a system of assigning permanent identification numbers for patients' tracking over time.
- Due to limitations in the number of facilities assessed, MAAP, in alignment with the WHO guide on facility AMU assessment, would recommend that future AMU and AMC surveillance attempts in the country be conducted through point prevalence surveys on a larger scale to give a nationally representative portrait of antimicrobials use in the country.
- MAAP recommends that a comprehensive guiding policy for routine AMC data surveillance be required in the country. The policy should aim to guide on, at the minimum, AMC data reporting variables, routine data cleaning and reporting practices to minimise the amount of time spent standardising and cleaning the data before routine surveillance exercises.
- To make future AMC surveillance more time- and cost-efficient, hospitals could consider converting to electronic systems and ensure such systems have the capabilities to transfer data across systems and/or produce user-friendly reports on AMC.
- MAAP recommends that the country's Antimicrobial Resistance Coordinating Committee (AMRCC) consider the introduction of facility-level antimicrobial stewardship programmes (ASPs) to regulate the use of these broader spectrum antibiotics and educate prescribers on the importance of reserving them to maintain efficacy.
- From the assessment, an overwhelming majority of antibiotics consumed within the 'Access' and 'Watch' categories were in the top five antibiotics in each category. Such a consumption pattern could be postulated to be sub-optimal as the evolutionary pressure driving resistance would be focused only on the narrow band of antibiotics consumed. It is therefore recommended that the country's ASP explores ways to ensure a wider spread in consumption of the antibiotics within each WHO AWaRe category.
- MAAP recommends an urgent review be conducted by the ministry of health (MoH) and the AMRCC to assess the availability of the 'Reserve' category antibiotics in the country. This may subsequently lead to the revision of the country's essential medicines list (EML) and treatment guidelines to include these vital antibiotics, if deemed necessary. This approach will ensure that the most vital antibiotics are available for all patients.
- National stewardship programmes led by the AMRCC could conduct educational campaigns for healthcare practitioners to ensure that they are aware of the full spectrum of antimicrobials available in the county's EML.

Overview

The Fleming Fund Grants Programme

The Fleming Fund Grants Programme is a United Kingdom-sponsored initiative aimed to address the critical gaps in surveillance of antimicrobial resistance (AMR) in LMICs in Asia and sub-Saharan Africa.1 The programme included Regional Grants, Country Grants and the Fleming Fellowship Scheme. Mott MacDonald was the authority for grant management.

The Fleming Fund Regional Grants Round 1 Programme

The Fleming Fund Regional Grant Round 1 covered four regions (West Africa, East and Southern Africa, South Asia and South-East Asia) and aimed to expand the volume of data available on AMR and AMU.

Problem Statement

The quantum and quality of surveillance data are sub-optimal in LMICs where AMR rates are typically lacking.2 This hinders the assessment of the current treatment efficacy and understanding of the drivers of AMR. Additionally, it impacts the adoption of appropriate policies to improve AMU, which has a downstream impact on patient care. However, in most LMICs, there are institutions (academic, research, public and private health facilities, etc.) which have, at times, been collecting data on AMR for decades.

While the 'hidden treasure' is simply inaccessible for use in large-scale analytics, collecting and, where necessary, digitising data from these institutions, has the potential to establish baselines of AMR across a wide range of pathogen/drug combinations and assessment of spatiotemporal trends. Likewise, retrieving information through prescriptions or sales in healthcare facilities, should provide a wealth of information on the potential drivers of AMR. Linking susceptibility data with patient information can further provide a valuable understanding of the current treatment efficacy, which can inform evidence-based policy and stewardship actions.

MAAP

Against this background, the Regional Grant Round 1 aimed to increase the volume of data available to improve spatiotemporal mapping of AMR and AMU across countries in each region and establish baselines. The programme was implemented by the (MAAP), a multi-organisational consortium of strategic and technical partners. ASLM was the Lead Grantee for the programme.3

MAAP's strategic partners included ASLM, the Africa Centres for Disease Control and Prevention, West African Health Organisation, the East Central and Southern Africa Health Community (ECSA-HC). The technical partners were the Center for Disease Dynamics, Economics and Policy (CDDEP), IQVIA, and Innovative Support to Emergencies, Diseases and Disasters (InSTEDD). ASLM oversaw consortium activities and ensured the fulfilment of ethical considerations and completion of data sharing agreements with the participating countries.

MAAP was set up to collect and analyse historical antimicrobial susceptibility and consumption or usage data collected during between 2016-2018 in each country, and to understand the regional landscape. MAAP's primary focus was to determine the levels of resistance of the bacterial priority pathogens that were listed by the WHO and other clinically important pathogens. Through standardised data collection and analytical tools, MAAP gathered, digitised and collated the available AMR and AMC data between 2016-2018. Based on feasibility, MAAP set out to collect information on AMC instead of AMU.

The results of this analysis contribute to the determination of baselines and trends for AMR and AMC, AMR drivers, as well as critical gaps in surveillance. The study recommendations aim to increase country-level capacity for future collection, analysis and reporting of AMR and AMC or AMU data.

Fourteen African countries across West Africa (Burkina Faso, Nigeria, Nigeria, Senegal and Sierra Leone), East (Kenya, Tanzania and Uganda), Central (Cameroon and Gabon), and Southern Africa (Eswatini, Malawi, Zambia and Zimbabwe) were included in MAAP activities.

Aim

To determine the spatiotemporal baselines and trends of AMR and AMC in Nigeria using the available historical data.

Specific Objectives

- To assess the sources and quality of historical AMR data generated routinely by the national laboratory network of Nigeria, including the public and private human healthcare sector
- To collect, digitise and analyse retrospective data from selected facilities using standardised electronic tools; to describe the completeness and validity of AMR data in selected facilities

- To estimate the country-level AMR prevalence and trends for WHO priority pathogens, other clinically important and frequently isolated pathogens as well as comparing countries on spatiotemporal maps
- To describe the in-country antimicrobial flow and highlight the status of the in-country AMC and AMU surveillance
- To quantify and evaluate the trends of AMC and AMU at national and pharmacy levels
- To assess the relationship between AMC and AMR through the DRI
- To assess the drivers of AMR

Outcome measures

- Number of laboratories from the national network generating AMR data and proportion of laboratories reporting compliance to standards of quality and bacteriology testing
- Level of AMR data completeness and validity among laboratories selected for AMR data collection
- AMR prevalence and trends for the WHO priority pathogens, other clinically important and frequently isolated pathogens
- A semi-quantitative analysis of the in-country status in AMC and AMU surveillance
- Total consumption of antimicrobials (defined daily dose) in addition to AMC and AMU trends over time at national and pharmacy levels country-level DRI
- Association between patient factors and AMR

The results are intended to serve as a baseline for prospective AMR, AMC and AMU surveillance, as well as to highlight any existing gaps and recommend measures for surveillance strengthening.

Key engagements and activities

The Regional Grants Round 1 engagement commenced with a kick-off meeting with representatives from Mott MacDonald (Grant Managers), MAAP consortium (for Africa Region) and CAPTURA ('Capturing Data on AMR Patterns and Trends in Use in Regions of Asia') consortium for the Asia Region. The meeting was held in Brighton, England, in February 2019. In April 2019, MAAP convened a stakeholder consultation in Addis Ababa, Ethiopia with representatives from the 14 participating countries in Africa to discuss continental efforts on AMR control and the implications of the Regional Grant. Over the next year and a half, workshops were held in each country to finalise data sharing agreements and methodologies. The workshops brought together representatives from MAAP and the countries, including representatives from the MoH, AMR coordinating committees, health facilities, laboratories and pharmacies. This was followed by site selection and data collection in each country. Data analysis was conducted by the technical partners. The final results were then shared through dissemination meetings (Figure 1).

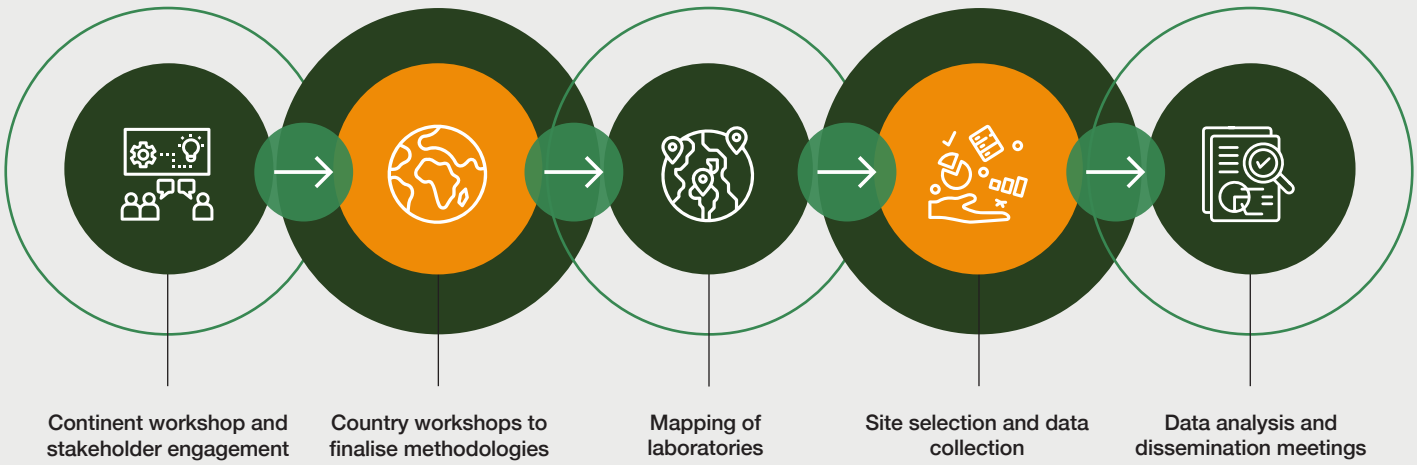


Figure 1: Key engagements and activities

Ethical issues and data sharing agreements

To ensure that ethical conduct, confidentiality, use and ownership of the data are regulated and adhered to during the project, a data-sharing agreement (DSA) was signed with the ministry of health. The DSA facilitated clear communication and established additional safeguards to the management of the collected data (see Appendix 1).

Country Profile

Health and Demographic Profile

As of 2020, Nigeria was estimated to have a population of 206 million inhabitants with a life expectancy of 55 years. The country has a high infectious disease burden with a TB incidence of 219 per 100 000 and an HIV prevalence of 1.3%. The country has a physician density rate of 0.38 per 1 000 inhabitants and nurses density rate of 1.5 per 1 000 inhabitants. With a universal health coverage index of 44, Nigeria appears to have a below average coverage of essential services (Table 1).

Table 1: Health and demographic profile of Nigeria

	Nigeria		Comparator values (most recent year)*		
	Year	Value	India	Argentina	United States
Population	2020	206 ,139 ,587	1 ,380 ,004 390	45 376 763	329 ,484 ,123
Life expectancy during the study period, total (years)	2019	55	70	77	79
Universal health coverage service index (0-100)	2019	44	61	67	83
GDP per capita (current US$)	2020	2 097.09	1 ,927.7	8 579.0	63 ,593.4
Immunisation, DPT (% of children ages 12-23 months)	2019	57	91.0	86.0	94.0
Incidence of tuberculosis (per 100 000 people)	2020	219	188.0	31.0	2.4
Prevalence of HIV, total (% of population ages 15-49)#	2020	1.3	0.2*	0.4 2020	0.4 2019
Primary education (%)#	2010	73.79	94.6	98.6	100
Physicians density (physicians per 1 000)#	2018	0.38	0.93	4.0	2.6
Nurses density (nurses and midwives per 1 000)#	2015	1.5	2.39	2.60	15.69

Sourced from World Bank[4,5,6] and *National AIDS Control Organisation[7]
#Data for some country parameters may not necessarily be of the same year (but sourced from the most recently available information between 2017-2020).

Policy frameworks

In May 2015, the World Health Assembly approved the Global Action Plan on Antimicrobial Resistance (GAP-AMR).[8] Later that year, the WHO launched the Global Antimicrobial Resistance Surveillance System (GLASS) to support the implementation of the GAP-AMR and strengthen AMR surveillance and research.[9] GLASS provides standardised methodologies for AMR data collection and analysis and encourages countries to share their data on the global surveillance platform. GLASS has various modules and tools including emerging AMR events, AMC, and promotes integration with surveillance in the animal and environment sectors.

Nigeria enrolled in GLASS in April 2017 and has been submitting national AMR surveillance data to GLASS in all subsequent data calls until 2019. Nigeria has a National Action Plan for Antimicrobial Resistance (2017-22)10 whose goal is to reduce, prevent and slow the evolution of resistant organisms and their impact on healthcare. Nigeria's National Action Plan for Antimicrobial Resistance also aims to ensure optimal use and improved access to effective, safe and quality-assured antimicrobials for continued successful management of infections.

Part A: Antimicrobial Resistance

Section I: Laboratory assessment

Objective

To assess the sources and quality of historical data on AMR generated routinely by the national laboratory network of Nigeria, including the public and private healthcare sectors.

Methodology

Initially, up to 16 laboratories (two reference, four private and 10 public) were expected to be included in the study for the purpose of AMR data collection. Ultimately, only those laboratories most likely to guarantee the highest level of data quality were selected. Country-specific circumstances, the actual number of selected laboratories, and their affiliations and levels necessitated some adjustments in the study protocol.

During the initial stages of in-country work, the laboratory network was mapped with support from the country's MoH. An inventory of laboratories in the tiered network was created and laboratories capable of conducting antimicrobial susceptibility testing (AST) were identified. A survey was administered to the identified laboratories, with the aim of obtaining site-specific details and assessing the laboratories on five aspects: status of commodities and equipment, quality management systems (QMS), personnel and training, specimen management and laboratory information systems (LIS) (AMR Appendix 2). Based on self-reported information on the above parameters, each laboratory was assigned a readiness score for AMR surveillance (AMR Appendix 3). The scoring scheme was standardised across all participating countries. The final selection of laboratories for data collection was made by the MoH and was not necessarily based on laboratory rankings.

Results

Mapping and selection of laboratories

During the initial stages of in-country work in Nigeria, 34 423 laboratories were mapped to the national laboratory network. An eligibility questionnaire was sent to 264 laboratories identified as having capacity for bacteriology testing. Of the 73 laboratories that responded to the questionnaire, the majority were affiliated with the government (Table 2, Supplementary Table 1). The laboratory readiness scores of the surveyed laboratories varied widely (range 13.2-84.2%). Twenty-five laboratories were selected for data collection (Figure 2). The laboratories named in the tables are listed in order of decreasing laboratory readiness scores.

Table 2: Laboratory readiness scores

Surveyed laboratories*	Laboratory readiness score (%)	Level of service	Affiliation
Selected			
Medical Microbiology &and Parasitology Laboratory Ladoke Akintola University of Technology Teaching Hospital Idi seke Osogbo Osun State(LAUTECH)	84.2	Regional/Intermediate	Government
Kubwa General Hospital Laboratory(Kubwa)	81.6	District/Community	Government
Medical microbiology laboratory, Babcock university teaching hospital(Babcock)	81.6	Regional/Intermediate	Private
National Hospital Abuja(Abuja)	81.6	Regional/Intermediate	Government
Muhammad Abdullahi Wase Teaching Hospital(Muhammad Abdullahi)	78.9	Regional/Intermediate	Government
Dept Of Medical Microbiology And Parasitology, University Of Port Harcourt Teaching Hospital(Port Harcourt)	78.9	Regional/Intermediate	Government
Bwari General Hospital Laboratoty Unit, Abuja(Bwari)	78.9	District/Community	Government
Department of Medical Microbiology and Parasitology, Lagos University Teaching Hospital(UHT Lagos)	76.3	Regional/Intermediate	Government
Medical Laboratory Department, Niger Delta University Teaching Hospital, Bayelsa state(UTH Niger Delta)	76.3	Regional/Intermediate	Government
Department of Medical Microbiology and Parasitology, University College Hospital Ibadan(UCH Ibadan)	73.7	Regional/Intermediate	Government
Medical Microbiology and Parasitology Laboratory, University of Ilorin Teaching Hospital Ilorin (UITH Ilorin)	73.7	Reference	Government
Medical Microbiology and Parasitology, OAUTHC, Ile-Ife(OAUTHC)	71.1	Regional/Intermediate	Government
Maitama District Hospital Laboratory, Abuja(Maitama)	71.1	District/Community	Government
General Hospital Lapai Niger State Nigeria(Lapai)	68.4	District/Community	Government
Medical Microbiology Laboratory, Aminu Kano Teaching Hospital, Kano(Aminu Kanu)	68.4	Regional/Intermediate	Government
Federal Medical Centre Birnin Kebbi, Kebbi State(FMC Birnin)	65.8	Regional/Intermediate	Government
Minna General Hospital, Niger state (Minna)	63.2	District/Community	Government
Microbiology laboratory, UNTH Ituku-Ozalla, Enugu(UNTH Enugu)	63.2	Regional/Intermediate	Government
Sir Muhammad Sinusi Specialist Hospital kano (Sinusi)	63.2	Regional/Intermediate	Government
Microbiology and Parasitology Laboratory, UCTH Calabar(UCTH Calabar)	63.2	Regional/Intermediate	Government
Murtala Muhammad Specialist Hospital Kano¬(Murtala Muhammad)	60.5	Regional/Intermediate	Government

Medical Laboratory Federal Neuropsychiatric Hospital, Yaba(FNPH Yaba)	60.5	Regional/Interm¬-ediate	Government
Medical Microbiology and Parasitology lab, Federal Medical Centre Bida, Niger state(FMC Bida)	57.9	Reference	Government
Federal Medial Centre Azare, Bauchi State(FMC Azare)	55.3	Regional/Intermediate	Government
Federal Medical Centre Abeokuta FMC Abeokuta)	47.4	Regional/Intermediate	Government
Not selected	Not selected	Not selected	Not selected
Albarka Diagnostic Center	71.1	Regional/Intermediate	Private
Ampat Diagnostic Medical Laboratory	68.4	District/Community	Private
Infectious Diseases Hospital (IDH) Bayara, Bauchi	68.4	District/Community	Government
Dambatta General Hospital Laboratory, Kano state	68.4	District/Community	Government
Bori Zonal Hospital Laboratory, Rivers State	65.8	District/Community	Government
Sagbama General Hospital Bayelsa	65.8	District/Community	Government
Sheik Muhammad jidda general hospital laboratory	65.8	District/Community	Government
Specialist Hospital Jalingo Taraba State.	65.8	Regional/Intermediate	Government
Koko General Hospital, Med Laboratory Department, Kebbi	65.8	District/Community	Government
Laboratory Unit, Nyanya General Hospital, Abuja	63.2	District/Community	Government
Ayodele Laboratory	60.5	Regional/Intermediate	Private
General Hospital Tafawa Balewa, Bauchi State	60.5	District/Community	Government
Federal Neuropsychiatric Hospital Calabar, Cross River State	60.5	Regional/Intermediate	Government
Medical Laboratory Department, Neuropsychiatric Hospital, Aro, Abeokuta	57.9	Regional/Intermediate	Government
Zing General Hospital Taraba state	57.9	District/Community	Government
Epe General Hospital	57.9	District/Community	Government
General Hospital Wukari,Taraba State	57.9	District/Community	Government
Karshi General Hospital Lab, Abuja	55.3	District/Community	Government
Kauje General Hospital, Kebbi	52.6	District/Community	Government
Yauri General Hospital, Kebbi state	52.6	Regional/Intermediate	Government
Martha Bamaiyi General Hospital Zuru, Kebbi	52.6	District/Community	Government
Medical Laboratory Department, General Hospital New Bussa, Borgu LGA, Niger State.	52.6	District/Community	Government
Ikorodu General Hospital	50	District/Community	Government
Department of Medical Microbiology, Federal Teaching Hospital, Ido-Ekiti	50	Regional/Intermediate	Government
Wasagu General Hospital, Kebbi	50	District/Community	Government
Federal Medical Centre, Yenagoa	50	Regional/Intermediate	Government

Federal Medical Centre Ebute Metta Medical Laboratory	47.4	Regional/Intermediate	Government
Diete-Koki Memorial Hospital	47.4	District/Community	Government
Orile Agege General Hospital	47.4	District/Community	Government
Bida General Hospital Niger	44.7	District/Community	Government
Laboratory Department, Specialist Hospital, Bauchi	44.7	Regional/Intermediate	Government
Aisha Muhammadu Buhari General Hospital Jega, Medical Laboratory, Kebbi	44.7	District/Community	Government
General Hospital Bangi, Niger state	39.5	District/Community	Government
State Specialist Hospital Med Lab Dept. Ikere-Ekiti	39.5	District/Community	Government
General Hospital Gembu Medical &and Diagnostic Laboratory, Taraba state	39.5	District/Community	Government
Ifako Ijaiye General Hospital	39.5	District/Community	Government
Kagara General Hospital, Niger state	36.8	District/Community	Government
Kaffin Koro General Hospital, Paikoro LGA, Niger State	34.2	District/Community	Government
Bichi General Hospital, Kano state	34.2	District/Community	Government
Dirin Daji General Hospital, Kebbi	34.2	District/Community	Government
Shanga General Hospital, Kebbi, Kebbi state	34.2	District/Community	Government
Medical Laboratory Services Department, National Obstetric Fistula Centre, Abakaliki.	31.6	Reference	Government
Kwali General Hospital Laboratory, Abuja	28.9	District/Community	Government
Federal Medical Center Jalingo, Taraba state	23.7	Regional/Intermediate	Government
General Hospital Takum, Taraba state	21.1	District/Community	Government
Sir Yahaya Memorial Hospital Pathology Dept, Birnin Kebbi, Kebbi state	18.4	District/Community	Government
Rambaza General Hospital, Kebbi	15.8	District/Community	Government
Ibeju Lekki General Hospital	13.2	District/Community	Government

** Laboratory names are abbreviated.*

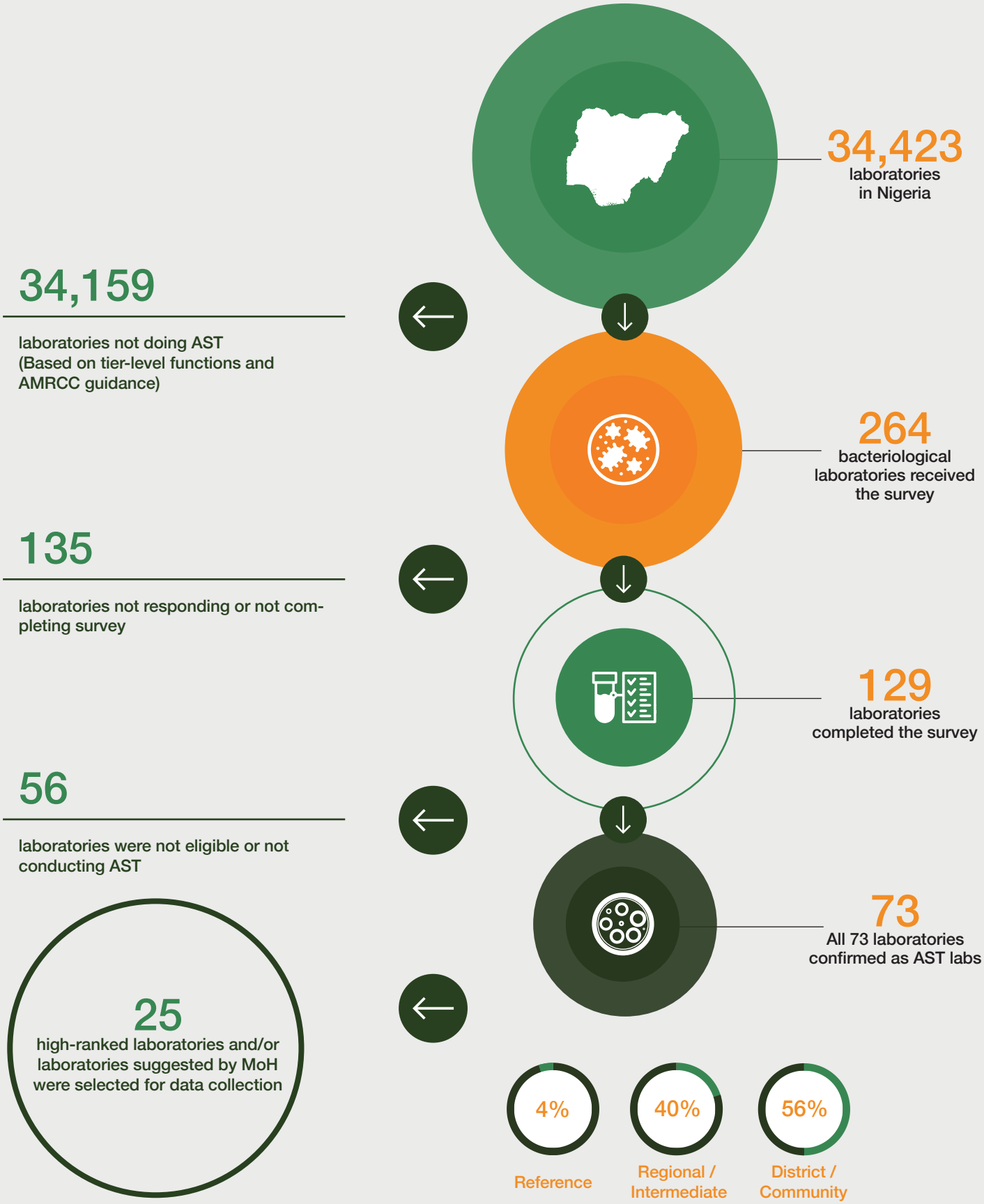


Figure 2: Selection of laboratories in Nigeria

Surveillance preparedness of surveyed laboratories

Based on self-reported information from 73 laboratories, laboratory function and quality compliance were assessed to understand the preparedness for AMR surveillance. Fifty laboratories reported implementing QMS and 63 laboratories had at least one qualified microbiologist on board. Twenty-six laboratories were accredited and only 11 used automated methods for pathogen identification (Figure 3, Supplementary Table 2). Since these findings may affect the quality of laboratory data, caution is warranted in interpreting the AMR rates presented in this report is.

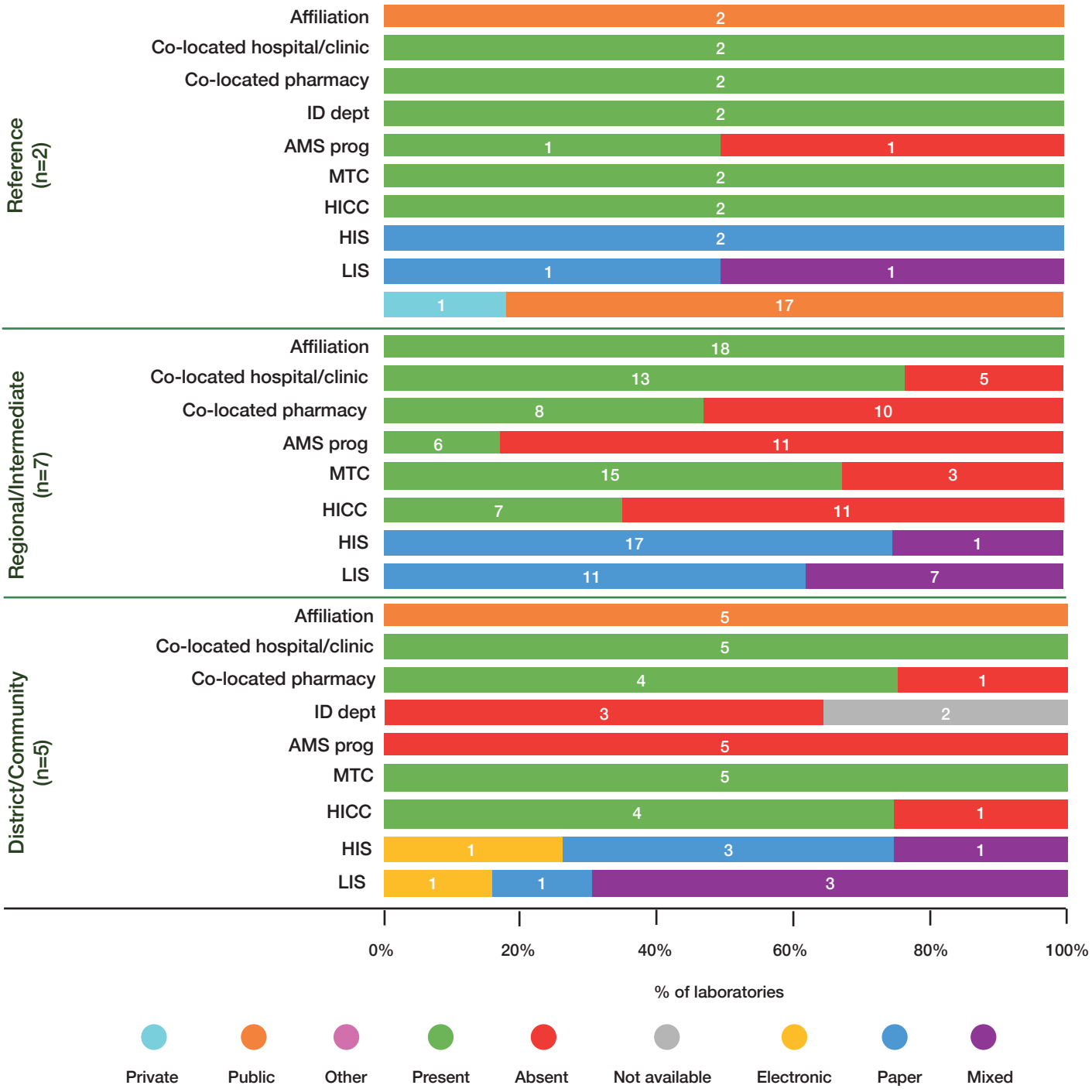
	Parameters			N (%)
Commodity and equipment status	Regular power supply and functional back up			53 (72.6)
	Continuous water supply)			60 (82.2)
	Certified and functional biosafety cabinets			26 (35.6)
	Automated methods for pathogen identification			11 (15.1)
	Automated methods for AST			9 (12.3)
	Methods for testing AMR mechanisms			30 (41.1)
QMS implementation	Reported QMS Implementation			50 (68.5)
		Types of QMS	LQMS	17 (34.0)
			SLIPTA	5 (10.0)
			SLMTA	0
			Mentoring	5 (10.0)
			Combination‡	6 (12.0)
			Others	11 (22.0)
	Quality Certification			13 (17.8)
		Types of Quality certification	SLIPTA	6 (46.2)
			Col. of Am. Path	0
			Others	7 (53.8)
	Accreditation			26 (35.6)
	Participation in proficiency testing			27 (37.0)
	Utilization of reference strains			37 (50.7)
	Reported consistent maintenance of QC records			44 (60.3)
	Designated focal quality person			59 (80.8)
	Reported compliance to standard operating procedures			58 (79.5)
	Reported compliance to AST standards			42 (57.5)
Personnel and training status	Presence of at least one qualified microbiologist			63 (86.3)
	Presence of an experienced laboratory scientist/technologist			72 (98.6)
	Up-to-date and complete records on staff training and competence			40 (54.8)
Specimen Management status	Reported compliance to SOPs on specimen collection and testing			71 (97.3)
	Reported compliance to SOPs on specimen rejection			67 (91.8)
	Average number of specimens processed for AST in 2018			64 (87.7)
LIS and Linkage to Clinical Data	Assigned specimen (laboratory) identification number			67 (91.8)
	Availability of system/database to store patient data			61 (83.6)
		Database format	Paper-based	45 (73.8)
			Electronic	0
			Mixed	15 (24.6)
	Captured patients' records on test request forms			56 (76.7)
			Retrievable	38 (67.9)

‡ Combination refers to more than one option presented in the questionnaire (laboratory quality management system, stepwise laboratory improvement process towards accreditation, strengthening laboratory management towards accreditation, and mentoring).

Figure 3: Laboratory preparedness for AMR surveillance

Profile of Selected Laboratories

All 25 selected laboratories were co-located with clinical facilities. Ten clinical facilities lacked infectious disease departments, while seven had antimicrobial stewardship programmes. Seventeen facilities had a medical therapeutic committee and 13 had a hospital infection control committee. Most laboratories had mixed (paper and electronic) information systems (n=11), while most hospitals had paper-based information systems (n=21) (Figure 4).



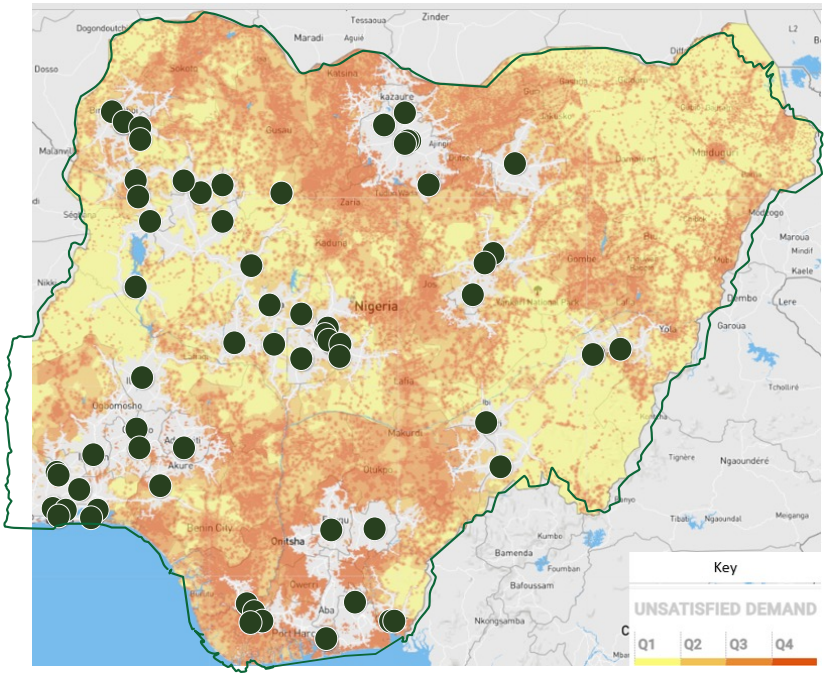
Abbreviations: AMS=antimicrobial stewardship; HICC=hospital infection control committee; HIS=hospital information system; IDD=infectious diseases department; LIS=laboratory information system; MTC=medical therapeutics committee

Figure 4: Profile of selected laboratories

Population coverage of laboratories

We analysed the data using the PlanWise® solution. PlanWise incorporates data on the population, road network and other variables and applies an algorithm as well as geospatial optimisation techniques to show unmet needs. We evaluated the proportion of the population covered by mapped laboratories within a two-hour drive (Supplementary Figure 1).

As of 2020, Nigeria had an estimated population of 206.1 million.



Supplementary Figure 1: Population coverage of AST laboratories in Nigeria

Population coverage of laboratory services is defined as the catchment population living within one-hour travel (by car or foot) from the testing laboratory. It is represented in grey on the map.
The analysis uses the assumption that the laboratory has sufficient testing capacity to serve the entire population within the catchment area.
The population outside the catchment area of the facilities is, by definition, representative of the overall unmet need. For ease of use, the unit of unmet need is represented on the map as a 'pixel', i.e., the lowest base unit of a raster image. To visualise the geographical areas with the most critical unmet needs, each base component is ranked from the lowest to the highest, according to the number of the population living in the 'pixel'. The ranking is then divided into quartiles made of equal population fractions (from Q1: lowest density of population to Q4: highest density) corresponding to different colours (from yellow to dark red, see the legend). Therefore, the colour on the map relates to the level of unmet need (people not in the reach of a facility) relative to the whole population.

In Nigeria, the catchment population living within one-hour travel time from the 73 participating AMR surveillance sites covers 49% of the population. Hence, 51% of the population is not covered at all by the existing facilities. To increase the population coverage, new capacity should be introduced (either by upgrading an existing laboratory to start providing services or by constructing a new laboratory) in regions in dark red (Q4) and thus prioritising regions with the highest absolute unmet need.

Section II: Collection, analysis and interpretation of AMR data

Objective

1. To collect, digitise and analyse retrospective data from selected facilities using standardised electronic data collection and analysis tools
2. To describe the completeness and validity of AMR data in selected facilities

Methodology

Data collection

The main variables were the patient's culture (laboratory) results, clinical information and antimicrobial usage (AMR Appendix 4). For all positive blood and cerebrospinal fluid (CSF) cultures, information on the patient's demographics, clinical profile and antimicrobial usage was also collected from clinics and hospitals. However, this was possible only where patient records could be tracked between the laboratories and hospitals (Figure 5). Additionally, data were collected on AMC at the facility and national level.

For laboratories with paper-based records, at least 5 000 records per laboratory per year were to be collected. However, no such limit was imposed for digitised data. The goal was to obtain at least 240 000 records from 16 laboratories across three years.

As a first step, MoH and IQVIA were jointly involved in recruiting local field data collectors. A capacity-building workshop was conducted as part of the MAAP to train the field staff on data collection, including the use of WHONET15 and the specially developed MAAP tool for secure transfer of collected data.

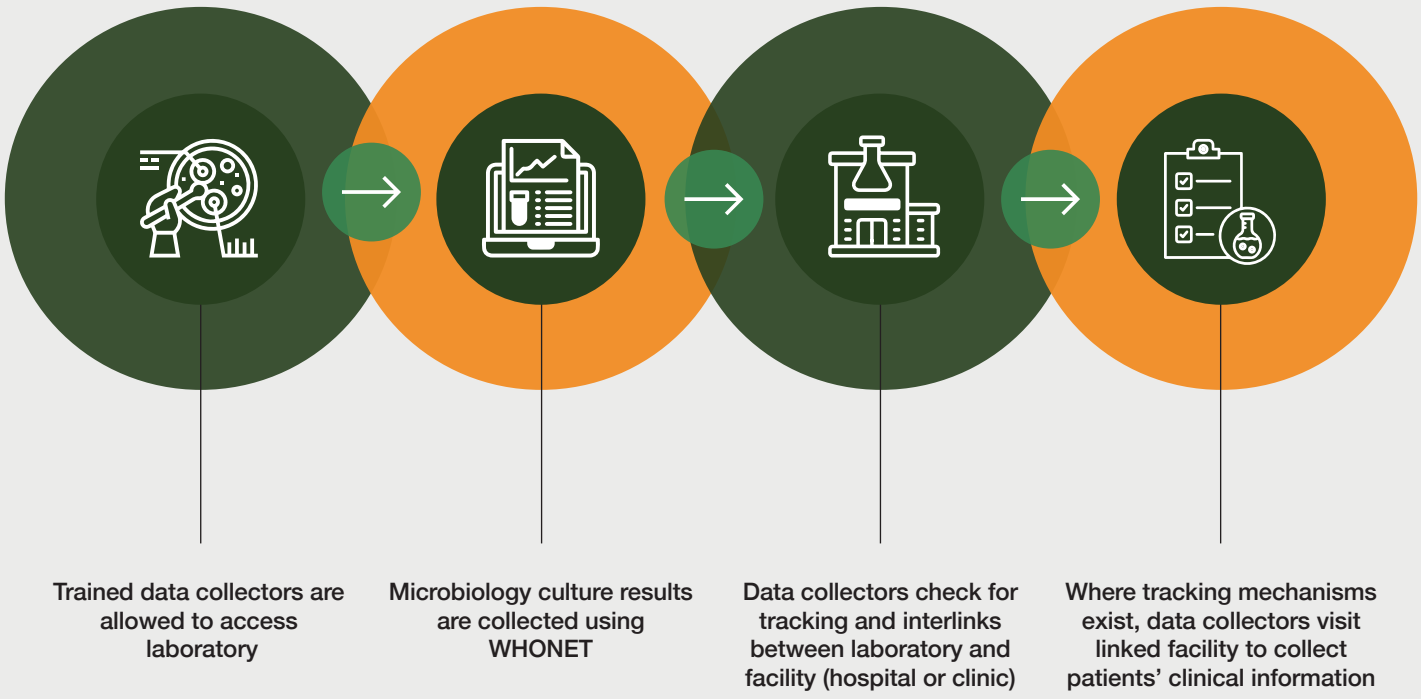


Figure 5: Steps of AMR data collection

Historical data were collected for the period January 1, 2016, through to December 31, 2018. The AMR data were initially captured through WHONET, a free Windows-based database software programme developed for the management and analysis of microbiology laboratory data. The software allowed data entry of clinical and microbiological information from routine diagnostic testing or research studies. WHONET has a simple data file structure and output formats compatible with major database, spreadsheet, statistical and word-processing software. It permits customisation to include variables of interest and has several alert features that highlight unlikely or important results. From WHONET, data were transferred onto an online application (repository) for further analysis. Each row of the database represented an individual patient's results. Where the laboratory or hospital issued unique patient identification numbers, it was also possible to track a patient along multiple visits.

Figure 6: Data collection at a Nigerian facility

Data analysis

- A preliminary data review was conducted to evaluate data completeness, accuracy and redundancy. Data summarisation was based on the following parameters: quantum of cultures (total cultures, valid cultures, positive cultures or positive cultures with AST results), level of pathogen identification, inappropriate testing, clinical information, culture characteristics, specimen characteristics and identified pathogens. Each parameter is described below.

- Quantum of cultures: Total cultures were the number of patient rows in the database received from the laboratories. Valid cultures were a subset of total cultures which had complete information on the specimen type, collection date and pathogen name. Positive cultures were valid cultures for which pathogen growth was reported, irrespective of AST results. Total cultures were quantified for each laboratory and over the entire study period. Valid cultures and positive cultures were stratified for each laboratory as well as for each study year (Figure 7).

- Level of pathogen identification: Positive cultures with AST results were summarised based on the level of pathogen identification. Gram identification and genus-level identification were considered incomplete, where reporting at a species level indicated complete pathogen identification. Data were stratified for each laboratory and assessment was conducted over the entire study period (Figure 7).

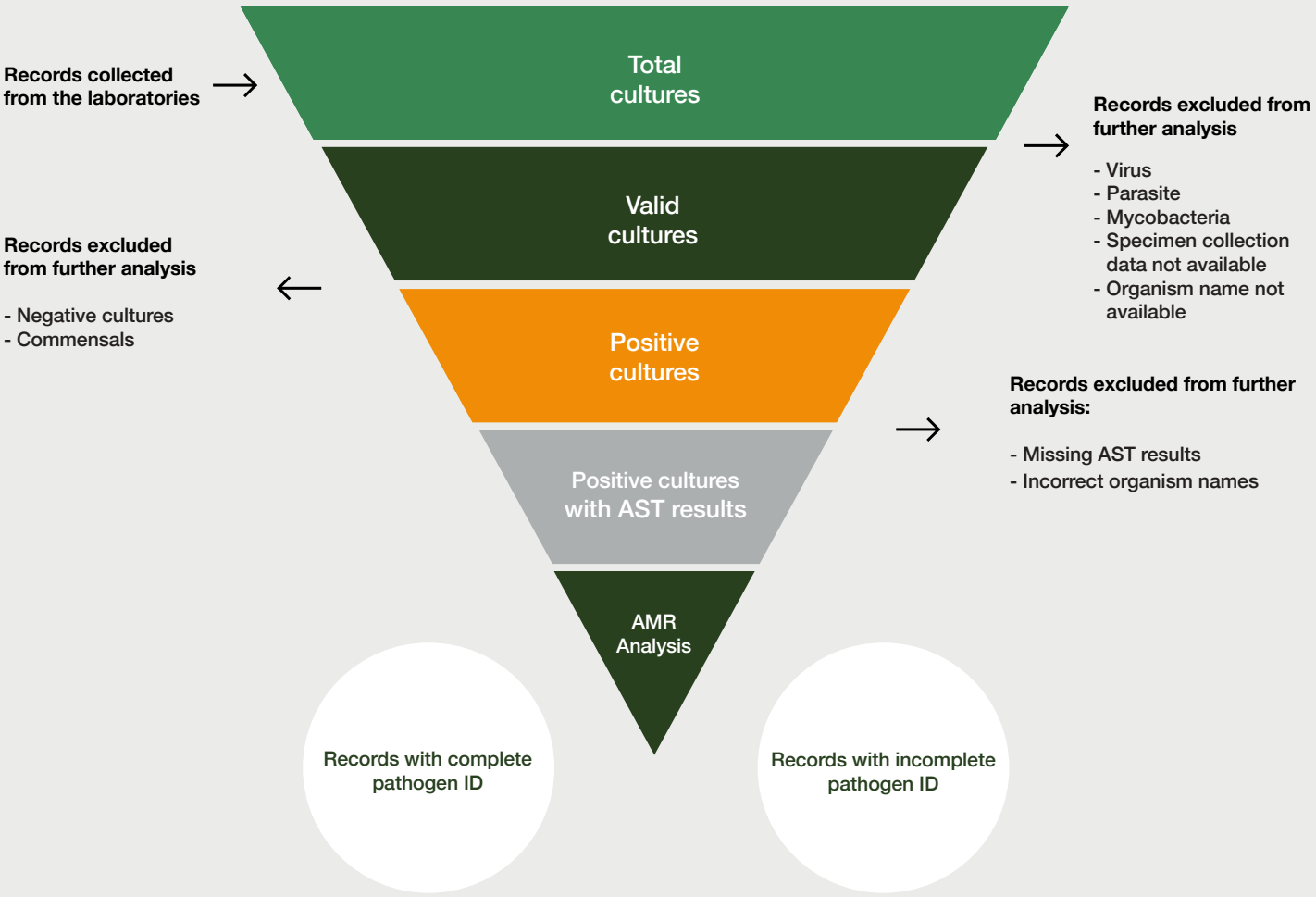


Figure 7: Conceptual framework for deriving quantum of cultures

- **Culture characteristics:** Cultures were characterised across gender, age group and pathogen type (bacteria or fungi). Data were pooled across all laboratories, and assessment was conducted for each study year.
- **Inappropriate testing:** Positive cultures with AST results were assessed for compliance to AST standards. However, comprehensive assessment of validity of AST results was beyond the study scope. Data were pooled across laboratories and assessed for each study year. The conventional AST standards are Clinical and Laboratory Standards Institute (CLSI), European Committee on Antimicrobial Susceptibility Testing (EUCAST) and Comité de l'antibiogramme de la Société Française de Microbiologie, the European Committee on Antimicrobial Susceptibility Testing.
- **Clinical information:** Positive cultures with AST results were summarised based on information available for the patient's clinical profile: diagnosis, origin of infection (whether hospital-acquired, or community-acquired), presence of indwelling device and antimicrobial use. Data were quantified for each laboratory and assessed over the entire study period.
- **Specimen characteristics:** Positive cultures with AST results were summarised based on information on specimen types. Data were pooled across all laboratories and assessed for each study year.
- **Quality of data:** We used the level of pathogen identification as a parameter to evaluate the data quality from each laboratory seeing as the complete identification of pathogens is key in AMR surveillance and implies the quality of the laboratory's testing practices. Scoring was based on quartiles of the proportion of completely identified pathogens. The laboratories with >75% of pathogens identified at the species level were awarded the highest score (4). Laboratories with <25% identification received the lowest score (1), (Table 3). Firstly, the scoring was performed per year (i.e., 2016–2018). Thereafter, the average was assigned as the laboratory data quality score for each laboratory.

Table 3: Data scoring scheme

Level of pathogen identification	Score
<25%	1
25-50%	2
51-75%	3
>75%	4

Seeing as we pooled all the data to obtain AMR rates at a national level, we computed a single metric to estimate the overall quality of data received from a country. This metric is referred to as the 'country data quality score' and weights the laboratory data quality score with the quantum of valid cultures contributed by each laboratory, as shown in the formula below. The maximum attainable score is 4. Table 4 below shows how the country data quality score was rated.

Table 4: Data quality rating

Score	Rating
4	Excellent
3-3.9	Good
2-2.9	Average
1-1.9	Poor

$$\text{Country data quality score} = \sum_{i=1}^{n} \frac{(\text{Laboratory data quality score}_{(i)} \times \text{Quantum of valid cultures}_{(i)}}{\sum \text{Quantum of valid cultures}_{(1\ldots n)}}$$

Where *n* is the total number of contributing labs and *i* represents individual laboratories.

Results

Retrospective data from 2016–2018 was collected from 25 laboratories and corresponding facilities in Nigeria.

1. Quantum of cultures and level of pathogen identification

Data were retrieved for 85 127 total cultures, of which 84 548 were valid and 27 135 were positive. Of the positive cultures, AST results were available for 23 963 cultures, the maximum (n=2 222) coming from Murtala Mohammad and the least (n=39) from Lapai (Figure 8 and 9, not all pathogens were identified completely (i.e., at species level). Complete identifications were highest for LAUTECH (99.1%) and lowest for Minna (18.7%) (Table 5).

Table 5: Data summary

Variable (Columns) / Laboratory (Rows)	Total Cultures (N=85 127)	Valid Cultures N=84 548	Positive cultures N=27 135	Positive cultures with AST results N=23 963	Incomplete identity* N= 8 536	Complete identity* N= 15 427
LAUTECH	3 466	3 460 (99.8)	1 258 (36.4)	1 026.0 (81.6)	9 (0.9)	1 017 (99.1)
Kubwa	5 498	5 497 (100.0)	910 (16.6)	731.0 (80.3)	248 (33.9)	483 (66.1)
Babcock	1 628	1 628 (100.0)	471 (28.9)	432.0 (91.7)	240 (55.6)	192 (44.4)
Abuja	9 593	9 589 (100.0)	2 005 (20.9)	1 654.0 (82.5)	175 (10.6)	1 479 (89.4)
Muhammad Abdullahi	4 583	4 583 (100.0)	2 180 (47.6)	1 711.0 (78.5)	1 037 (60.6)	674 (39.4)
Port Harcourt	2 792	2 656 (95.1)	847 (31.9)	737.0 (87.0)	230 (31.2)	507 (68.8)
Bwari	3 645	3 645 (100.0)	1 018 (27.9)	674.0 (66.2)	182 (27.0)	492 (73.0)
UTH Lagos	3 642	3 638 (99.9)	1 384 (38.0)	1 355.0 (97.9)	546 (40.3)	809 (59.7)
UTH Niger Delta	1 644	1644 (100.0)	738 (44.9)	670.0 (90.8)	312 (46.6)	358 (53.4)
UCH Ibadan	5 125	4 984 (97.2)	2 178 (43.7)	1 943.0 (89.2)	353 (18.2)	1 590 (81.8)
UITH Ilorin	5 713	5 532 (96.8)	1 455 (26.3)	1 251.0 (86.0)	205 (16.4)	1 046 (83.6)
OAUTHC	2 937	2 900 (98.7)	652 (22.5)	600.0 (92.0)	234 (39.0)	366 (61.0)
Maitama	4 253	4 249 (99.9)	1 286 (30.3)	1 051.0 (81.7)	357 (34.0)	694 (66.0)
Lapai	135	135 (100.0)	44 (32.6)	39.0 (88.6)	19 (48.7)	20 (51.3)
Aminu Kano	3 592	3 533 (98.4)	243 (6.9)	208.0 (85.6)	71 (34.1)	137 (65.9)
FMC Birnin	1 827	1 827 (100.0)	793 (43.4)	758.0 (95.6)	385 (50.8)	373 (49.2)
Minna	4 694	4 694 (100.0)	2 038 (43.4)	2 036.0 (99.9)	1 655 (81.3)	381 (18.7)
UNTH Enugu	1 146	1 144 (99.8)	494 (43.2)	473.0 (95.7)	199 (42.1)	274 (57.9)
Sinusi	742	742 (100.0)	242 (32.6)	235.0 (97.1)	147 (62.6)	88 (37.4)
UCTH Calabar	1 203	1 203 (100.0)	379 (31.5)	328.0 (86.5)	55 (16.8)	273 (83.2)
Murtala Muhammad	3 578	3 577 (100.0)	2 429 (67.9)	2 222.0 (91.5)	1 041 (46.8)	1 181 (53.2)
FNH Yaba	537	535 (99.6)	154 (28.8)	108.0 (70.1)	40 (37.0)	68 (63.0)
FMC Bida	4 576	4 575 (100.0)	1 648 (36.0)	1 558.0 (94.5)	78 (5.0)	1 480 (95.0)
FMC Azare	6 043	6043 (100.0)	1 637 (27.1)	1 572.0 (96.0)	490 (31.2)	1 082 (68.8)
FMC Abeokuta	2 535	2 535 (100.0)	652 (25.7)	591.0 (90.6)	228 (38.6)	363 (61.4)

* Subsets of the category 'Positive cultures with AST results' where 'incomplete' includes cultures with only Gram or genus-level identification; 'complete' includes cultures with species-level identification; — information not available

AST=Antibiotic Susceptibility Testing

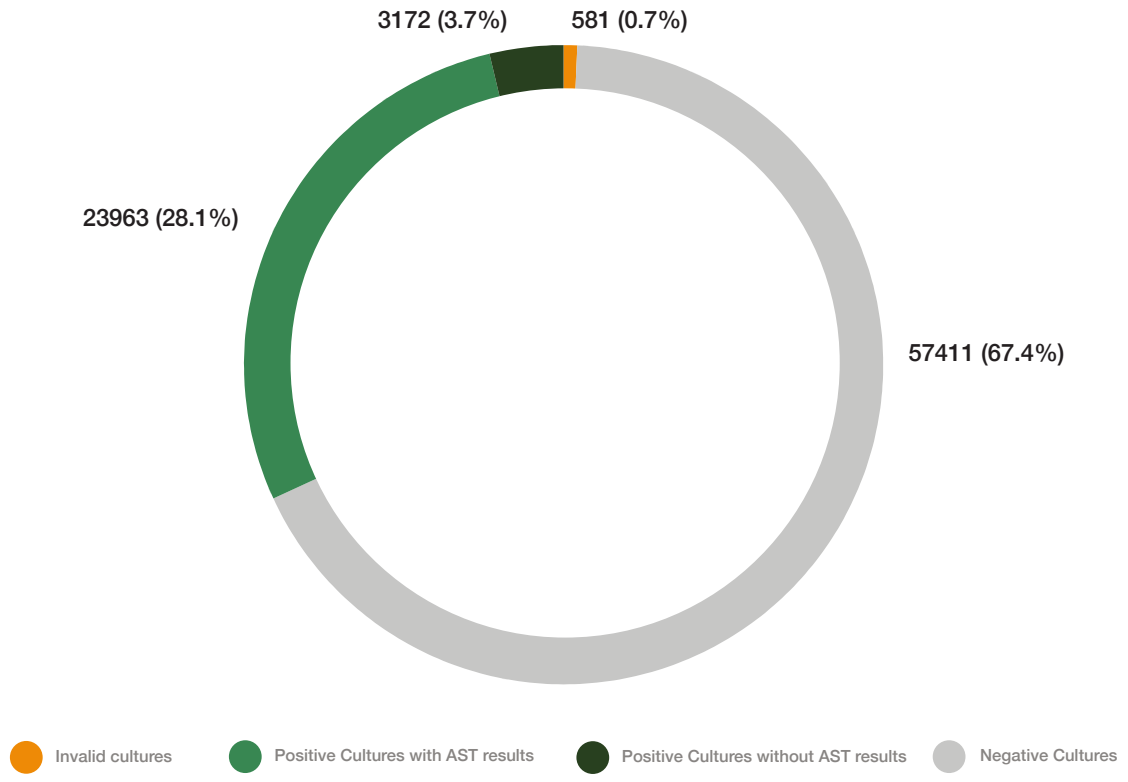


Figure 8: Quantum of cultures across all selected laboratories in Nigeria from 2016 -2018

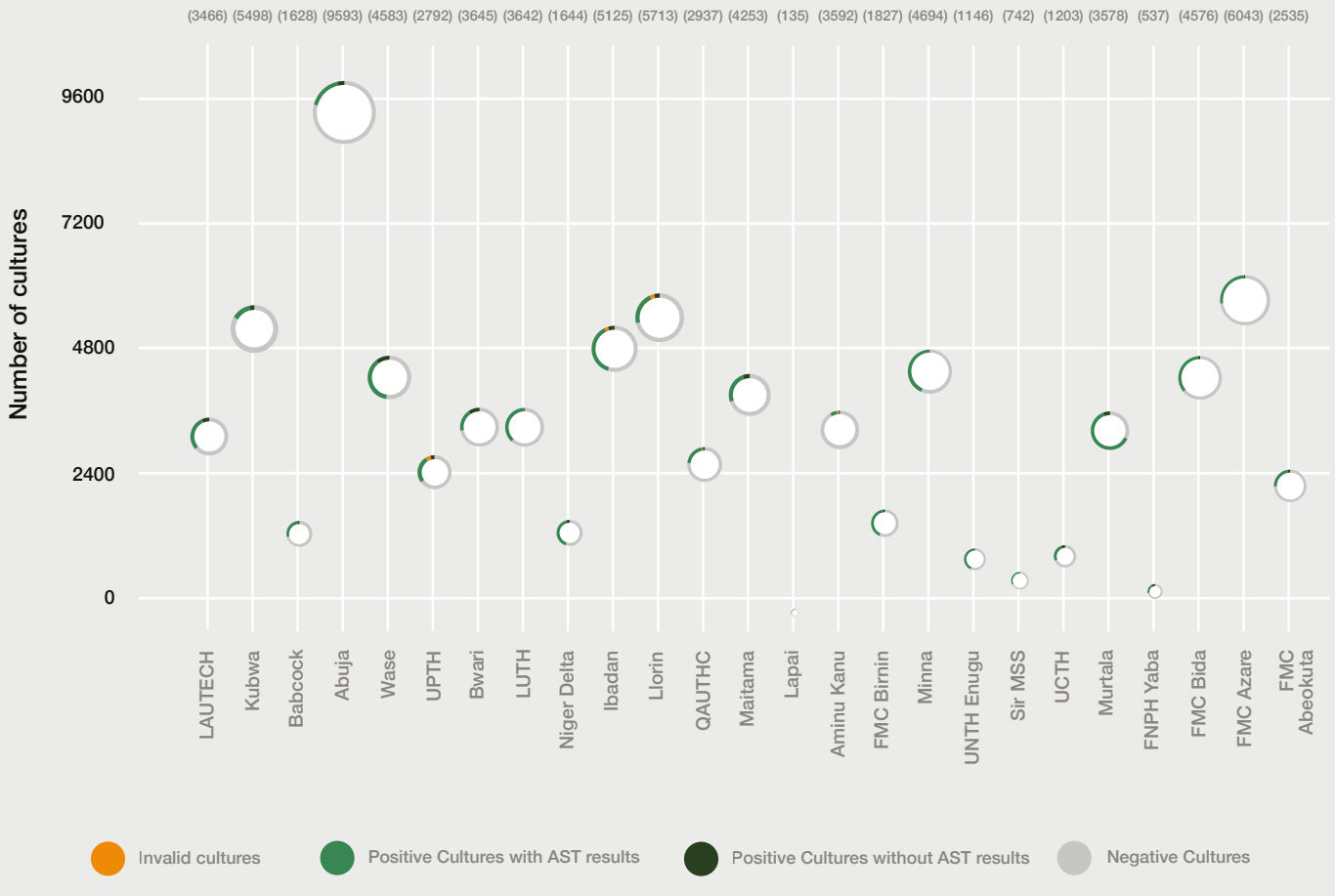


Figure 9: Quantum of cultures in each selected laboratory

2. Culture characteristics

Bacterial pathogens (23 943) were more commonly isolated from positive cultures than fungal pathogens. Information on age was missing from 23.6% of cultures, but where available, data showed a median age of 28 years (range 0–101 years), with most cultures (7 629) obtained from patients 18–49 years old. Females (13 803) contributed more to the quantum of positive cultures with AST results. More data came from 2017 (9 501) than other years (Table 6, Supplementary Table 3).

Table 6: Culture characteristics

Characteristics	Positive cultures with AST results n=23 963 n (%)
Gender	
Male	10 160 (42.4)
Female	13 803 (57.6)
Age, years	
Less than 1	2 711 (11.3)
1 to 17	4 526 (18.9)
18 to 49	7 629 (31.8)
50 to 65	1 630 (6.8)
Above 65	1 806 (7.5)
Unknown age	5 661 (23.6)
Years	
2016	6 532 (27.3)
2017	9 501 (39.6)
2018	7 930 (33.1)
Pathogen	
Bacteria	23 943 (99.9)
Fungi	20 (0.1)

3. Inappropriate testing

All the selected laboratories reported compliance to CLSI standards for AST testing. However, during a review of AST results, the following instances of inappropriate testing were noted:
Bacteria were tested against antifungals and fungi tested against antibiotics (Supplementary Figure 2a). Enterobacterales were tested against inappropriate agents such as vancomycin, penicillin G or oxacillin and Staphylococcus aureus was tested against vancomycin using the disk diffusion method (Supplementary Figure 2b). Other instances of inappropriate testing were also noted (Supplementary Figure 2c).

4. Clinical information

Patient metadata, particularly clinical information, were sparse (Table 7).

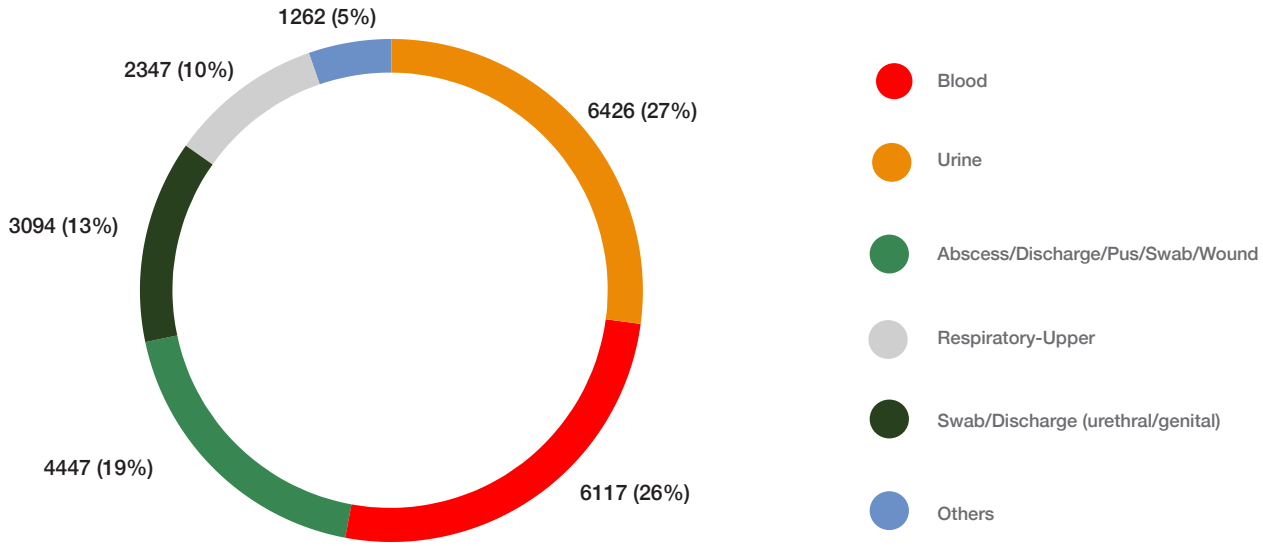
Table 7: Clinical information

Laboratory	Positive cultures with AST results N=23 963	Diagnosis data	Infection origin data*	Indwelling device data	AMU data
LAUTECH	1 026	25	20	23	25
Kubwa	731	-	-	-	-
Babcock	432	35	10	29	17
Abuja	1 654	-	-	-	-
Muhammad Abdullahi	1 711	-	-	-	-
Port Harcourt	737	57	-	-	5
Bwari	674	-	-	-	-
UTH Lagos	1 355	16	7	16	8
UTH Niger Delta	670	9	-	3	10
UCH Ibadan	1 943	101	-	1	2
UITH Ilorin	1 251	37	-	38	38
OAUTHC	600	12	1	1	10
Maitama	1 051	17	-	1	14
Lapai	39	-	-	-	-
Aminu Kano	208	33	32	32	33
FMC Birnin	758	-	-	-	-
Minna	2 036	-	-	-	-
UNTH EnuguUNTH Enugu	473	5	-	1	5
Sinusi	235	0	-	-	-
UCTH Calabar	328	4	-	3	2
Murtala Muhammad	2 222	-	-	-	-
FNH Yaba	108	-	-	-	-
FMC Bida	1 558	18	-	12	19
FMC Azare	1 572	50	40	50	47
FMC Abeokuta	591	15	10	15	2

- information not available; * hospital acquired, or community acquired; AMU=antimicrobial use; AST=antibiotic susceptibility testing.

5. Specimen characteristics

Urine, blood, and purulent discharge accounted for most of the positive cultures in each study year (Figure 10, Supplementary Table 4)

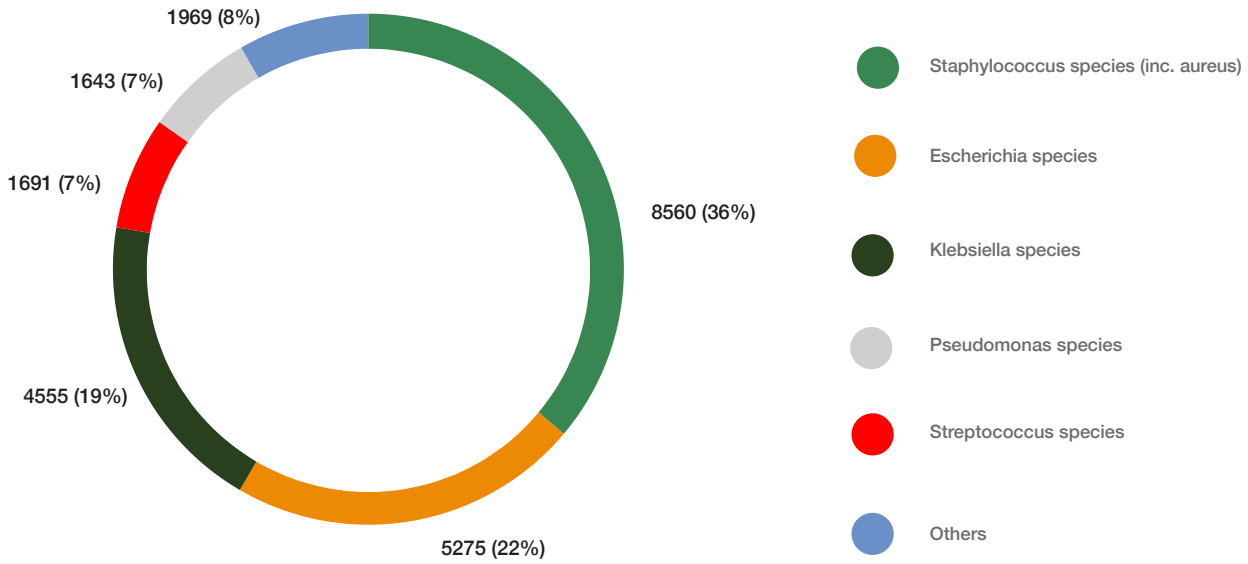


* Others include all other specimens excluding the top 5 mentioned here
Figure 10: Specimen characteristics

6. Identified pathogens

Staphylococcus species (36%), Escherichia species (22%), and Klebsiella species (19%) largely contributed to the quantum of positive cultures (Figure 11).

In 2016, of the 6 532 positive cultures with AST results, Staphylococcus species (32.1%), Escherichia species (28.5%) and Klebsiella species (16%) were the most reported. In 2017, of the 9 501 positive cultures with AST results, Staphylococcus species (38.5%), Escherichia species (18.1%) and Klebsiella species (20.5%) were again the most reported. In 2018, information was available for a greater number of cultures (7 930) although pathogen distribution remained similar to prior years (Supplementary Table 5).



* Others include all other pathogens excluding the top 5 mentioned here
Figure 11: Pathogens identified

7. Quality of data

The country data quality score of the 84 548 valid culture records obtained from the 25 laboratories in Nigeria was 3.2 and was rated as good for AMR analysis. For individual laboratory data quality scores from each contributing laboratory, see Supplementary Table 6.

Section III: AMR rates

Objective

To estimate the country-level AMR prevalence and trends for WHO priority pathogens and other clinically important and frequently isolated pathogens as well as to enable the comparison of countries on spatiotemporal maps.

Methodology

Data from positive cultures with AST results were analysed to estimate the country-level AMR prevalence of pathogens and identify the drivers of resistance.

Estimation of AMR rates

In this report, the AMR rate is the extent to which a pathogen is resistant to a particular antimicrobial agent or class and is determined by the proportion of isolates that are non-susceptible (i.e., either intermediate or resistant) over a one-year period:

$$\text{AMR rate} = \frac{\text{No. of non-susceptible isolates}}{\text{No. of tested isolates}} \times 100 \ (\text{CI } 95\%)$$

AMR rates were estimated for the WHO priority pathogens16 where the number of tested isolates exceeded 30 regardless of the specimen type (AMR Appendix 5). AMR trends were mapped for the WHO priority pathogens depending on data availability.

In addition, AMR rates were estimated for the following:

1. Clinically important pathogens isolated from blood and cerebrospinal fluid (AMR Appendix 6)
2. Top three highly resistant bug-drug combinations (regardless of the specimen type)
3. Pathogens tested against the most and least consumed antimicrobial classes (regardless of the specimen type, please refer to part C)

Data were analysed as per resistance interpretation submitted by the laboratories. Where laboratories provided quantitative results (i.e., diameter measurements or minimum inhibitory concentrations), data were adjusted based on the updated breakpoints available on WHONET. Although non-susceptibility interpretations were based on results from the tested antimicrobials, they are represented at the antimicrobial class level wherever possible (AMR Appendix 7). Analysis was limited to bacterial and fungal pathogens.

Removal of duplicate records

Before AMR rates were calculated, duplicate AST results were removed such that only the results of the first pathogen isolate per patient per year, irrespective of AST profile (and body site or specimen type in the case of WHO priority pathogens), were included. This approach follows the CLSI M39A4 criteria.[17,18] Duplicate removal was based on the availability of unique patient identifiers. When no patient identifiers were available, the results of all isolates were included. The AST data from all laboratories were then aggregated and rates were calculated as the proportion of non-susceptible isolates.

AMR estimates statistics

Confidence intervals (CIs) were calculated to quantify the uncertainty in the estimated resistance rates, at the 95% level of confidence. Typically, CIs for AST data have been constructed using the Wilson score method. This is a binomial calculation that assumes that all samples are independent.[19] However, there are likely correlations between data within each laboratory and between laboratories that draw from similar populations. Thus, where appropriate, the Wilson cluster robust CI method was employed to account for a lack of data independence such that each laboratory represented a cluster.[20]

Estimated AMR rates should be interpreted with caution because they were derived from aggregated data from laboratories with varying testing capabilities and not all selected laboratories contributed to the AST results. The validation of AST results was beyond the study scope and data were taken at face value for assessment of resistance rates.

Online data visualisation

AMR data were aggregated to the national level and definitions of resistance were harmonisedacross countries to enable comparisons. Data were uploaded to a private and secure portal for countries and laboratories to permit analysis of their data at the patient level (CDDEP's ResistanceMap Surveillance Network [RSN]). RSN provides a simple, approach to analysing AMR data. Point-and-click editing tools allow the user to mine the data to answer complex questions where the resulting analyses can be displayed as bar charts representing resistance over a time period or line graphs showing changes over time by month or year. RSN will be made available for at least one year, following completion of the study, to each participating country.

Data were also uploaded to CDDEP's ResistanceMap platform, a publicly available repository for aggregated country-level data.[21] Spatiotemporal analysis for the combined AMR and AMC-AMU datasets were built on the ResistanceMap framework. Current capabilities include maps, trend line charts and frequency bar charts.

Results

(i) AMR rates and trends for WHO priority pathogens

AMR rates for the WHO priority pathogens were calculated as the proportion of isolates that were non-susceptible over each one-year interval. Across 2016–2018, AMR rates for some organisms remained consistent; the rates for others varied. High AMR rates were noted for 3rd-generation cephalosporin-resistant Enterobacterales (67-73%) and methicillin-resistant S. aureus (MRSA) (58-82%). Moderate to high levels of resistance was noted for carbapenem-resistant P. aeruginosa (30-53%) and fluoroquinolone-resistant Salmonella species (46-75%). Rates of carbapenem-resistant Enterobacterales (15-19%) were low (Table 8, Figures 12 and 13). Statistics for vancomycin-resistant and intermediate Staphylococcus species and Staphylococcus aureus are not included.

Table 8: AMR rate estimates for WHO priority pathogens

Pathogen	Antibiotic, class	2016				2017				2018			
		N	n (%)	95% CI	Labs* (range)	N	n (%)	95% CI	Labs* (range)	N	n (%)	95% CI	Labs* (range)
Acinetobacter baumannii	Carbapenems	6	1	-	2 (1 - 5)	19	11	-	2 (4 - 15)	24	10	-	4 (1 - 21)
Pseudomonas aeruginosa	Carbapenems	55	29 (52.7)	35.2-69.6	8(1-25)	361	109 (30.2)	20.9-41.4	11 (1 - 136)	129	43 (33.3)	20.8-48.8	11 (1 - 40)
Enterobacterales	Carbapenems	458	87 (19)	7.7-39.8	13(1 - 114)	1342	230 (17.1)	11.2-25.4	17 (1 - 361)	927	134 (14.5)	8.4-23.8	15 (1 - 327)
Enterobacterales	Cephalosporins (3rd generation)	2 341	1 705 (72.8)	60.9-82.2	24(1 - 362)	3028	2035 (67.2)	59.3-74.2	24 (9 - 660)	2528	1766 (69.9)	60.1-78.1	23 (2 - 368)
Enterococcus faecium	Vancomycin	-	-	-	-	-	-	-	-	-	-	-	-
Haemophilus. influenzae	Ampicillin	-	-	-	-	-	-	-	-	1	1	-	1(1)
Helicobacter pylori	Clarithromycin	-	-	-	-	-	-	-	-	-	-	-	-
Neisseria gonorrhoeae	Cephalosporins (3rd generation)	3	1	-	2(1 - 2)	2	1	-	1(2)	1	1	-	1(1)
N. gonorrhoeae	Fluoroquinolones	3	1	-	2(1 - 2)	2	0	-	1(2)	1	0	-	1(1)
Campylo-bacter species	Fluoroquinolones	-	-	-	-	-	-	-	-	-	-	-	-
Salmonella species	Fluoroquinolones	100	75 (75)	36.4-94	8(1 - 60)	130	60 (46.2)	17.2-77.9	12 (1 - 68)	100	69 (69)	37.7-89.1	9 (1 - 63)
Shigella species	Fluoroquinolones	14	8	-	3(1 - 7)	5	2	-	2 (2 - 3)	5	2	-	3 (1 - 3)
S. aureus	Methicillin	458	362 (79)	61.5-89.9	17(1 - 100)	1 152	673 (58.4)	37.7-76.6	21 (1 - 623)	646	527 (81.6)	65.9-91	21 (1 - 126)
S. pneumoniae	Beta-lactam combinations	18	12	-	6(1 - 9)	59	48 (81.4)	53.3-94.3	9 (1 - 44)	7	4	-	2 (3 - 4)
S. pneumoniae	Penicillins	3	2	-	2(1 - 2)	12	10	-	3 (2 - 6)	1	1	-	1(1)

N = number of tested isolates; n = number of non-susceptible isolates; n% and 95% CI are shown only if >30 isolates/ year; — information not available; # contributing laboratories and range of tested isolates; where the pathogen is suffixed as species, all isolates of same genus are grouped as one entity.

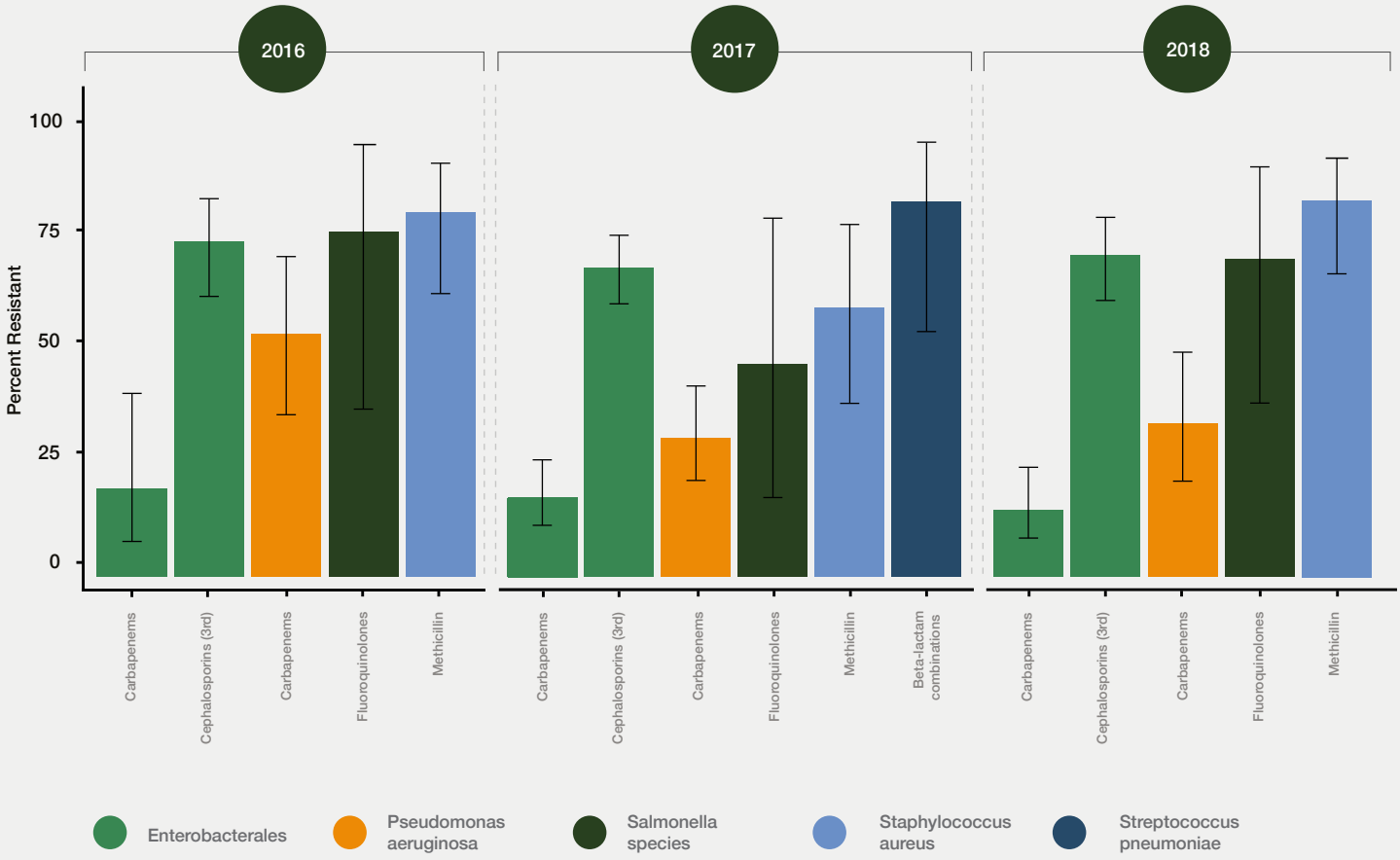
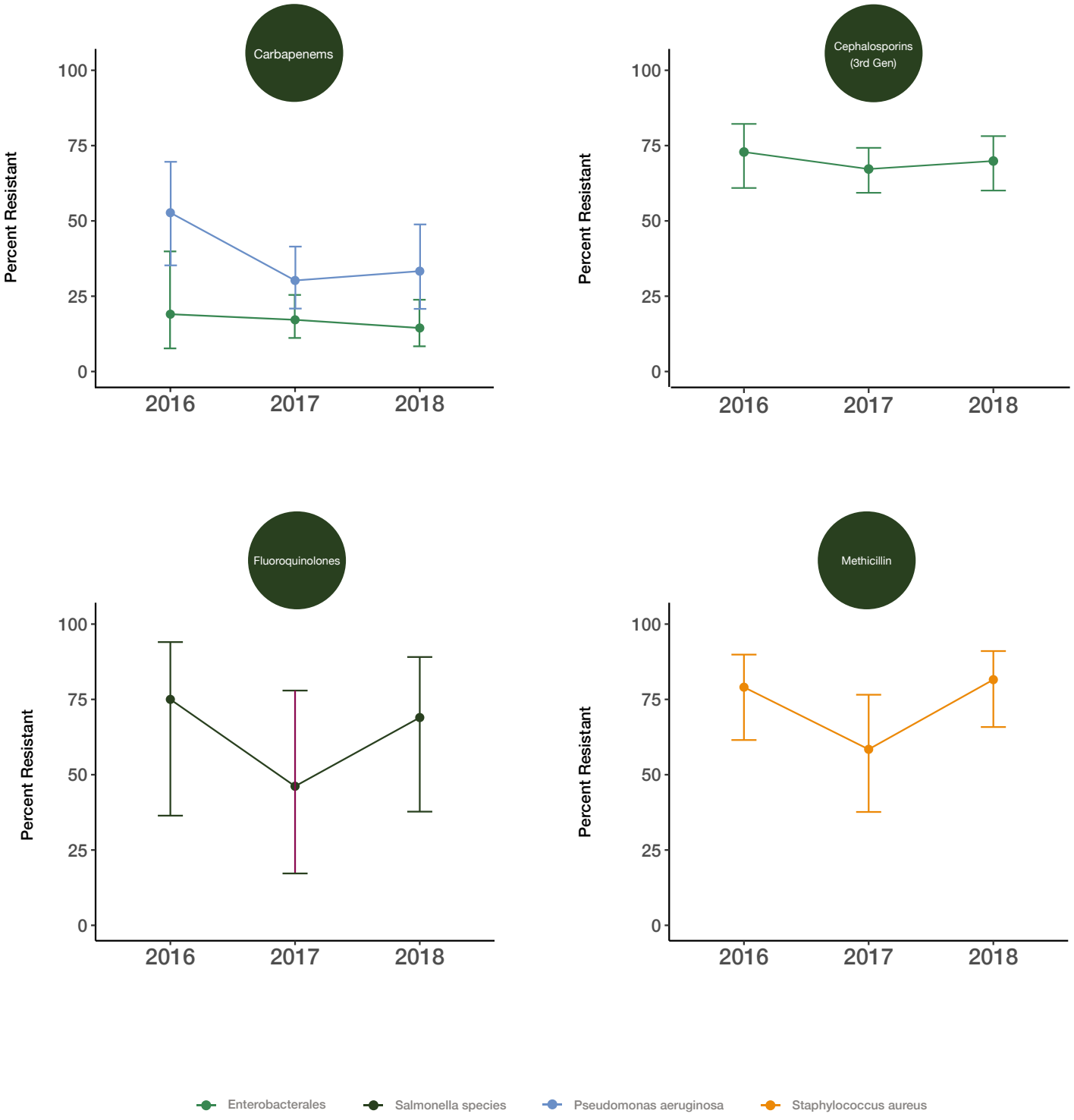


Figure 12: AMR rate estimates for WHO priority pathogens



3rd Gen = third generation

Figure 13: AMR trends for WHO priority pathogens

(ii)AMR rates for other pathogens of clinical importance

Analysis of AST data from blood and CSF isolates revealed high AMR rates for third-generation cephalosporin-resistant Klebsiella species (76-80%) and methicillin-resistant Staphylococcus species (47-72%). Moderate resistance rates were noted for carbapenem-resistant Acinetobacter species (37-48%), carbapenem-resistant Pseudomonas species (39-43%) and carbapenem-resistant Klebsiella species (23-30%) (Table 9).

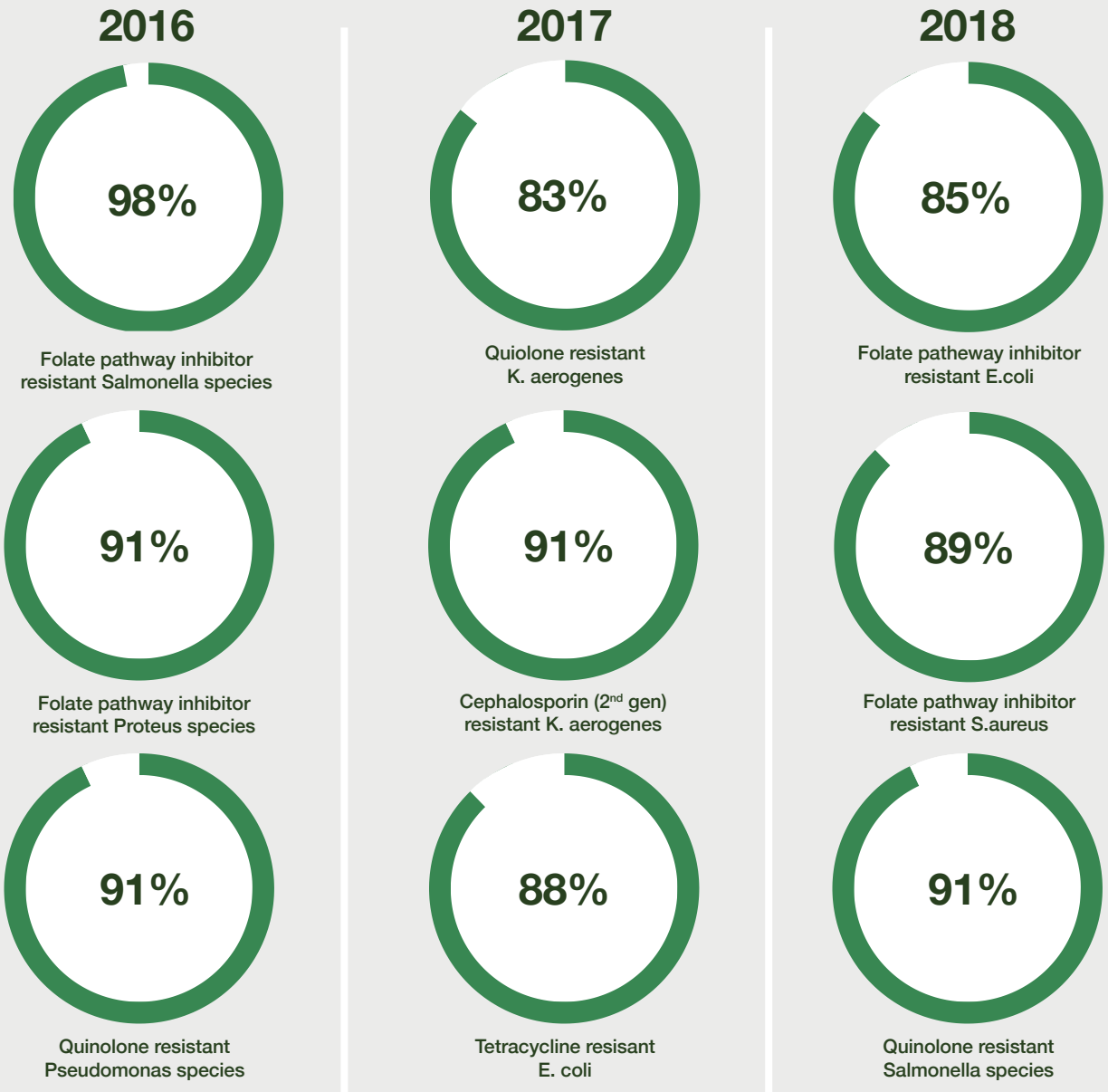
*Table 9: AMR rate estimates for other clinically important pathogens**

Pathogen	Antibiotic, class	2016				2017				2018			
		N	n (%)	95% CI	Labs# (range)	N	n (%)	95% CI	Labs# (range)	N	n (%)	95% CI	Labs# (range)
Acinetobacter species	Carbapenems	31	15 (48.4)	20.4-77.4	5 (2 - 16)	16	2	-	5 (1 - 11)	30	11 (36.7)	24.2-51.2	5 (1 - 16)
Acinetobacter species	Lipopeptides	-	-	-	-	-	-	-	-	-	-	-	-
Enterococcus species	Aminoglycosides (high level)	4	2	-	1(4)	-	-	-	-	-	-	-	-
Enterococcus species	Vancomycin	4	0	-	1(4)	5	3	-	2 (1 - 4)	12	4	-	3 (1 - 8)
H. influenzae	Ampicillin	-	-	-	-	-	-	-	-	-	-	-	-
H. influenzae	3rd generation cephalosporins	1	0	-	1(1)	-	-	-	-	-	-	-	-
Klebsiella species	Carbapenems	222	63 (28.4)	16.6-44.2	12 (1 - 113)	69	21 (30.4)	14.8-52.5	7 (1 - 29)	94	22 (23.4)	12.4-39.8	7 (4 - 21)
Klebsiella species	Cephalosporins (3rd generation)	430	334 (77.7)	70.8-83.3	16 (1 - 208)	207	158 (76.3)	55.6-89.2	13 (1 - 66)	162	130 (80.2)	56.5-92.7	14 (1 - 26)
N. meningitidis	Ampicillin	-	-	-	-	-	-	-	-	-	-	-	-
N. meningitidis	Cephalosporins (3rd generation)	2	1	-	2(1 - 1)	-	-	-	-	-	-	-	-
Pseudomonas species	Carbapenems	72	31 (43.1)	26.9-60.9	6 (3 - 31)	15	4	-	5 (2 - 5)	31	12 (38.7)	20.9-60.1	7 (1 - 10)
Pseudomonas species	Lipopeptides	-	-	-	-	-	-	-	-	-	-	-	-
Salmonella species	Fluoroquinolones	-	-	-	-	-	-	-	-	-	-	-	-
Salmonella species	Macrolides	-	-	-	-	-	-	-	-	-	-	-	-
Salmonella species	3rd generation cephalosporins	-	-	-	-	-	-	-	-	-	-	-	-
Staphylococcus aureus	Methicillin	-	-	-	-	-	-	-	-	-	-	-	-
Staphylococcus species (excluding aureus)	Methicillin	306	189 (61.8)	59.1-64.3	10 (1 - 277)	64	46 (71.9)	47.2-88	9 (1 - 16)	51	24 (47.1)	18.1-78.1	6 (2 - 32)
S. pneumoniae	Penicillins	-	-		-	-	-	-	-	-	-	-	-
S. pneumoniae	Beta-lactam combinations	4	3	-	3(1 - 2)	6	1	-	3 (1 - 3)	2	0	-	1 (2)
S. pneumoniae	Macrolides	8	3	-	4(1 - 3)	5	2	-	3 (1 - 3)	2	0	-	1 (2)
S. pneumoniae	Vancomycin	-	-	-	-	-	-	-	-	-	-	-	-

* From blood and CSF; N = number of tested isolates; n = number of non-susceptible isolates; 95% CI are shown only if >30 isolates/year; # contributing laboratories and range of tested isolates; — information not available; where the pathogen is suffixed as species, all isolates of same genus are grouped as one entity.

(iii) AMR rates for highly resistant pathogens

Based on the available data, very high resistance (>90%) was estimated for clinically important pathogens like Salmonella species (vs. folate pathway inhibitors), Proteus species (vs. folate pathway inhibitors), K. aerogenes (vs. 2nd generation cephalosporins), Salmonella species (vs. quinolones) and Pseudomonas species (vs. quinolones) (Figure 14).



Pathogen nomenclature is shown as reported by laboratories; antimicrobials are reported at the class level
Figure 14: Top five highly resistant pathogens

(iv) AMR rates for fungal pathogens

Available AST data on fungal isolates was insufficient for further analysis.

Section IV: Drivers of antimicrobial resistance

Objective

To assess the drivers of AMR

Methodology

AMR drivers are factors that could predispose patients to AMR. To determine the association between AMR and its potential drivers, the following patient and country-level factors were considered:

- Patient-level factors: demographics (age and gender), diagnosis, comorbidities, antimicrobial usage, presence of device (catheter, central line, ventilator) and origin of infection (hospital or community)
- Country-level factors: Global Health Security index scores on AMR prevention, primary education, GDP per capita, physician and nurse density, disease prevalence and antibiotic consumption in DDD per 1 000 inhabitants (the country-level associations are presented separately at a regional or continental level).

To identify the drivers of resistance, a composite AMR rate for select groups of pathogens (Acinetobacter baumannii, Escherichia coli, Klebsiella pneumoniae, Pseudomonas aeruginosa, Staphylococcus aureus, Enterococcus faecium and Enterococcus faecalis) and antibiotics or antibiotic classes (aminoglycosides, broad-spectrum penicillins, carbapenems, cephalosporins, glycopeptides, narrow spectrum penicillins and quinolones) was estimated (AMR Appendix 8). The choice of pathogens and antimicrobials was guided by the DRI methodology (Part C).

Statistical analysis

An initial exploration of the data was done to identify missing information and any collinearity between the patient-level factors (drivers). Logistic regression analyses (univariate and multiple) were performed to determine the association with AMR. The analyses were adjusted for the number of contributing laboratories to account for the variation in the respective laboratory datasets. Crude odds ratios (ORs) were estimated in the univariate logistic regression analysis to describe the association between AMR and the investigated variables. Only those variables with $p<0.2$ were evaluated in a multiple logistic regression analysis (statistical significance was set at $p<0.05$). The Wilson score method with robust standard error was used to construct CIs for the AMR rates.

To explore the association between country factors (continuous variables) and AMR, correlation analysis (Pearson's) was performed with reporting at a continental level.

All results should be interpreted with caution as they were derived from data aggregated from facilities with varying capabilities in addition to the data from the laboratories being varied.

Results

Two variables namely, age and gender were evaluated for possible association with AMR. The data availability for these variables was age: 85.7% and gender: 98.8%. The univariate logistic regression results did not reveal any significant association between the variables and AMR rates (Table 10). Data for other patient variables were insufficient to assess their association with AMR.

Table 10: Univariate logistic regression analysis

Variable	Options	N	NS (%)	Adjusted OR (95% CI)	P-value
Gender	Female	15 664	60.5	**Ref**	
	Male	10 966	61.2	**1.03 (0.86 - 1.24)**	0.753
Age	<1	2 954	60.2	0.96 (0.63 - 1.44)	
	1-17	5 445	58.1	0.86 (0.61 - 1.26)	0.06
	18-49	10 021	61.2	**Ref**	
	50-65	2 684	57.9	**0.87 (0.76 - 1.00)**	
	>65	2 116	62.0	**1.03 (0.77 - 1.37)**	

N=number of tested isolates; NS (%)=proportion of non-susceptible isolates.

Information on other patient factors was unavailable or inadequate for analysis.

Part B: Antimicrobial (antibiotic) Consumption

Section I: Background of antimicrobial consumption (AMC) and antimicrobial use (AMU)

Overuse and misuse of antimicrobials are crucial factors in the complex web of AMR causation. Widespread and unregulated antimicrobials usage exert a selective pressure by reducing the reproductive success of some of the microorganisms and consequently accelerating the development of AMR.[22,23] Therefore, close surveillance on how antimicrobials are utilised is a key step for stewardship programmes in order to stem AMR. The surveillance mechanisms recommended by WHO include the monitoring of AMC and AMU. This aligns with the MAAP's aim to expand the volume of data presently available on AMR and AMC or AMU across Africa and aligns with the country's (2017-2022) National Action Plan for AMR.[14]

Definition of AMC and AMU

AMC is defined as the quantification of antimicrobials used within a specified setting (e.g., national-level, hospital or community healthcare-level) over a specified period. AMC is calculated from aggregated data such as imports, wholesalers, insurance, or facility dispensing or procurement data sources. AMU on the other end tracks whether antimicrobials are prescribed appropriately, for the right infections and according to treatment guidelines. AMC and AMU are terminologies that are sometimes used interchangeably and incorrectly so. It is therefore prudent to delineate these definitions further through clarification that AMC data describes quantities of antimicrobials dispensed (e.g., at national stores or pharmacies) whereas AMU data describes how and why antimicrobials are used (e.g., whether required laboratory tests and clinical assessments were conducted prior to issuing a prescription, whether the right antimicrobial was prescribed at the correct strength and frequency over an appropriate duration to treat the right indication as per country guidelines and finally whether the patient correctly and/or completely consumed the prescribed antimicrobial).[24]

Link between the antimicrobial usage and AMR

The unwarranted use of antimicrobials is in part attributable to the emergence of AMR. This association implies that a reduction in the unnecessary consumption of antimicrobials could, in turn, reduce AMR levels.[22] The inappropriate use of antimicrobials refers to the use of the wrong type of antimicrobial, and/or at the wrong dose, frequencies or duration and/or for the wrong indication. For the past few decades, there has been a global increase in the consumption of antimicrobials and a shift in consumption towards the use of both broad-spectrum and last-resort antimicrobials, particularly in LMICs. These shifts are because of improved access and increased economic strength within some of these countries. However, AMR can also develop because of a lack of access to antimicrobials, leading to the prolonged use of particular antimicrobial over a long time and thus permitting selective pressure to favour microbes that evade these predominantly-used antimicrobials. This is often the picture in several LMICs where inequities in antimicrobials access still persist.[25]

This complicated picture demonstrates the need for the research and development of new agents that counteract emerging AMR, but also strongly indicates the need to use the available antimicrobials appropriately and ensure their accessibility. In view of obtaining an elaborate and complete picture of the link between AMC or AMU and AMR in Nigeria, the identification of prevalent gaps, as well as areas for targeted intervention to encourage rational use of antimicrobials and a surveillance system for the consumption, is of paramount importance. In this regard, one of MAAP's key objectives was to evaluate the ability to conduct AMC and AMU surveillance (data collection and analysis) in Nigeria, that would equip the country with valuable information to support the appropriate use of antimicrobials. The objective was to identify gaps that may exist in establishing a comprehensive surveillance system and provide the country with the needed information to support the setup of such a monitoring system.

AMC and AMU surveillance impact

To ensure the successful treatment of infectious diseases in patients, optimising the correct usage of antimicrobials is one of the strategic objectives within the WHO Global Action Plan (GAP).[8] For the successful implementation of the above objective, there is a need to understand a country's pattern of antimicrobials use and quantification of their consumption. At present, there are only few published reports on AMC surveillance and AMU in Africa[26-30] including a few reports in Nigeria.[31,14] The process of obtaining AMC or AMU data equips the country with local information on various problems that exist with antimicrobial use and allows for monitoring the accessibility of antimicrobials. Furthermore, obtaining AMC or AMU data permits the continuous local assessment of correlations between antimicrobial usage to emerging local AMR, which permits for proper mitigation policies and activities to be planned using relevant data. Data obtained from local surveillance exercises also presents the opportunity to better inform stewardship programmes. In this regard, MAAP set out to quantify consumption and analyse AMC and AMU trends at selected facilities as well as at the national level. This would in turn better inform the design of future stewardship programmes and policies which will optimise the use of antimicrobials in Nigeria. In addition, providing the country with a reference point to measure the impact and success of future implemented interventions.

The aim of this work

1. To describe the in-country antimicrobial flow and highlight the status of the AMC and AMU surveillance system in Nigeria

2. To quantify and evaluate the trends of AMC and AMU at national and pharmacy levels

Section II: AMC or AMU surveillance status

Objective

To describe the in-country antimicrobial flow and highlight the status of the AMC and AMU surveillance system in Nigeria

Methodology

AMC and AMU data sources

Through open-structured key informant interviews (KIIs) (AMC Appendix 1), the AMRCC contacts shared their insights about the current landscape of AMC surveillance in the country as well as from where national AMC data can best be surveilled. Consequently, NAFDAC was identified as the source for national AMC data in Nigeria as they were the sole entity involved in approving and regulating all medicine importations into the country, as well as those locally manufactured. While from the facility level, the Nigeria AMRCC, advised MAAP on the recruitment of pharmacies.

Under the guidance of the Nigeria AMRCC, MAAP targeted to recruit and obtain data from thrice as many pharmacies as the selected AST laboratories (i.e., a total of 75 pharmacies). Pharmacy-level AMC data were targeted to be collected from the pharmacies that were co-located in the same facility with AST laboratories (n=25) (AMC Appendix 2 for tool used). Additionally, community pharmacies (n=50) were also targeted, these pharmacies were nominated by the co-located pharmacies based on their proximity to the AST laboratories. Community pharmacies were also selected based on their serving as the preferred patient medicine purchase sites or backup prescription fulfilment sources in case of stockouts in the main hospital pharmacy. Furthermore, availability of retrospective data from 2016-2018 and willingness to share data were key criteria considered for selection.

Besides AMC data, AMU data were to be targeted for collection from hospital pharmacies (n=25) and this was to be abstracted from the facilities' prescription or patient medical records. To clarify, community pharmacies, which are also known as retail pharmacies, are licensed commercial pharmaceutical stores that provide medicinal products (prescription only and over-the-counter medicines) to a specific community group or region and excludes unregulated and informal medicine dispensers. Hospital pharmacies, on the other hand, are pharmacies located within a hospital for the provision of supply of medicinal products to inpatients and outpatients who visit the hospital.

Data collection scope

MAAP purposively selected data collection on J01 (antibiotics for systemic use) consumption trends. J01 medicines are one of the WHO core monitoring ATC medicine categories for AMC surveillance. In addition, as per the country's request, selected P01AB (nitroimidazole derivates) and/or selected J02 (antimycotics for systemic use) were also included in the scope for AMC data collection (See AMC Appendix 3 for full list of selected antimicrobials in Nigeria). P01AB and J02 ATC antimicrobials are part of the WHO core and optional monitored medicine classes respectively for AMC surveillance.[32] AMC data from the above medicine categories was collected from January 2016 to December 2018.

Data collection

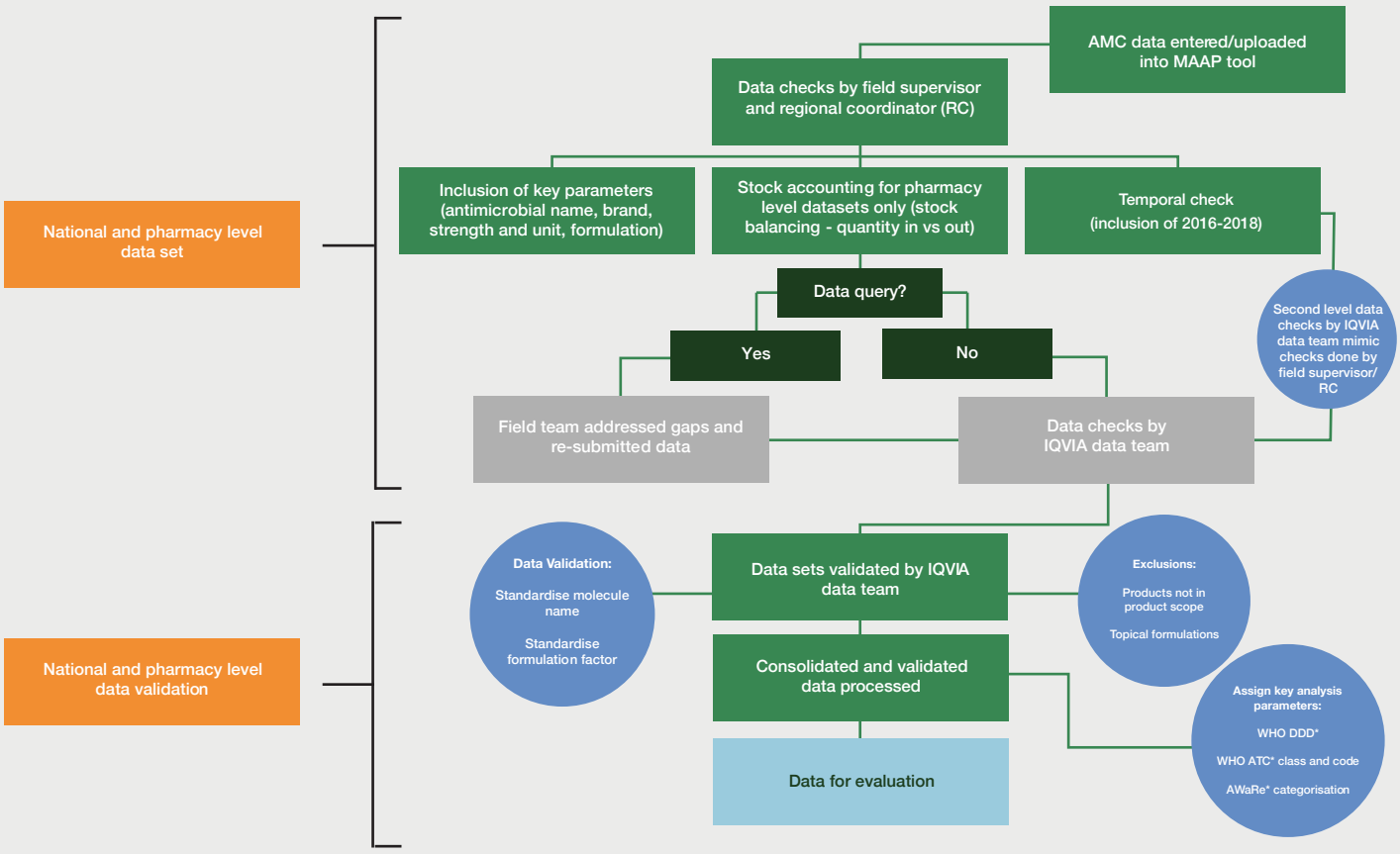
The NAFDAC datasets were provided directly to the MAAP field data collectors electronically in the form of a Microsoft Excel™ sheet. These datasets included all commodities imported and locally manufactured in country. Firstly, the datasets were sorted to filter out the products within scope. The datasets were then reviewed and cleaned by the data collection teams using Excel™ which was then transferred securely through the MAAP tool that captured all antimicrobials by their standard molecular name and/or product brand, pack size, strength, and formulation (e.g., tablets/capsules, suspensions/syrups). AMC Appendix 4 captures the full list of data variables collected to tally national- and pharmacy-level AMC.

For the pharmacy-level data, the trained MAAP data collectors extracted the consumption data from the facility's Health Information System (HIS) into an Excel™ sheet where data were available electronically. Alternatively, abstracted data from stock record cards were manually entered into the MAAP tool within facilities that held manual records. The electronic datasets were reviewed and cleaned by the data teams and then transferred securely through MAAP tool to the central data processing and analysis team. AMC Appendix 5 details the data collection process.

MAAP also planned to collect the AMU data in pharmacies that were co-located within facilities also housing AST laboratories and clinical services to assess the appropriateness of consumed antimicrobials. Data to be captured included patient characteristics, indication for which the antimicrobial is being used and the appropriateness of the prescription in relation to national guidelines (including conducting of any relevant laboratory testing and clinical assessment done prior to prescribing, assessment of dose, strength, frequency and duration of prescription).

Data cleaning and validation

Once the national-level antimicrobial datasets from NAFDAC were received by MAAP, both the national-and pharmacy-level AMC data were then subjected to a series of data validation checks to ensure accuracy and consistency. (Data checks and the validation process for national AMC data are detailed in AMC Appendix 6). Here, the pharmacy and national AMC data were subjected to secondary and tertiary checks by field supervisors, the regional coordinator and the IQVIA data team. The validation and processing of the data were carried out by the IQVIA regional coordinator and IQVIA data team, as outlined in Figure 15.



*WHO World Health Organisation - *DDD Defined Daily Dose - * AWaRe Access, Watch, and Reserve

Figure 15: Flow chart explains the data checks procedures and validation process for the national and pharmacy level AMC datasets collected in Nigeria.

Results

Flow of antimicrobials in the country

To characterise the pathway through which antimicrobials get to patients in the country, five KIIs were conducted with stakeholders. Stakeholders included the AMRCC, representatives from the Government of Nigeria, non-government organisations (NGOs) and private community retail pharmacies. In Nigeria, medicines including antimicrobials, are imported (approximately 70% of market share) as well as locally manufactured (approximately 30% of market share) in the country.[11] NAFDAC regulates and licenses all of the pharmaceutical products (imported as well as locally manufactured). After importation or local production, private for-profit wholesalers and public-sector central medical stores (CMS) then pass along the antimicrobials to the community pharmacies, private (both for-profit and non-profit) facilities and public facilities who eventually issue the antimicrobials to patients.[12] There are approximately (n=36) state CMS, one for each state in Nigeria. The flowchart below (Figure 16) illustrates the route through which antimicrobials get to patients in Nigeria.

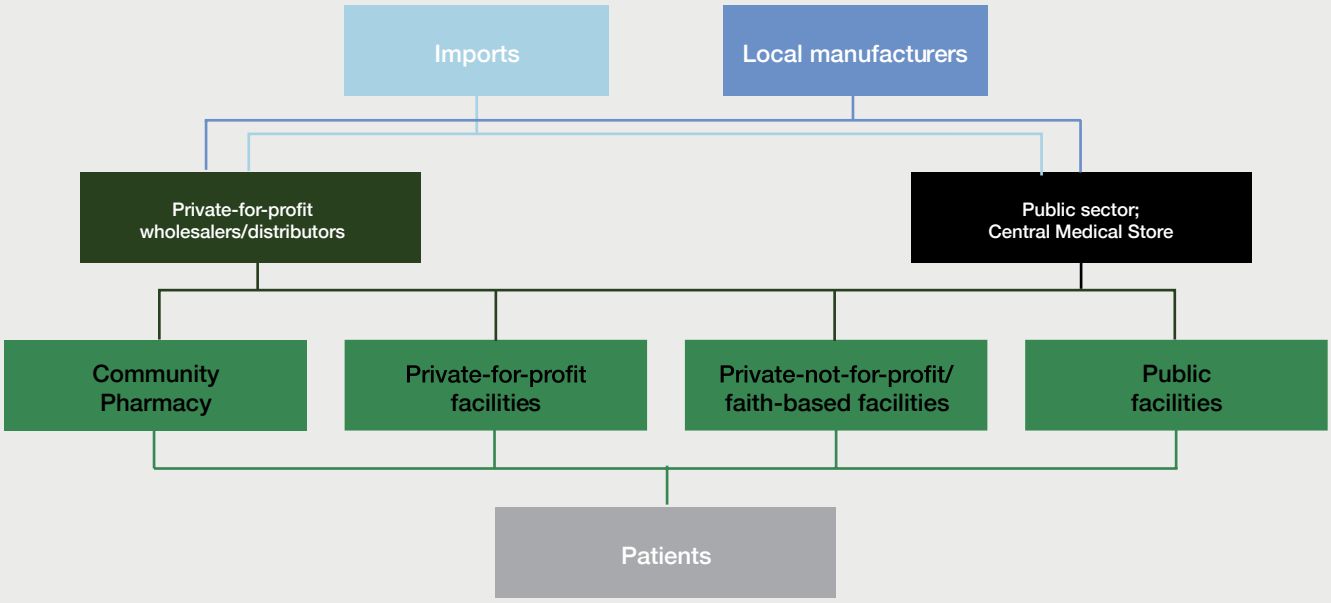


Figure 16: Flow chart explaining the circulation of antimicrobials within the country to the patients in Nigeria. A dotted line indicates supplies are not mainstream

Regulation of antimicrobials consumption

In Nigeria, antimicrobials for human consumption are regulated under the Poisons and Pharmacy Act, Cap 366 of 1990.[13] This law stipulates that requisite antimicrobials can only be sourced from registered suppliers and dispensed with a valid prescription. Despite this regulation on dispensation of antimicrobial medicines, it is still perceived that there is poor enforcement, which has led to widespread availability of over-the-counter antimicrobials without a prescription in Nigeria.[12,14] Routine over-the-counter sale of prescription-only antimicrobials is practiced both in pharmacies as well as via patent and proprietary medicine vendors. This is despite proprietary medicine vendors only holding licenses for sale of over-the-counter medicines.[14] This non-authorised over the counter retail practice for prescription antimicrobials agents, may lead to their overuse and/or misuse. The overuse and misuse of antimicrobials are significant contributors towards the emergence of AMR. Therefore, to address the above issues and other prevalent gaps, the country developed the National Action Plan for AMR (2017-2022), that seeks to further build regulations around AMC in an effort to curb the growth or emergence of AMR.

Availability of data for AMU surveillance

Attempts were made to obtain AMU data from the participating pharmacies that were co-located in the AST laboratories that also offered clinical services (n=25). Unfortunately, no AMU data were obtained during the MAAP data collection. The inability to collect AMU data was due to the nature of the data sources at the participating pharmacies, (i.e., stock issuance record cards), which did not allow for retrieval of AMU variables (i.e., patient characteristics and indication for which the antimicrobial is being used, appropriateness of prescription in relation to national guidelines including conducting of any relevant laboratory testing and clinical assessment prior to prescribing, and assessment of dose, strength, frequency, and duration of prescription) as stock issuance records do not track specific patients and the medicines they received. As a result, MAAP was unable to collect AMU data in Nigeria from the selected health facilities.

Availability of data for AMC surveillance

National-level data

National AMC data were obtained from NAFDAC for the years 2016 to 2018. However, these import manifests had key information missing which are critical for AMC data analysis such as antimicrobial strength and their formulation type. Furthermore, the antimicrobials supply quantities were recorded in measurements of cartons, boxes and drums, rendering it unsuitable to estimate the number of tablets or suspensions and vials etc. Thus, the MAAP data team was unable to calculate DDDs consumed (primary requirement for AMC analysis) from collected NAFDAC national AMC datasets. Therefore, this report only analysed and presented results from aggregated pharmacy-level AMC datasets.

Facility-level data

Out of the targeted 75 hospital pharmacies and 50 community pharmacies, data collection was successfully conducted in 52 targeted pharmacies which included hospital pharmacies (n=25) and community pharmacies (n=27). Of the participating hospital pharmacies (n=25) that were co-located with the AST laboratories, 24 were in public government hospitals (17 within tertiary care facilities and seven co-located in secondary care facilities). The remaining recruited hospital pharmacy (n=1) was located in a private tertiary care hospital. The remaining recruited pharmacies (n=27) were stand-alone community pharmacies. MAAP was unable to recruit additional targeted community pharmacies (n=23) as they were unwilling to share the data for the years reviewed.

In the case of pharmacy-level data, necessary variables were available in stock cards or electronic records of 52 pharmacies where the data were collected. However, there were instances in each of the visited facilities wherein strength or pack size information for a few line items or transactions were missing from the stock cards. These information gaps were addressed by re-visiting the facilities and gathering information from the facility staff or through secondary desk research using the available product details. Of the 25 hospital pharmacies and 27 community pharmacies, MAAP was able to collect data across the three years in 21 pharmacies. The remaining 10 recruited pharmacies did not provide data for at least one of the years because of data archival challenges or information technology issues. Due to the lack of the total number of hospital or community pharmacies in Nigeria, data representativeness at facility level could not be assessed.

In Nigeria, due to the lack of any national AMC surveillance policy or structured AMC surveillance system during the reviewed period, none of the recruited pharmacies actively reported AMC data regionally or centrally. Table 11 below summarises the core characteristics of the hospital pharmacies from which AMC data were collected.

Table 11: Characteristics of the 26 recruited hospital and community pharmacies in Nigeria, 2016-2019

Hospital Pharmacies (co-located with AST laboratories)

Pharmacy Name	Level of Service#	Affiliation	Region	Record keeping*	Pharmacy system directly linked to patient records *†	AMC reporting*
Aminu Kano Teaching Hospital	Tertiary care	Public	Kano State	Manual	No	No
BABCOCK University Teaching Hospital	Tertiary care	Private	Ogun State	Manual	No	No
Bwari General Hospital	Secondary care	Public	FCT-Abuja	Mixed*	No	No
Federal Medical Center Abeokuta	Tertiary care	Public	Ogun State	Manual	No	No
Federal Medical Centre Azare	Tertiary care	Public	Bauchi State	Manual	No	No
Federal Medical Centre Bida	Tertiary care	Public	Niger State	Manual	No	No
Federal Medical Centre Birnin-Kebbi	Tertiary care	Public	Kebbi State	Manual	No	No
Federal Neuropsychiatric Hospital Abeokuta branch	Tertiary care	Public	Ogun State	Manual	No	No
Kubwa General Hospital	Secondary care	Public	FCT-Abuja	Mixed*	No	No
Ladoke Akintola University Teaching Hospital, Idi-seke	Tertiary care	Public	Oyo State	Manual	No	No
Lagos University Teaching Hospital	Tertiary care	Public	Lagos State	Manual	No	No
Lapai General Hospital	Secondary care	Public	Niger State	Manual	No	No
Maitama District Hospital	Secondary care	Public	FCT-Abuja	Mixed*	No	No
Minna General Hospital	Secondary care	Public	Niger State	Manual	No	No
Muhammad Abdullahi Wase Teaching Hospital	Tertiary care	Public	Kano State	Manual	No	No
Murtala Mohammed Specialist Hospital	Secondary care	Public	Kano State	Manual	No	No
National Hospital Abuja	Tertiary care	Public	FCT-Abuja	Mixed*	No	No
Niger Delta University Teaching Hospital	Tertiary care	Public	Bayelsa State	Manual	No	No
Obafemi Awolowo Teaching Hospital	Tertiary care	Public	Oyo State	Manual	No	No
Sir Muhammad Sanusi Specialist Hospital, Kano	Secondary care	Public	Kano State	Manual	No	No
University College Hospital Ibadan	Tertiary care	Public	Oyo State	Manual	No	No
University of Calabar Teaching Hospital	Tertiary care	Public	Cross-River State	Manual	No	No
University of Ilorin Teaching Hospital	Tertiary care	Public	Kwara State	Manual	No	No
University of Nigeria Teaching Hospital Nsukka	Tertiary care	Public	Enugu State	Manual	No	No
University of Port Harcourt Teaching Hospital	Tertiary care	Public	Rivers State	Manual	No	No

Community pharmacies

Pharmacy Name	Level of Service#	Affiliation	Region	Record keeping*	Pharmacy system directly linked to patient records *†	AMC reporting*
Al Mansoorul Huq Pharmacy Azare	Dispensing	Private	Bauchi State	Manual	N/A	No
Buya Pharmacy	Dispensing	Private	Bauchi State	Manual	N/A	No
Dabinai Pharmacy	Dispensing	Private	Kano State	Manual	N/A	No
Drug Avenue Pharmacy	Dispensing	Private	Rivers State	Manual	N/A	No
Emmabros Pharmacy	Dispensing	Private	Niger State	Manual	N/A	No
Florence Pharmacy Minna	Dispensing	Private	Niger State	Manual	N/A	No
Hamdallah Pharmacy	Dispensing	Private	Kebbi State	Manual	N/A	No
Hepzibah Pharmacy Lapai	Dispensing	Private	Niger State	Manual	N/A	No
Hexo Pharmacy	Dispensing	Private	Lagos State	Manual	N/A	No
Idera Pharmacy	Dispensing	Private	Ogun State	Manual	N/A	No
Kunle Ara Pharmacy	Dispensing	Private	Oyo State	Manual	N/A	No
Nauzo Pharmacy	Dispensing	Private	Niger State	Manual	N/A	No
Ntyang Pharmacy	Dispensing	Private	Kano State	Manual	N/A	No
Rockfort Pharmacy	Dispensing	Private	Lagos State	Electronic	N/A	No
Rose Well Pharmacy	Dispensing	Private	Lagos State	Electronic	N/A	No
Santefort Pharmacy	Dispensing	Private	Lagos State	Electronic	N/A	No
Sauki Pharmacy	Dispensing	Private	Niger State	Manual	N/A	No
Skymax Pharmacy	Dispensing	Private	FCT-Abuja	Manual	N/A	No
Slainte Pharmacy	Dispensing	Private	Rivers State	Manual	N/A	No
Tagfast Pharmacy	Dispensing	Private	FCT-Abuja	Electronic	N/A	No
Tulip Pharmacy	Dispensing	Private	Oyo State	Electronic	N/A	No
Ulti Pharmacy	Dispensing	Private	FCT-Abuja	Electronic	N/A	No
Vanguard Pharmacy	Dispensing	Private	Oyo State	Electronic	N/A	No
Victory Drugs Pharmacy	Dispensing	Private	Lagos State	Manual	N/A	No
Wonderful Direct Pharmacy	Dispensing	Private	Ogun State	Manual	N/A	No
Vivy Pharmacy	Dispensing	Private	Enugu State	Electronic	N/A	No
Zinna Pharmacy	Dispensing	Private	Enugu State	Electronic	N/A	No

#Tertiary care facilities provide mainly specialised healthcare services such as oncology, orthopaedic, trauma, geriatric etc. Patients must be referred to a tertiary care facility, from either a secondary or primary in Nigeria, to receive care from these facilities. The majority of the tertiary care facilities in Nigeria are owned and managed by the National Government, and they are designated as University Teaching Hospitals, Referral Hospitals and Regional Hospitals. Secondary care facilities are overseen by the respective Regional, District/Municipal Governments (where the hospital is located). The secondary care facilities are mainly designated as District Hospitals, Municipal Hospitals and General Hospitals. The majority of the private hospitals in Nigeria (owned by private individuals/ organisations, including faith-based facilities) provide secondary care services. Secondary care hospitals offer services such as emergency care, neonatal care, and acute obstetric care, among other non-specialised services.
*Mixed recording keeping refers to pharmacy dispensing and recording systems that exist partially in an electronic form and partially in a manual form.
**For the review period, i.e., 2016-2018. AMC: Antimicrobial consumption.
† Refers to the ability of the pharmac to link dispensing records with the patient's hospital records to obtain patient diagnostic and characteristic information.

Section III: AMC or AMU analysis trends over time at national and pharmacy levels

Objective

To quantify and evaluate the trends of AMC and AMU at the national and pharmacy levels

Methodology

Statistical analysis

Data analysis for MAAP was conducted according to WHO's protocol for conducting AMC analysis using the DDD-ATC-AWaRe methodology[32,33] Figure 17 provides a high-level summary of the AMC analysis that was conducted. Each of these WHO methodologies are described below as well as the additional analysis conducted. In addition, and where possible, associations were drawn between AMC and AMR. Details of this analysis can be found in Part A, Section II:3c.

i. Defined Daily Dose (DDD)

DDDs or related metrics are utilised to study AMC analysis. Considering different doses (in milligrams) for each antibiotic for managing infections, the DDD metric helps in standardising for easy comparison. Additionally, it is recommended to use drug utilisation figures such as DDD using a relevant denominator for the health context e.g., DDDs/1000 inhabitants/day, DDD/ inhabitant/year or as DDDs/100 patient bed days. Studying DDDs or associated metrics over time helps to understand the consumption pattern or determine whether any national- or facility-level interventions have led to a change (+/-) in the consumption patterns over the study period or pre-defined base period.

Using the WHO 2020 DDD guide, the total DDDs were the quotient of the total consumed milligrams per antimicrobial divided by the standard DDD value issued by WHO.[34] The total DDDs were then adjusted for the country population size[35] in the years of data collection (2016-2018) and presented as DDDs/1000 inhabitants/day (DID). However, due to missing pack size information within the dataset received, analysis of the national level AMC was not possible. Furthermore, pharmacy-level AMC datasets were to be adjusted as DDD per the number of inpatients and presented as DDD/100 patient bed days. However, the use of WHO DDD per 100 patient bed days presented limitations at the point of analysis as patient bed days were not an appropriate denominator to use across the pharmacy-level AMC datasets. For most of the hospital facilities, patient bed days and patient days information were not easily accessible. Secondly, this metric would not allow for comparison between hospital pharmacy consumption and community pharmacy consumption as in the latter, the patient bed days metric is not applicable. Therefore, the pharmacy-level AMC datasets are presented as absolute DDD to aid comparison between hospital and community pharmacies for downstream analysis. Detailed DDD calculations can be found in Appendix 7. All calculations were conducted in Excel ™.

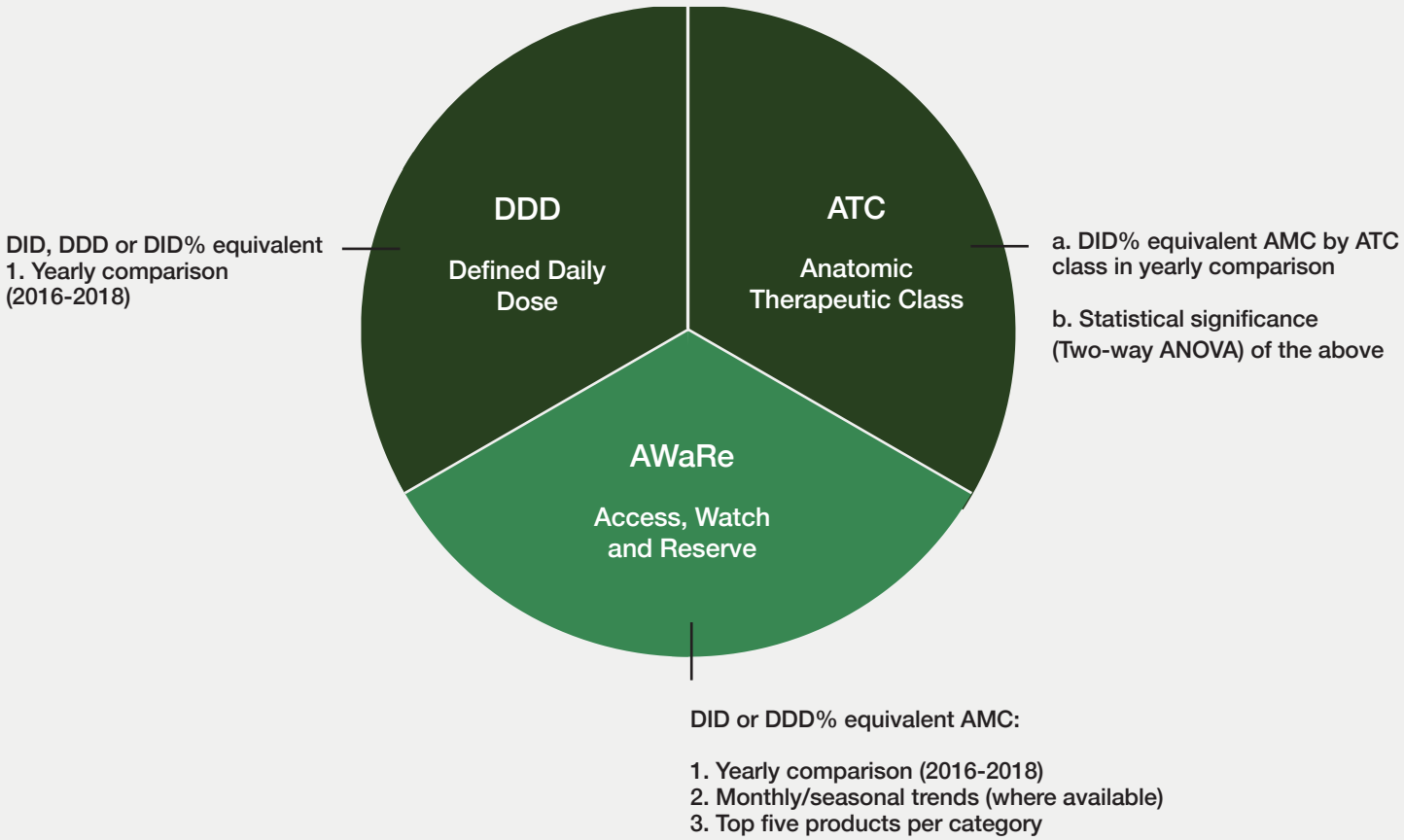
ii. Anatomic Therapeutic Chemical (ATC) Classification

Using the standard list of antimicrobial names, the pharmacy-level datasets collected were coded in an Excel TM analysis database in accordance with the 2020 WHO ATC codes and then analysed to characterise the macro (above-molecule) AMC trends. The description of ATC codes is presented in Appendix 7. Furthermore, MAAP aimed to conduct statistical testing to determine the year-on-year differences within each ATC class. However, this was not possible as the aggregated pharmacy-level datasets included AMC datasets from six pharmacies that did not provide full coverage of the three-year review period.

iii. WHO Access, Watch and Reserve (AWaRe)

The WHO AWaRe categorisation classifies antibiotics under the 'Access', 'Watch', and 'Reserve' groups. The 'Access' category includes antibiotics of choice for the 25 most common infections and should be affordable and available at all times as well as the quality assured in the country or facilities. 'Watch' includes antibiotics indicated for specific and limited infective syndromes (since they are prone to be a target of antibiotic resistance). Hence, their use is controlled through stewardship programmes and monitoring). Lastly, 'Reserve' antibiotics are considered as a 'last resort' treatment option. They are indicated in case of life-threatening infections due to multi-drug resistance (closely monitored and prioritised in stewardship programmes to ensure their continued effectiveness).

Through WHO AWaRe analysis, the total AMC by DDDs per antibiotic molecule were labelled as either 'Access', 'Watch' or 'Reserve' in accordance with the 2019 WHO AWaRe list[36] in Excel ™ sheet. Total DDDs per WHO AWaRe category were then analysed to determine the proportion of AMC per category and over time i.e., yearly and monthly (where possible). WHO recommends that at least 60% of a country's total AMC should come from the 'Access' category of antibiotics. Finally, an analysis was conducted to identify the top five antibiotics consumed in each WHO AWaRe category.



Defined Daily Dose (DDD) indicators utilised for volume metric standardisation was sourced from WHOCC 2020, ATC Classification utilised to categorise the antibiotics according to the organ or system on which they act and their therapeutic, pharmacological and chemical properties sourced from WHOCCC ATC database. The Access, Watch and Reserved categorisation was sourced from 2019 WHO AWaRe classification[36]

Figure 17: Methods and indicators used for the analysis of the data collected in Nigeria.

iv. Review of Essential Medicines List (EML)

According to the WHO, essential medicines are those that satisfy the priority healthcare needs of a population. They are selected with regard to disease prevalence and public health relevance, evidence of efficacy and safety and comparative cost-effectiveness. They are intended to always be available in functioning health systems, in appropriate dosage forms, of assured quality and at prices individuals and health systems can afford. A document analysis was conducted in which the antimicrobials listed in the WHO EML were compared with the antimicrobials listed in the Nigeria EML and against the documented antimicrobials from the national- and pharmacy-level data collection. The comparison was conducted as per WHO-defined AWaRe categories.

Results

Pharmacy AMC datasets analysed by DDD per year

The average total in-country AMC for the pharmacies sampled between 2016 to 2018 was 4,479,320.2 DDDs. The total consumption of the antimicrobials from the year 2016 to 2018 was almost similar with minimal fluctuation through the years reviewed (2016-2018) (Figure 18).

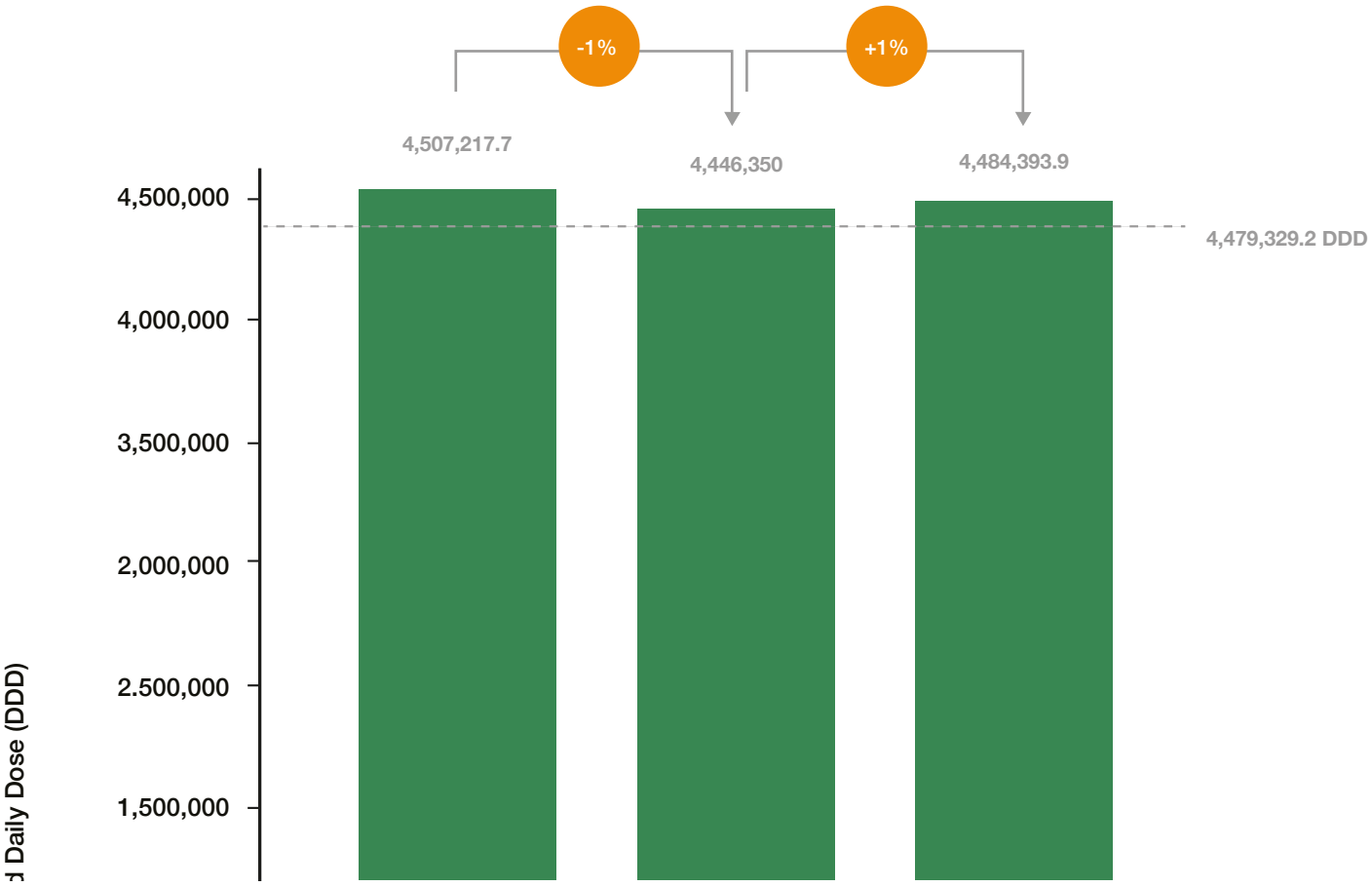


Figure 18: Bar graphs represent the total DDD and percentage variation from the year 2016 to 2018 for the pharmacy-level AMC data analysed in Nigeria. (*NB: DDDs shown here are not normalised to the country population levels or facility catchment population)*

Pharmacy AMC analysed by ATC classification

Combinations of penicillins, including beta-lactamase inhibitors (J01CR) were the overall most consumed ATC class for the pharmacies sampled in Nigeria across the review period at 14.9% in 2016, 16.8% in 2017 and 15.2% in 2018 (Figure 19). Amoxicillin/Clavulanic acid was the most frequently consumed antibiotic within this class. Nitroimidzole derivatives (P01AB) and Fluoroquinolones (J01MA) were the second- and third-most consumed ATC classes, with Metronidazole and Ciprofloxacin leading consumption within these ATC classes respectively. The top five most consumed antimicrobials were Metronidazole, Amoxicillin/Clavulanic acid, Cefuroxime, Ciprofloxacin and Amoxicillin. Together, they account for >55% of total consumption share. A detailed list of pharmacy-level AMC by antimicrobial molecule and by ATC class is mentioned in AMC Appendix 8 and Appendix 9 respectively.

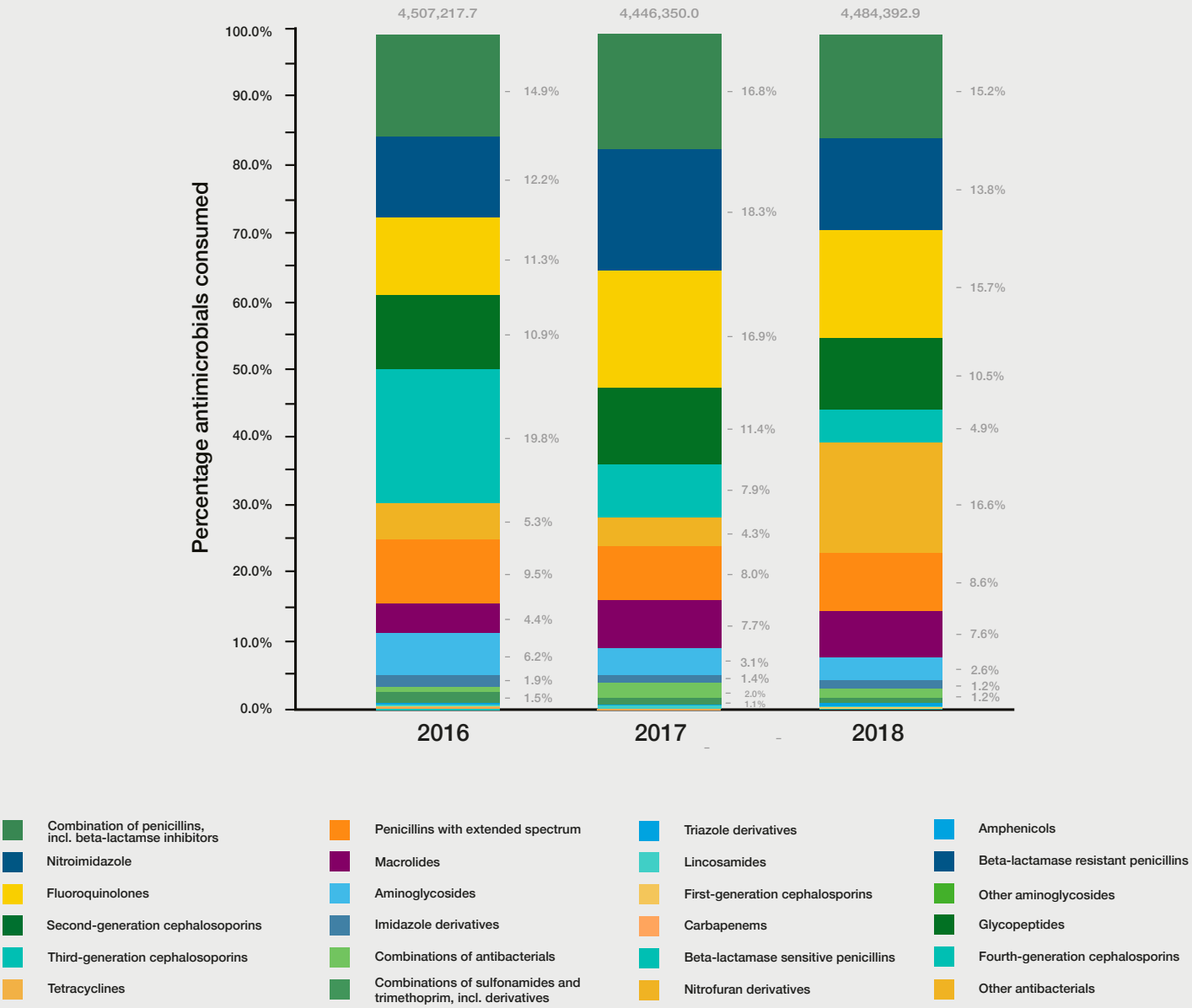


Figure 19: Results of the pharmacy level AMC data analysed in Nigeria are presented by total DDDs and percentage of antimicrobials consumed by ATC classes for the years 2016 to 2018. Combinations of penicillins, including beta-lactamase inhibitors class of molecules were on average the highest consumed antimicrobials for the reviewed period (2016 to 2018). Statistical testing was not carried out due to the nature of the data obtained. See Appendix 9 for a more detailed breakdown of AMC by ATC classes

Pharmacy AMC analysed by WHO AWaRe categorization

The average consumption of antibiotics for the sampled pharmacies across 2016-2018 were 54.2% 'Access', 45.8% 'Watch' and <0.1% 'Reserve'. Annual AMC trends indicated an increase of 2.1% in the consumption share of 'Access' antibiotics between 2016 and 2017, followed by an increase of 6.3% between 2017 and 2018. This was against a corresponding decrease of 2.1% in 'Watch' antibiotics between 2016 and 2017 and a further 6.3% decrease in consumption share between 2017 and 2018 (Figure 20). Both, overall and within each year analysed, the share of consumption of 'Access' category antibiotics within the sampled pharmacies failed to meet the 60% minimum consumption threshold set by WHO. This analysis of pharmacy-level AMC by WHO AWaRe categories omits 6% (266,623.0 DDDs) of total AMC that are not categorised within the WHO AWaRe list of 2019.

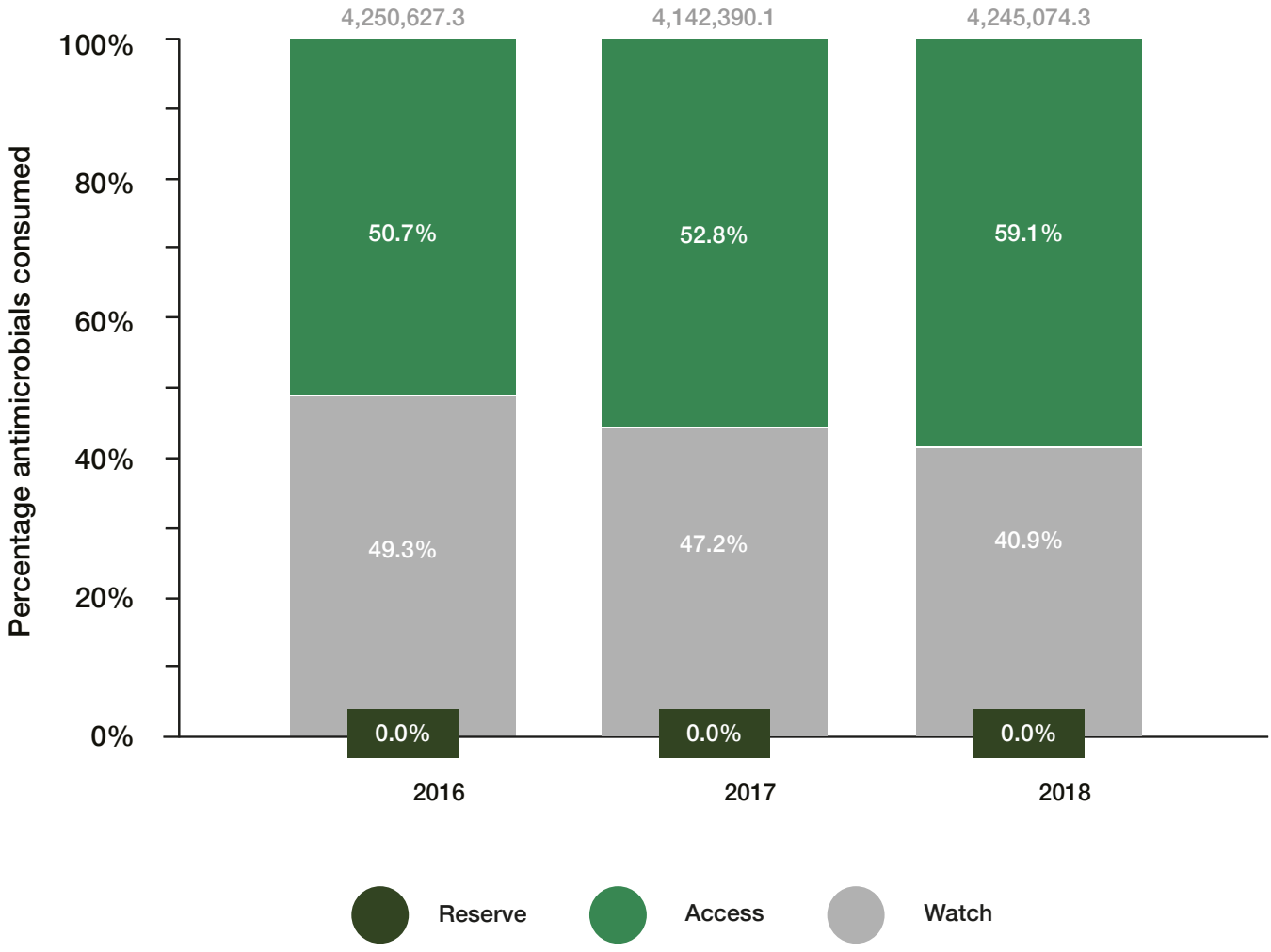
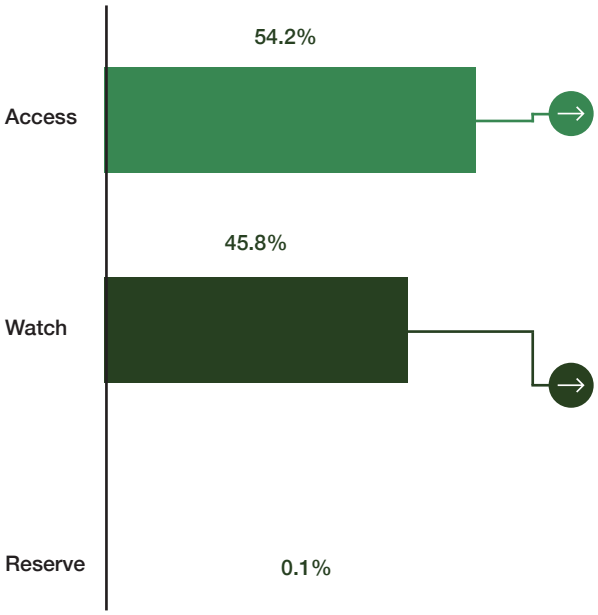


Figure 20: Results for the AMC data analysed for the sampled pharmacies in Nigeria are presented by the total DDDs and percentage of antibiotics consumed by WHO AWaRe categories for the years 2016 to 2018. Additionally, it shows the percentage change in consumption of 'Access' and 'Watch' category antibiotics from the years 2016 to 2018

Further analysis was conducted to identify the most frequently consumed antibiotics within the sampled pharmacies, within each WHO AWaRe category (Figure 21). In the 'Access' category, the top five consumed antibiotics, as listed in figure 3.3.b, accounted for 95.4% of all AMC within this group. While in the 'Watch' category, the top five antibiotics accounted for 80.5% of all consumption within this group. In the 'Reserve' category, the pharmacy-level consumption was only recorded for one antibiotic, tigecycline representing 100% of the consumption within this category.



Molecule Name	% Total	Mean DDDs
Metronidazole	31.2%	712,442.1
Amoxicillin/Clavulanic Acid	23.5%	537,363.8
Amoxicillin	16.9%	385,252.1
Doxycycline	16.3%	371,376.7
Gentamicin	7.5%	171,500.6

Molecule Name	% Total	Mean DDDs
Cerfuroxime	25.3%	488,323.8
Ciprofloxacin	22.3%	429,896.8
Ceftriaxone	17.2%	332,251.4
Erythromycin	8.3%	159,414.1
Levofloxacin	7.4%	141,797.3

Molecule Name	% Total	Mean DDDs
Tigecycline	100.0%	41.7

Figure 21: Breakdown of the 'Access', 'Watch' and 'Reserve' categories of antibiotics consumed at the sampled pharmacies by percentage and total DDD for the years 2016 to 2018 in Nigeria. It also depicts the top-five consumed antibiotics in their respective categories

Within the WHO AWaRe database exists a list of 'antibiotics not recommended'. This group of antibiotics consists of fixed dose combination (FDC) multiple broad-spectrum antibiotics that are neither evidence-based nor recommended by high-quality international guidelines. As a result, WHO does not recommend their use in clinical practice. Furthermore, these antibiotics are represented as 'uncategorised' by MAAP and excluded from the WHO AWaRe analysis results presented above. Analysis of the pharmacy AMC data was made to identify their consumption in the country. Consumption of (n=13) of these antibiotics was observed (representing 5.1% consumption of total pharmacy AMC) and is listed in Table 12 below. Among them, the FDC of Ampicillin/Cloxacillin was the most frequently consumed (accounting for 68.1% of total consumption of the listed FDC antibiotics in Table 12) with a mean DDD of 157 091.4. This FDC antibiotic was also found to be the ninth most frequently consumed antimicrobial in the overall pharmacy-level datasets analysed.

Table 12: Consumption ranking of WHO AWaRe uncategorised antimicrobials from 26 selected pharmacies in Nigeria for the years 2016 to 2019*

AMC rank*	Molecule
9	Ampicillin/Cloxacillin
16	Ofloxacin/Ornidazole
20	Ciprofloxacin/Tinidazole
21	Cefixime/Clavulanic Acid
28	Azithromycin/Fluconazole/Secnidazole
33	Ampicillin/Flucloxacillin
34	Ceftriaxone/Sulbactam
35	Cefuroxime/Clavulanic Acid
43	Levofloxacin/Ornidazole
51	Amoxicillin/Flucloxacillin
54	Ceftriaxone/Tazobactam
61	Cefoperazone/Sulbactam
62	Cefpodoxime proxetil/Clavulanic Acid

**AMC rank reports the position of antibiotics consumed (in terms of the total DDD and percentage share) from the reviewed list of antimicrobials for the sampled pharmacies in Nigeria (see appendix 8 for consumption rate of each listed antibiotics).*

Disaggregation of the pharmacy-level data represented above was conducted from the (n=52) participating pharmacies and examined by the type of pharmacy (community against hospital), by the level of service of the hospitals (secondary care against tertiary care and private versus public) and by their proportional consumption of WHO AWaRe category antibiotics (Table 13). Community pharmacies on average met the WHO threshold of 60% antibiotics consumption of represented within the 'Access' category at 63.9%, while the hospital pharmacies failed to meet this target at 50.7%. Hospital pharmacies consumed on average 12.7% more 'Watch' category antibiotics compared to community pharmacies (hospital pharmacies 48.8%, community pharmacies 36.1% 'Watch' antibiotics consumption). Additionally, within the hospital pharmacies, the public hospital pharmacies consumed 27.6% more 'Watch' antibiotics compared to private hospital pharmacies.

It was also observed that while the public hospital pharmacies failed to meet the 'Access' consumption target (with consumption recorded at 50.7%), the (n=1) private hospital pharmacy far exceeded this target (recording a consumption of 78.3%). Furthermore, within the public hospital pharmacies, the tertiary care hospital pharmacies consumed 11.7% more 'Watch' category antibiotics compared to the secondary care hospital pharmacies. Consumption of 'Reserve' category antibiotics were only identified within the public tertiary care hospital pharmacies and accounted for < 0.1% (total of 125 DDDs) of the total consumption. A closer look within the pharmacies found that 72% (n=18) of the hospital pharmacies and 56% (n=15) of the community pharmacies failed to meet the WHO 'Access' threshold.

Table 13: Percentage share in the consumption of antibiotics by WHO AWaRe categories for both the recruited hospital and community pharmacies between the years (2016-2018) in Nigeria.

Pharmacy Type	AWaRe Categorisation		
	Access	Watch	Reserve
	Percentage share (Absolute DDD)		
Hospital Pharmacies (25/52)	51.2% (4.9 million)	48.8% (4.7 million)	0.0% (125)
Public hospital pharmacies (24/52)	50.7% (4.7 million)	49.3% (4.6 million)	0.0% (125)
Secondary care hospitals (7/24)	59.4% (1.4 million)	40.6% (993,033.8)	0.0% (0)
Tertiary care hospital (17/24)	47.7% (3.3 million)	52.3% (3.6 million)	0.0% (125)
Private hospital pharmacy (1/52)	78.3% (134,700)	21.7% (37395.5)	0.0% (0)
Community pharmacies (27/52)	63.9% (1.9 million)	36.1% (1.0 million)	0.0% (0)
Grand Total	54.2% (6.8 million)	45.8% (5.7 million)	0.0% (125)

Comparison of the WHO EML and the Nigeria EML with documented antibiotics by WHO AWaRe categorisation

The WHO EML includes 39 antibiotics across the AWaRe categories. A total of 81 antibiotics were documented during pharmacy-level data collection. Figure 22 shows the number of antibiotics in the WHO EML for each AWaRe category the number of antibiotics in the WHO EML and Nigeria EML, thereby indicating if whether the antibiotic was documented during data collection.

It was determinedfound that seven antibiotics in the 'Access' category and five in the 'Watch' category are listed in the WHO EML and were documented during data collection although, yet they are not part included of in the Nigeria EML. In addition, one 'Access' category and eight 'Reserve' category antibiotics are part of the WHO EML, yet they are not listed in the Nigeria EML and nor were they documented during data collection. There were three 'Access' category antibiotics, two 'Watch' and two 'Reserve' that were listed in the Nigeria EML and documented during data collection, but not listed in the WHO EML. For each of the categories, including the uncategorised, antibiotics were documented during data collection, which are neither part of the WHO EML or Nigeria EML. The detailed breakdown of antibiotics documented and their inclusion in the WHO EML and Nigeria EML is provided in the AMC Appendix 10.

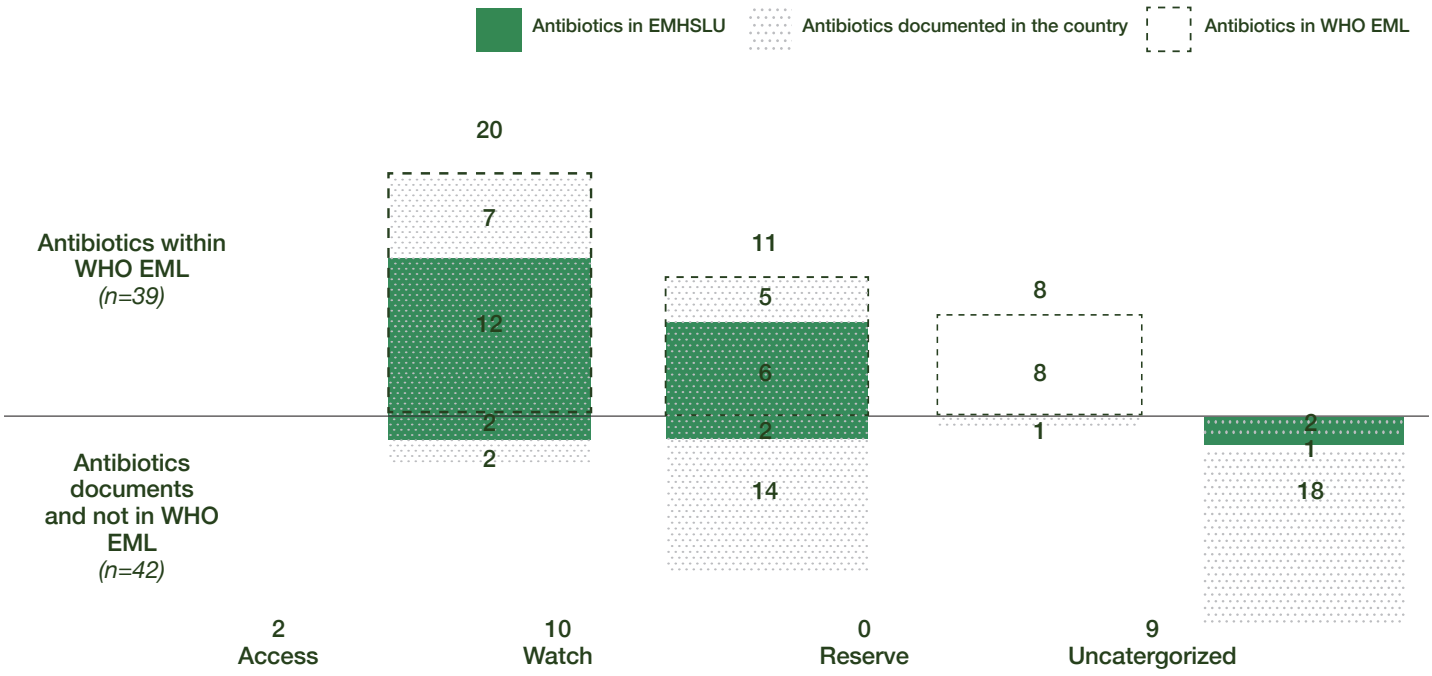


Figure 22: AWaRe analysis of documented antibiotics in pharmacy-level data for the years 2016 to 2018 compared to WHO-and Nigeria EML definitions.
**Data represented is based on aggregated facility data only; National data could not be retrieved and analysed for Nigeria*

Part C: Resistance and Consumption Interlinkages

Objective

To assess the relationship between antimicrobial consumption and antimicrobial resistance.

Methodology

The DRI was estimated to convey aggregate rates of resistance as well as measurements of AMC (at a national level since AMU data was not available) across select pathogen-antimicrobial combinations (Pathogens - A. baumannii, E. coli, K. pneumoniae, P. aeruginosa, S. aureus, E. faecium and E. faecalis; antibiotics -aminoglycosides, broad-spectrum penicillins, carbapenems, cephalosporins, glycopeptides, narrow-spectrum penicillins and quinolones). The DRI estimates were generated using a previously published methodology[37,38] (AMR Appendix 8) and help communicate the effectiveness of antibiotic therapy to decision makers. DRI value ranges from 0 (100% susceptibility) to 100 (100% resistance). Available AST results for at least 30 tested isolates and for at least 15 of the 25 combinations were prerequisites for the estimation of the DRI. To generate CIs for the DRI as the variance of the product of variables, the variance of the proportions of non-susceptible isolates was combined with a uniform standard deviation based on the estimated DDD.[39,40]

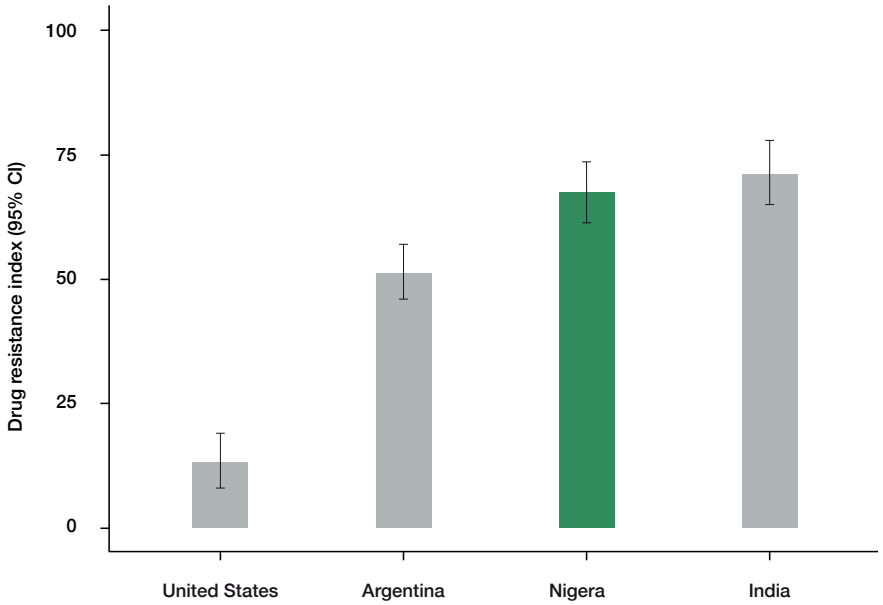
Apart from the DRI, correlation between AMC and AMR was conducted. Data on AMC were obtained from facilities and based on the total DDD over the entire study period. The AMC of a particular antimicrobial class was correlated with a composite resistance rate (covering all pathogens tested against the same antimicrobial class, as reported by the laboratories). Pearson's correlation analysis was performed between the two variables (AMR rate [%] and total DDD). Antibiotic classes contributing less than 0.05% to the total antibiotics consumed were excluded from the analysis.

Based on previously described methodology, the resistance of all pathogens was tested against the most and least consumed antimicrobial classes and reported by the laboratories based on data availability in each study year.

Results

Drug Resistance Index

The DRI estimate was found to be high at 66% (95% CI, 59.9-72.0%) implying low antibiotic effectiveness, which is a threat to effective infectious disease management and calls for urgent policy intervention (Figure 23).



AMC and AMR correlation

The top three highly consumed antibiotic classes at facility level were cephalosporins (2nd-generation), fluoroquinolones, and aminopenicillins. The AMR rates were highest for folate pathway inhibitors (80.5%), tetracyclines (75.4%), and aminopenicillins (74.8%) (Table 14) Pearson's correlation analysis revealed a weak positive correlation (r2=0.099) between AMR and AMC, implying that AMC is a not a significant driver of AMR in Nigeria (Figure 24).

Table 14: AMC and AMR rates across antibiotic classes

Antibiotic class	Year	Total DDD in millions	Resistance rate (%)
Cephalosporins (2nd- generation)	2016-18	1.20	74.5
Fluoroquinolones	2016-18	1.17	57.1
Aminopenicillins	2016-18	1.09	74.8
Cephalosporins (3rd- generation)	2016-18	1.05	70.9
Beta-lactam combinations	2016-18	1.03	30.5
Tetracyclines	2016-18	1.02	75.4
Macrolides	2016-18	0.66	67.5
Aminoglycosides	2016-18	0.44	59.0
Penicillins	2016-18	0.28	61.0
Folate pathway inhibitors	2016-18	0.08	80.5
Carbapenems	2016-18	0.01	23.0
Lincosamides	2016-18	0.01	49.7

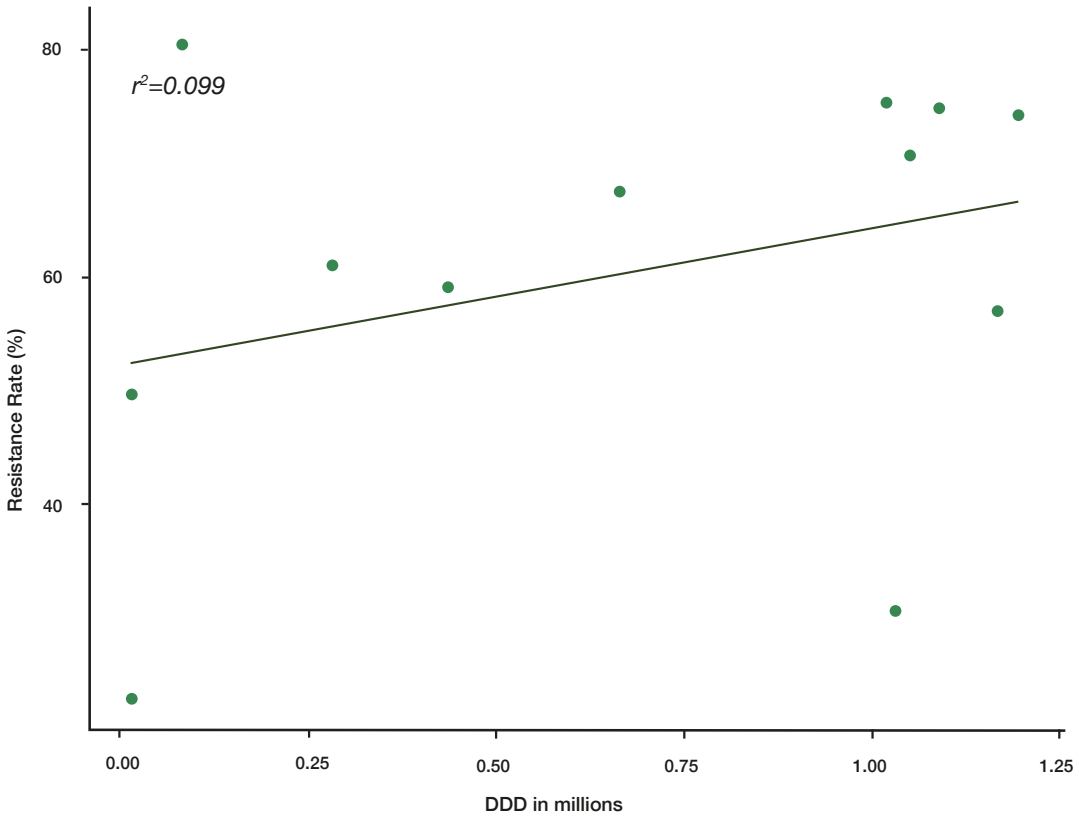


Figure 24: Correlation between AMR and AMC

Resistance profiles of most and least consumed antimicrobial classes

The most consumed antimicrobial classes across the study years were beta-lactam combinations, nitroimidazoles, fluoroquinilones, and tetracyclines. In 2016, resistance rates were more than >75% for cephalosporin (3rd-generation) resistant Staphyloccocus species and Escherichia species. In 2017, high resistance rates (>50%) were observed for fluoroquinolone-resistant Streptococcus species, Escherichia species, Enterococcus species, Staphyloccocus species and Acinetobacter species. In 2018, the highest resistance rates (>75%) were observed for tetracycline-resistant Pseudomonas species and Escherichia species. (Figure 25, 26 and 27).

The least consumed antimicrobial classes across the study years were carbapenems cephalosporins (1st-generation), phenicols and methicillin. Although the consumption of these antimicrobial classes was low, high reistance rates were noted across many pathogen-antimicrobial class combinations. In 2016, resistance rates were more than >75% for methicillin-resistant Pseudomonas species, Klebsiella species, Streptococcus species, Escherichia species and Staphylococcus species. In 2017, resistance rates were more than >50% for cephalosporin (1st generation)- resistant Escherichia species, Klebsiella species and Staphylococcus species. In 2018, resistance rates were more than >75% for cephalosporin (1st-generation) resistant Salmonella species, Escherichia species, and Staphylococcus species (Figure 25, 26 and 27).

Figure 25: AMR rates for least (left) and most (right) consumed antimicrobial classes (AMs) in 2016

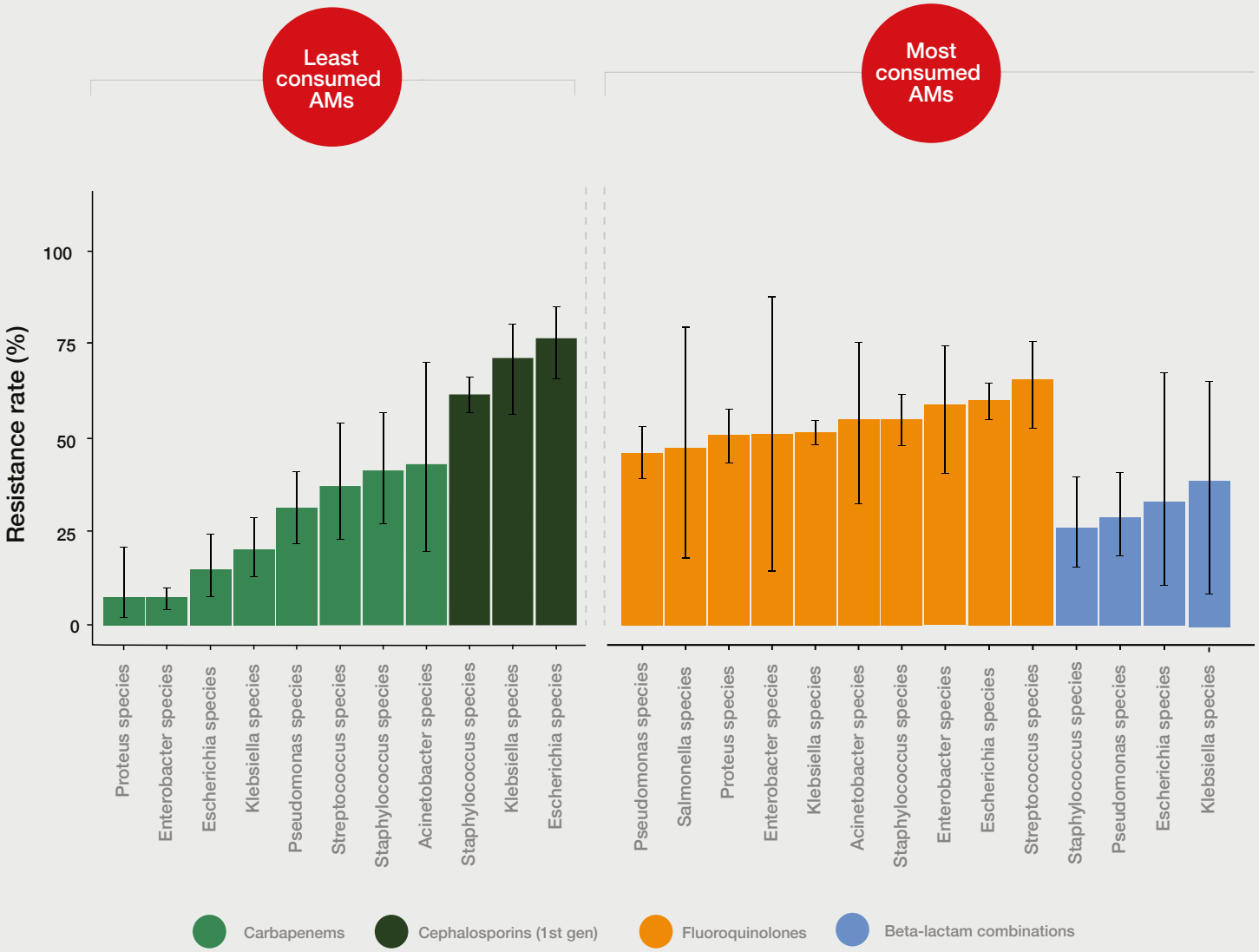


Figure 26: AMR rates for least (left) and most (right) consumed antimicrobial classes (AMs) in 2017

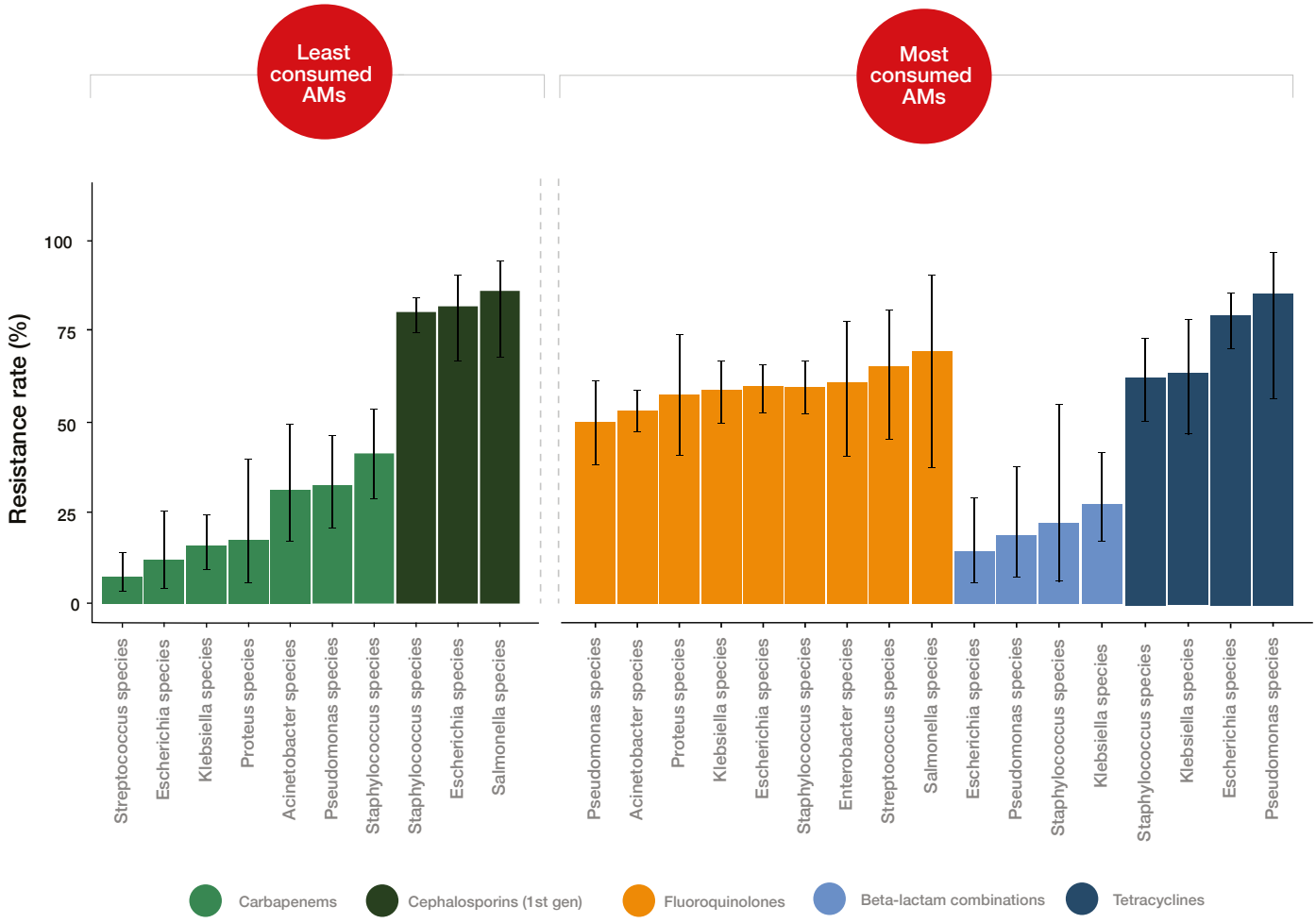


Figure 27: AMR rates for least (left) and most (right) consumed antimicrobial classes (AMs) in 2018

Part D: Recommendations

AMR is a major threat to medical advancements and has drawn global attention over the past few years and more so recently, due to the COVID-19 pandemic. Unfortunately, owing to inconsistent surveillance data, the AMR burden is not well quantified in most countries. A recent review reported non-availability of AMR data for more than 40% of African countries and expressed concerns about the quality of the microbiology data that did exist.41

The mitigation of AMR calls for a multipronged approach including building resilient health and laboratory systems as well as improving stewardship (diagnostic, antimicrobial use, and infection prevention). Based on our study findings, we propose the following recommendations to strengthen AMR surveillance in Nigeria.

Significance of AMR and DRI data and recommendations

Analysis of available AMR data from Nigeria revealed high AMR rates were noted for 3rd-generation cephalosporin-resistant Enterobacterales (67-73%) and methicillin-resistant S. aureus (MRSA) (~58-82%). Moderate to high levels of resistance were noted for carbapenem-resistant P. aeruginosa (30-53%) and fluoroquinolone-resistant Salmonella species (46-75%).

Enterobacterales can be asymptomatic colonisers or result in community- and healthcare- associated infections (commonly affecting the urinary tract, bloodstream, lower respiratory tract and surgical sites). Various risk factors predispose to resistance against 3rd-generation cephalosporins and carbapenems. These risk factors include prior use of cephalosporins and/or carbapenems, indwelling catheters, mechanical ventilation, underlying comorbidities (such as diabetes, malignancy, severe illness, etc.), injuries and transplantation. To limit the spread of resistant Enterobacterales, compliance to standard and contact precautions (including hand hygiene), the minimal use of catheters and invasive devices, compliance to infection prevention bundles, and antimicrobial stewardship, is essential. Additionally, high-risk patients should be screened for rectal colonisation.

S.s aureus (methicillin resistant or sensitive) is a common cause of many skin and soft tissue infections, in both community and healthcare settings. It can also cause invasive infections like endocarditis, osteomyelitis, pneumonia, visceral abscess, brain abscess, shunt infections and bacteraemia. Risk factors for MRSA infections include past infections/colonisation/close contact, trauma, invasive devices (catheters, shunts, implants and prosthesis), prior antibiotic use, neutropenia, other underlying conditions, post-surgical status, dialysis and admission to long-term care facilities.

While antimicrobial therapy and source control (drainage or catheter removal) are essential for the treatment modalities, it is as important to prevent and control the spread of MRSA infections. Use of catheters and invasive devices must be minimised, and stewardship principles practised (culture taken prior to initiating antibiotics and prompt de-escalation from empirical to targeted therapy). High-risk and pre-operative patients must be screened for MRSA carriage and decolonised. Patients and caregivers should be educated on the importance of handwashing and contact precautions.

P. aeruginosa is notorious for causing healthcare-associated infections. The organism is often multidrug resistant (either intrinsically or acquired). Prior use of carbapenems is a known risk factor for emergence of carbapenem-resistant Pseudomonas aeruginosa. Other risk factors include extended ICU stay, presence of invasive devices, prolonged bladder catheterisation, underlying comorbidities (such as diabetes, cystic fibrosis, etc.), burns, and immunocompromised status. Since resistant Pseudomonas infections are often fatal, it is essential to promptly initiate the appropriate treatment as well as adopt simple source control measures such as standard precautions (including hand hygiene), catheter care, early device removal, and compliance to the infection prevention bundles. Antimicrobial stewardship and infection control programmes must be established as they may provide effective ways in which to control AMR.

Salmonella (also member of Enterobacterales) strains are known causes of enteric fever, food-borne gastroenteritis and invasive infections. Salmonella infections are acquired through the faecal-oral route and various risk factors (such as extremes of age, malaria, schistosomiasis, hemoglobinopathies, immunocompromised state and chronic liver disease) predispose to non-typhoidal Salmonella bacteraemia. While earlier simple antibiotics like Ampicillin, trimethoprim-sulfamethoxazole, and Chloramphenicol were effective, multidrug resistance has rapidly spread and fluoroquinolone non-susceptibility is a current global concern. To control Salmonella infections, food and water safety, screening food handlers for chronic carrier state and typhoid vaccination of susceptible vulnerable populations, must be ensured. Patients must complete their full antibiotic course and be monitored for carriage and relapse. Use of fluoroquinolones in hospitals and animal husbandry must be restricted, and the surveillance of antimicrobial resistance patterns should be essential.

The estimated DRI for Nigeria was also high and indicates decreasing effectiveness of antimicrobials. Evidently, this calls for targeted interventions which should include improved ASP, infection prevention as well as regulations on the use of high-end antibiotics. We observed that males and the elderly were prone to resistant infections although further studies are necessary to establish an association.

Service delivery

The laboratory network in Nigeria was found to consist of 34 423 laboratories, of which 73, were identified as bacteriological laboratories with confirmed AST capabilities. While most of the surveyed laboratories reported implementing QMS, not all were certified or accredited. Considering a country population of over 206 million, the laboratories did not equitably cover the country's population. The testing load (quantum of cultures) at most participating laboratories was found to be low and suggested a lack of routine microbiology testing. Hence, this risks overestimating the AMR rates as the majority of tests would have been conducted on special patient categories (such as failure of first-line therapy or admission to intensive care).

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Health workforce

As reported by the surveyed laboratories, nearly all laboratories had an experienced laboratory scientist or technologist, 86% had at least one qualified microbiologist and only 55% had up-to-date records on training and competence. For high quality microbiology testing and reporting, staff training on laboratory standards, ability to identify common pathogens and data management skills are essential.42 Capacity-building of staff may be completed through in-house expertise or outsourced to external organisations or tertiary facilities.

Information systems

The Regional Grant was a step towards the collection and digitisation of data. We observed that most of the surveyed laboratories relied on paper-based records and very few had linkages to patients' clinical records. In the current study involving 25 laboratories over a three-year period, susceptibility results could be collected for just 23 963 positive cultures. In order to strengthen AMR surveillance, it is essential to curate the right data and generate evidence. We recommend data collection through standardised formats at all levels (laboratories, clinics and pharmacies) as well as the use of automation for data analyses. For the current study, we used WHONET for data digitisation. Empirical guidelines for management of infectious diseases should be based on epidemiology specific to patient settings and resistance data should be shared on national and supra-national platforms. We also recommend establishing a system of assigning permanent identification numbers for patient tracking over time. This would help to collect data on a patient's clinical profile, antimicrobial history as well as pathogens' molecular profile (where available), thus offering more context to the AMR epidemiology than stand-alone antimicrobial susceptibility data.

Medicines and technologies

While there are various determinants of patient care, the importance of quality diagnostics can never be undermined. Even though laboratory audit was not the scope of the current study, we observed instances of inappropriate testing and hence, data unfit for analysis. Such results can be misleading and impact patient care. In order to strengthen AMR surveillance, it is imperative to generate reliable laboratory results through appropriate testing methods, use of authorised surrogates and ensuring the uninterrupted availability of reagents, including antibiotics, for susceptibility testing. Improving supply chains for essential reagents, should be a country priority and interruptions in routine testing must be minimal. Standardisation of testing methods across laboratories can aid in this process as purchases can be pooled and coordinated by the MoH. All laboratories and testing centres must conform to AST quality standards and aim for accreditation and quality certification status.

Finally, we recommend increasing the community awareness on the importance of public health interventions (vaccinations, clean water, sanitation and hand hygiene) as well as compliance to physicians' advice. The strengthening of health and laboratory systems must be prioritised at national level and complemented with the right investment.

Significance of AMC and AMU data including recommendations

This section discusses the significance of our AMC and AMU findings and puts forth suggested recommendations for Nigeria to better facilitate future surveillance activities as well as antimicrobial stewardship activities.

Feasibility of obtaining AMC and AMU data in Nigeria and recommendations

MAAP successfully collected and analysed pharmacy-level AMC data for Nigeria for the years reviewed i.e., 2016 to 2018. MAAP was unable to analyse national-level AMC data due to gaps in the antimicrobials pack size information provided by NAFDAC, making this data unusable for the calculation of total consumed antimicrobials. Therefore, to ensure that Nigeria can utilise AMC data for policy development and respond to WHO's call to participate in GLASS, which now has an AMC reporting component, a comprehensive guiding policy for routine AMC data surveillance is required in the country. This policy should aim to guide on the minimum reporting AMC data variables (including explicit details on required package content information) and routine data cleaning and reporting practices. This will further serve as a guide to inform agencies supplying AMC data on the minimum data recording and quality requirements for surveillance exercises to ensure that the data received is accurate and usable for informing the country's antimicrobial policies and programmes.

Antimicrobial imports and the country's local manufacturing data assumes that all antimicrobials will be consumed locally but does not account for expiries or losses. It would be better to obtain national AMC data from sources as close as possible to the end user to improve the accuracy of the estimation of national AMC. Therefore, efforts should be made by relevant regulatory authorities to identify and recruit medicine wholesalers, distributors or large volume health facilities to serve as sub-national points for AMC surveillance. This would be in an effort to succeed single national AMC data sourcing from importation manifests and locally manufactured product records found at NAFDAC. Such a decentralised approach would also offer the added benefit of allowing the examination of AMC trends within the private and public sector and end-user institutions consuming the antimicrobials (i.e., primary, secondary and tertiary levels). Pharmacy-level AMC data from the hospitals were mainly collected from manual records. To make future AMC surveillance more time- and cost-efficient, hospitals could consider converting to electronic systems and ensure such systems have the capabilities to transfer data across systems and/or produce user-friendly reports on AMC.

MAAP was unable to obtain AMU data in Nigeria which would have helped to characterise the reasons antimicrobials were used and whether their consumption according to country guidelines and WHO's drug use research methodology.[43] This inability to collect AMU data from participating pharmacies that were co-located with AST laboratories was due to the fact that AMC data sources (i.e., stock record cards at the pharmacy) did not allow back-tracing to individual patients to whom antimicrobials were dispensed as prescription chits were not archived. Previous Nigeria AMU situational analysis studies successfully used global point prevalence survey methodology[14,33] Nonetheless, the success of these AMU studies implies that the retrieval of AMU data, where sub-optimal data systems exist, can only be achieved through the set-up of prospective studies for which collection procedures are intentionally set up to assess the patient in real-time through the cascade of care. Thus, retrospective studies, such as that which MAAP attempted to do for AMU data, may not be ideal.

Therefore, MAAP, in alignment with the WHO guide on facility AMU assessment, would recommend that future AMU surveillance attempts in the country be conducted through prospective data collection approaches but on a larger scale to give a nationally representative depiction of AMU in the country.

Overview of AMC consumption trends and recommendations

The pharmacy-level AMC trends documented in this report provide a useful benchmark to be compared against future consumption trends following implementation of stewardship programmes. MAAP was unable to estimate the total national AMC levels in Nigeria due to the missing product packaging information during data validation that prevented the analysis of the national-level datasets received from NAFDAC. Despite the absence of nationally representative AMC data, this report provides useful insights on AMC trends based on how antimicrobials are consumed within sampled pharmacies in Nigeria. Our analysis indicated that there was a near constant consumption of antimicrobials across the three reviewed years. However, not much insight can be drawn from total AMC consumption in DDDs as MAAP was not able to normalise the data per facility catchment population as data were unavailable for community pharmacies. Furthermore, a few pharmacies provided data for only part of the reviewed years. However, the majority of the consumption is represented as a percentage share within each year and observations provided within a given year are an accurate reflection of a particular trend. This section therefore focuses on the relative comparison of consumption within pharmacies as per WHO AWaRe proportion analysis.

The evaluation of antibiotic relative consumption according to the WHO AWaRe categories depicted the consumption of narrow spectrum antibiotics in the 'Access' category failed to meet the minimum WHO recommended consumption threshold of at least 60%.[36] Additionally, the consumption of broader spectrum 'Watch' category antibiotics observed and accounted for close to half of the total consumption recorded. The inability to meet the minimum consumption thresholds of 'Access' category antibiotics implies that the broader spectrum antibiotics ('Watch' category) may be used more regularly than recommended as first- and second-line treatments to treat common infections. Furthermore, it implies that antimicrobial stewardship activities may not be active within these facilities or may be sub-optimal in regulating the use of 'Watch' category antibiotics that have a higher resistance potential. MAAP would therefore recommend that the AMRCC consider the introduction of facility-level ASPs to regulate the use of these broader spectrum antibiotics and educate prescribers on the importance of reserving them to maintain efficacy.

Several interesting trends were also observed when the AMC was examined by the classification of sampled pharmacies. Firstly, despite the fact that the total sampled pharmacies as a whole did not meet the 60% threshold, upon examination of pharmacy sub-categories, it was identified that some of them did in fact meet the threshold. The community pharmacies and the single private hospital pharmacy met the WHO recommended consumption threshold (i.e., > 60% from the 'Access' category) unlike the public hospital pharmacies which failed to meet the threshold requirement. The variation in the consumption of 'Access' category antibiotics could be difficult to understand and further research should be conducted to establish whether this could be a result of better stewardship interventions within the private sector.

Secondly, within the public hospital pharmacies, the tertiary care hospital pharmacies consumed more 'Watch' category antibiotics compared to the secondary care hospital pharmacies. Higher consumption of 'Watch' category antibiotics at the tertiary care hospital pharmacies could be attributed to the fact that these facilities deal with the complex infection cases which would require treatment regimens using second- and third-line antimicrobial agents. Finally, the consumption of a 'Reserve' group antibiotic, Tigecycline, was only observed within the public tertiary care hospitals with no consumption recorded in the other sampled pharmacies. This observation is both expected and commendable as it implies that these 'last resort' antibiotics are likely being used to treat complex infection cases managed within specialist tertiary care hospitals. Interestingly, the country's EML only includes one antibiotic, Linezolid, out of the seven WHO 'Reserve' category antibiotics listed as essential medicines within the WHO's EML. However, the pharmacy AMC observed consumption of Tigecycline which is a different 'Reserve' antibiotic to that listed within Nigeria's EML. MAAP therefore recommends an urgent review be conducted by the MoH and AMRCC to assess the availability of the 'Reserve' category antibiotics in the country. that may subsequently lead to the revision of the country's EML and treatment guidelines to include these vital antibiotics. This approach will ensure that the most vital antibiotics are available for all patients.

A closer examination of the spectrum of antibiotics used within each AWaRe category revealed that an overwhelming majority of antibiotics consumed within the 'Access' and 'Watch' categories came only from the top five antibiotics in each category. Such a consumption pattern could be postulated to be sub-optimal as evolutionary pressure driving resistance would be focused only amongst the narrow band of antibiotics consumed.[44] This narrow consumption of antibiotics within the 'Access' and 'Watch' categories of antibiotics can also make the country susceptible to stockouts if manufacturing and supply chain issues are encountered for these few antibiotics. Considering the observations, it is therefore recommended that the country's ASPs explore ways to ensure a wider spread in consumption of the antibiotics within each WHO AWaRe category. This could include offering incentives for the importation and distribution of other antibiotics in the WHO AWaRe categories (in line with the country's EML) to avoid such a limited spectrum of consumed antibiotics.

WHO also provides guidance on antibiotics that are 'not recommended' for use in clinical practice due to their multiple broad-spectrum activity and lack of evidence-based clinical case that advocates for their use.[36] In Nigeria, the use of thirteen such FDCs 'not recommended' by WHO were detected. Of these antibiotic combinations, the use of Ampicillin/Cloxacillin was most prevalent. The clinical utility of using the combination of Ampicillin/Cloxacillin has been questioned as the two antibiotics have overlapping spectra of activity and indications that require treatment with both these antibiotics are uncommon.45 Therefore, as there is no recommendation for the use of these FDC antibiotics within the Nigeria's EML, it is recommended that the AMRCC identify the reasons and exact locations that commonly prescribe or dispense these FDC antibiotics. This will allow the country's MoH and associated medicine regulatory bodies (e.g., NAFDAC) to embark on sensitising prescribers on more appropriate treatments for those ailments to correct the prescribing practice.

AMC and AMU summary and way forward

Data generated from AMC and AMU surveillance trends can provide unique insights for national stewardship programmes and for the formulation of policies to stem the emergence of AMR. From the sampled pharmacies, Nigeria failed to meet the WHO threshold of at least 60% of antibiotics consumed from the 'Access' (narrow spectrum, first choice antibiotics) category. In addition, only five antibiotics make up for >55% of the consumption, which indicates the opportunity for more diversification. Table 15 describes the next steps for AMC and AMU surveillance.

Table 15: Next steps for AMC and AMU surveillance

A.

Leadership and Governance

The country will require an AMC surveillance policy and address by whom, how and when national AMC datasets should be reported. This activity could be led by the AMRCC. .

- Such a policy should provide guidance on the minimum required reporting variables, data quality appraisals, data analysis and reporting pathways to both the MoH and the WHO GLASS system. This would ensure a continuous stream of localised AMC data beyond MAAP that will help inform or assess future policy decisions by the national ASP.
- Lessons learned from the ongoing Fleming Fund Country Grants and MoH surveillance programmes could be taken into consideration in the development of the policy.

The regulatory authority, NAFDAC, could reconsider the registration status of unapproved FDCs.

The national stewardship programmes, led by the AMRCC, could work to review the national treatment guidelines, and review the Nigeria EML to include essential 'Reserve' category antibiotics, if deemed necessary for complex case management.

B.

Service Delivery

Future attempts to collect AMU data in the country should seek to identify facilities that have unique patient identifiers and fully electronic medical records capabilities or, as a limited number of facilities have such systems in place, the country could aim to prospectively collect this data as guided by the WHO methodology for point prevalence surveys.[33]

Although ASPs should be country-wide, the public hospitals were responsible for <60% 'Access' category consumption and therefore should be specifically targeted for mentorship and follow-ups by the AMRCC once ASPs are established. To address the lower than recommended consumption of 'Access' category antibiotics within these facilities, state- and facility-level ASPs should be implemented as an effort to increase consumption of 'Access' category antibiotics above the target set by the WHO.

National stewardship programmes led by the AMRCC could conduct educational campaigns for healthcare practitioners to ensure that they are aware of the full spectrum of antimicrobials available in the Nigeria EML

C.

Medical products and technologies

The country could establish national stewardship programmes to collaborate with pharmacists and medicine importers to increase the availability of varieties of antibiotics as per the reviewed Nigeria EML, including the availability of WHO 'Reserve' category antibiotics.

Part E: Limitations

Since the participating laboratories were at different levels of service and had variable testing capacity, all results in this report should be interpreted with caution. We encountered a few limitations during the conducting of the current study, as summarised below:

1. It was often difficult to obtain patients' hospital identifiers from laboratory records, thus impacting the collection of demographic and clinical information from medical archives. Where identifiers could be matched, it was found that hospital records were paper based, thus requiring manual retrieval. This was often compounded by issues of illegibility and/or incomplete demographics and clinical information.

2. The laboratories had varying levels of quality and testing practices. Consequently, data contributions were uneven and it proved challenging to consolidate data to provide robust analyses of resistance and clinical impact.

3. The participating laboratories (n=25) may not fully represent the true resistance rates in the country as they only encompassed a small proportion of the country's population (over 206 million). Furthermore, as routine testing does not appear to be the norm in most hospitals and laboratories, the data may overestimate the resistance rates as infections that fail therapy may be more likely to be tested.

4. Clinical data and AMU information were not sufficient to provide robust analysis of the drivers of resistance.

5. National AMC records from NAFDAC were intended to be used as a proxy for national antimicrobials consumption levels. However, the data received from NAFDAC had several key information gaps that were crucial for analysis. These gaps included key details of the antimicrobials (e.g., strength and formulation) and non-standardisation in relation to quantities (e.g., quantities recorded as cartons instead of number of tablets). Therefore, as a result of these gaps in information, it was not possible to conduct a national AMC analysis on these datasets.

6. MAAP further attempted to collect data from selected pharmacies in the absence of national-level analysed data. Here, a sample of 52 pharmacies were purposively selected for data collection. This sample size was a relatively small proportion of total pharmacies in Nigeria and did not represent all regions. Therefore, this data cannot be assumed to represent Nigeria's national consumption.

7. MAAP was unable to obtain AMU data from the participating pharmacies co-located with AST laboratories. Therefore, an understanding of how and why antimicrobials are prescribed as well as dispensed (i.e., appropriateness of prescriptions and antimicrobials consumed) was not achieved. This information is important as it would help better inform the country on where they would need to focus their stewardship programmes.

References

1. Fleming Fund. Accessed April 2, 2020. https://www.flemingfund.org/.
2. World Health Organisation. Worldwide Country Situation Analysis: Response to Antimicrobial Resistance. Accessed June 15, 2021. http://apps.who.int/iris/bitstream/handle/10665/163468/9789241564946_eng.pdf;jsessionid=040F003DCA2DE23A0E1484CFCF-967D32?sequence=1.
3. African Society for Laboratory Medicine. MAAP. Accessed April 16, 2020. https://aslm.org/what-we-do/maap/.
4. DataBank | The World Bank. Accessed December 26, 2021. https://databank.worldbank.org/home.aspx
5. Education Statistics - All Indicators | DataBank. Accessed December 26, 2021. https://databank.worldbank.org/source/education-statistics-%5E-all-indicators
6. UHC service coverage index | Data. World Bank. Published 2019. Accessed April 14, 2022. https://data.worldbank.org/indicator/SH.UHC.SRVS.CV.XD
7. HIV Facts and Figures | National AIDS Control Organisation | MoHFW | GoI. Accessed May 24, 2022. http://naco.gov.in/hiv-facts-figures
8. World Health Organisation. Global Action Plan on Antimicrobial Resistance.; 2015. Accessed April 16, 2019. https://apps.who.int/iris/bitstream/handle/10665/193736/9789241509763_eng.pdf?sequence=
9. World Health Organisation. Global Antimicrobial Resistance Surveillance System (GLASS). Published 2021. Accessed April 16, 2021. https://www.who.int/glass/en/
10. Federal Ministry of Health. National Action Plan for Antimicrobial Resistance 2017-2022. .; 2017. Accessed November 5, 2021. https://www.flemingfund.org/wp-content/uploads/1c9f6c1283bc2fa18029ab2a65b9b6f0.pdf
11. Samuel, A., 2020. Key Informant Interview - Private Community Pharmacy [Interview] (11 December 2020).
12. Lawal, F., 2020. Key Informant Interview - Private Community Pharmacy [Interview] (13 December 2020).
13. Government of Nigeria, 1990. Poisons and Pharmacy Law. Chapter 366., s.l.: Law of Federal Republic of Nigeria .
14. Federal Ministries of Agriculture, Environment and Health., 2017. National Action Plan for Antimicrobial Resistance 2017-2022.. [Online]
15. WHONET | Welcome to the WHONET Community website! Accessed December 23, 2021. https://whonet.org/
16. World Health Organisation. Prioritization of Pathogens to Guide Discovery, Research and Development of New Antibiotics for Drug-Resistant Bacterial Infections, Including Tuberculosis.; 2017.
17. Clinical and Laboratory Standards Institute. CLSI. Analysis and Presentation of Cumulative Antimicrobial Susceptibility Test Data; Approved Guideline—Fourth Edition. CLSI Document M39-A4.; 2014.
18. Li F, Ayers TL, Park SY, et al. Isolate removal methods and methicillin-resistant Staphylococcus aureus surveillance. Emerging Infectious Diseases. 2005;11(10):1552-1557. doi:10.3201/eid1110.050162.
19. Brown Lawrence D. CTTDA. Interval Estimation for a Binomial Proportion. Stats Sci. 2001;16(2):101-133.
20. Kalanxhi E, Osena G, Kapoor G, Klein E. Confidence interval methods for antimicrobial resistance surveillance data. Antimicrobial Resistance and Infection Control. 2021;10(1). doi:10.1186/s13756-021-00960-5.
21. The Center for Disease Dynamics Economics and Policy. ResistanceMap: Antibiotic resistance. 2018. Accessed June 15, 2021. https://resistancemap.cddep.org/About.php
22. World Health Organisation. (2018). WHO report on surveillance of antibiotic consumption: 2016-2018 early implementation. Retrieved December 23, 2020, from https://apps.who.int/iris/bitstream/handle/10665/277359/9789241514880-eng.pdf?ua=1
23. Van Boeckel, T. P., Gandra, S., Ashok, A., Caudron, Q., Grenfell, B. T., Levin, S. A., and al., e. (2014). Global antibiotic consumption 2000 to 2010: an analysis of national pharmaceutical sales data. The Lancet Infectious Diseases, 14(8), 742-750.

24.	Gordon, C. (2020, April). Technical Bulletin: Surveillance and AMU. Retrieved June 01, 2021, from https://www.flemingfund.org/wp-content/uploads/29e140d66670221b9d95aaaa108ef03e.pdf
25.	Martinez, E. M., Klein, E. Y., Van Boeckel, T. P., Pant, S., Gandra, S., Levin, S. A., . . . Laxminarayan, R. (2018). Global increase and geographic convergence in antibiotic consumption between 2000 and 2015. Proceedings of the National Academy of Sciences, 115(15), E3463-E3470.
26.	Kanu, J. S., Khogali, M., Hann, K., Tao, W., Barlatt, S., Komeh, J., . . . al., e. (2021). National Antibiotic Consumption for Human Use in Sierra Leone (2017–2019): A Cross-Sectional Study. Tropical Medicine and Infectious Disease, 6(2), 77.
27.	Namugambe JS, D. A. (2021). National Antimicrobial Consumption: Analysis of Central Warehouses Supplies to In-Patient Care Health Facilities from 2017 to 2019 in Uganda. Tropical Medicine and Infectious Disease, 6(2), 83.
28.	Okoth, C., Opanga, S., Okalebo, F., Oluka, M., Kurdi, A. B., and Godman, B. (2018). Point prevalence survey of antibiotic use and resistance at a referral hospital in Kenya: findings and implications. Hospital Practice, 46(3), 128-136.
29.	Maina, M., Mwaniki, P., Odira, E., Kiko, N., McKnight, J., Schultsz, C., . . . Tosas-Auguete, O. (2020). Antibiotic use in Kenyan public hospitals: Prevalence, appropriateness and link to guideline availability. International Journal of Infectious Diseases, 99, 10-18.
30.	Mukokinya, M. M., Opanga, S., Oluka, M., and Godman, B. (2018). Dispensing of Antimicrobials in Kenya: A Cross-sectional Pilot Study and Its Implications. Journal of Researc in Pharmacy Practice, 7(2), 77-82.
31.	Fowotade , A. et al., 2020. Point Prevalence Survey of Antimicrobial Prescribing in a Nigerian Hospital: Findings and Implications on Antimicrobial Resistance. West Afr J Med, 37(3), pp. 216-220.
32.	World Health Organisation. (2016). WHO methodology for a global programme on surveillance of antimicrobial consumption. Version 1.0. Retrieved December 23, 2020, from https://www.who.int/medicines/areas/rational_use/WHO_AMCsurveillance_1.0.pdf
33.	World Health Organisation. (2019). WHO Methodology for Point Prevalence Survey on Antibiotic Use in Hospitals. Version 1.1. Retrieved June 21, 2021, from https://www.who.int/publications/i/item/WHO-EMP-IAU-2018.01
34.	World Health Organisation. (2020). WHOCC - ATC/DDD Index. Retrieved December 21, 2020, from https://www.whocc.no/atc_ddd_index/
35.	Worldometer, 2020. Nigeria population (2020 and historical) - Worldometer. [Online] Available at: https://www.worldometers.info/ [Accessed 21 December 2020].
36.	World Health Organisation. (2019). Essential medicines and health products: WHO releases the 2019 AWaRe Classification Antibiotics. Retrieved December 21, 2020, from https://www.who.int/medicines/news/2019/WHO_releases2019AWaRe_classification_antibiotics/en/
37.	Klein EY, Tseng KK, Pant S, Laxminarayan R. Tracking global trends in the effectiveness of antibiotic therapy using the Drug Resistance Index. BMJ Global Health. 2019;4(2):1315. doi:10.1136/bmjgh-2018-001315.
38.	Laxminarayan R, Klugman KP. Communicating trends in resistance using a drug resistance index. BMJ Open. 2011;1(2): e000135. doi:10.1136/bmjopen-2011-000135.
39.	Barnett HAR. The Variance of the Product of Two Independent Variables and Its Application to an Investigation Based on Sample Data. Journal of the Institute of Actuaries. 1955;81(2):190-190. doi:10.1017/S0020268100035915
40.	Goodman LA. The Variance of the Product of K Random Variables. Journal of the American Statistical Association. 2012;57(297):54-60. doi:10.1080/01621459.1962.10482151
41.	Tadesse BT, Ashley EA, Ongarello S, et al. Antimicrobial resistance in Africa: a systematic review. BMC Infectious Diseases 2017 17:1. 2017;17(1):1-17. doi:10.1186/S12879-017-2713-1
42.	Carey RB, Bhattacharyy S, Kehl SC, et al. Implementing a quality management system in the medical microbiology laboratory. Clinical Microbiology Reviews. 2018;31(3). doi:10.1128/CMR.00062-17
43.	World Health Organisation. (2003). Introduction to Drug Utilization Research. Retrieved May 19, 2021, from https://www.who.int/medicines/areas/quality_safety/safety_efficacy/Drug%20utilization%20research.pdf?ua=1
44.	Laxminarayan, R., Matsoso, P., Pant, S., Brower, C., Røttingen, J.-A., Klugman, K., and al., e. (2016). Access to effective antimicrobials: a worldwide challenge. The Lancet, 387(10014), 168-175.
45.	Bortone, B. et al., 2021. High global consumption of potentially inappropriate fixed dose combination antibiotics: Analysis of data from 75 countries.. PLoS ONE, 16(1), p. e0241899.

Glossary

Accreditation:
According to National Accreditation Board for Testing and Calibration Laboratories, accreditation is a procedure by which an authoritative body formally recognises technical competence for specific tests/ measurements based on third-party assessment and following international standards.

Antimicrobial consumption:
According to the WHO, antimicrobial consumption is defined as quantities of antimicrobials used in a specific setting (total, community, hospital) during a specific period of time (e.g., days, months, and years).

Antimicrobial resistance:
According to the WHO, antimicrobial resistance occurs when bacteria, viruses, fungi, and parasites change over time and no longer respond to medicines making infections difficult to treat and increasing the risk of disease spread, severe illness and death. Drug resistance makes antibiotics and other antimicrobial medicines ineffective, making infections increasingly difficult or impossible to treat.

Antimicrobial resistance rate:
It is the extent to which a pathogen is resistant to a particular antimicrobial agent or class, determined by the proportion of non-susceptible isolates (i.e., either intermediate or resistant) over a one-year period:
AMR rate = No. of non-susceptible isolates / No. of tested isolates [CI 95%]

Antimicrobial susceptibility testing:
Tests used to determine the specific antibiotics a particular bacteria or fungus is sensitive to and to what extent.

Antimicrobial susceptibility testing standards:
A number of internationally recognised agencies produce standards to be followed by laboratories while performing antimicrobial susceptibility testing, such as the Clinical Laboratory Standards Institute, European Committee on Antimicrobial Susceptibility Testing etc. It is essential that laboratories comply with at least one of these standards while performing AST.

Country data quality score:
A metric computed to estimate the overall quality of AMR data received from a country. First, each laboratory was assigned a data score based on the level of pathogen identification. Scoring was based on quartiles of the proportion of completely identified pathogens, laboratories with >75% of pathogens identified at the species level were awarded the highest score (4), and those with <25% identification received the lowest score (1). Scoring was performed per year, and then the average of all years was assigned as the laboratory data quality score for each laboratory. Secondly, the country data quality score was computed, which weights the laboratory data quality score with the quantum of valid cultures contributed by each laboratory. The maximum country data quality score was 4

Eligibility questionnaire:
A questionnaire to be answered by laboratories in the country's laboratory network. It comprised questions on site, commodity and equipment, quality assurance, accreditation and certification, personnel and training, specimen management, and laboratory information systems. Laboratories were scored on their response.

GLASS:
According to the WHO, Global Antimicrobial Resistance Surveillance System provides a standardised approach to the collection, analysis and sharing of AMR data by countries and seeks to support capacity development and monitor the status of existing or newly-developed national AMR surveillance systems.

Laboratory readiness assessment:
It is the process of scoring the responses on the laboratory eligibility questionnaire to assess the laboratory's readiness/ preparedness for AMR surveillance.

Laboratory readiness score:
The score obtained by the laboratory based on the laboratory readiness assessment. The maximum possible score was 38.

MAAP:
Mapping Antimicrobial resistance and Antimicrobial use Partnership is a multi-organisational consortium of strategic and technical partners. It was set up to collect and analyse historical antimicrobial susceptibility, consumption and usage data collected for the period 2016-2018 in each country and understand the regional landscape.

Positive cultures:
Positive cultures are valid cultures for which pathogen growth was reported, irrespective of AST results.

Positive cultures with AST:
Positive cultures with AST are a subset of positive cultures for which pathogen growth was reported, and AST results were also available.

Proficiency testing:
According to National Accreditation Board for Testing and Calibration Laboratories, proficiency testing is the evaluation of participant performance against pre-established criteria by means of inter-laboratory comparisons.

Quality Certification:
Certification is used to verify that laboratory personnel have adequate credentials to practice certain disciplines and that products meet certain requirements.

Quality Management Systems:
It is a systematic, integrated set of activities to establish and control the work processes from pre-analytical through post-analytical processes, manage resources, conduct evaluations, and make continual improvements to ensure consistent quality results.

Total cultures:
The number of patient rows received from the laboratories in the database.

Valid cultures:
Valid cultures are a subset of total cultures, those that include information on specimen type and collection date and signify the laboratory's testing volume.

AMR Appendices and Supplementary Data

Appendix 1: Terms of Reference and Data Sharing Agreements

Data-Sharing Agreement

Between

Nigeria Center for Disease Control (NCDC)

(The Provider)

AND

The African Society for Laboratory Medicine (ASLM)

(Recipient)

1. Purpose of Agreement.

This agreement establishes the terms and conditions put in place to facilitate the sharing of antimicrobial resistance (AMR) and antimicrobial use (AMC) associated data between the parties. As such, the provider agrees to share the data with the Mapping Antimicrobial Resistance & Antimicrobial Use Partnership (MAAP) consortium hereby represented by ASLM, the lead grantee for the Fleming Fund Regional Grant (East, South and West Africa) on the terms set out in this agreement. MAAP agrees to use the data on the terms set out in this Agreement.

2. Description of Data.

2.. Pursuant to the terms of this agreement, the Ministry of Health hereafter referred to as the Provider, shall grant permission to ASLM and the MAAP consortium partners to access data contents as set forth in the MAAP methodology which include:

- AMR data linked to patient demographics and information on clinical syndrome
- AMU (procurement, sales and distribution) of antibiotics

AMR and AMR associated data will be collected in laboratory facilities conducting antibiotic susceptibility testing and in clinical facilities linked to those laboratories. AMU data will be collected in pharmacies or other distribution points and in central procurement units as described by the MAAP methodology and as per prior agreement with the Ministry of Health. The parties shall take any reasonable steps necessary to facilitate the principle of data sharing to strengthen AMR data publication and usage in line with the objectives of the Fleming Fund.

3. Confidentiality, use and storage of data

3.1 The confidentiality of data pertaining to individuals will be protected as follows:

3.1.1 The data recipient will not release the names of individuals, or information that could be linked to an individual, nor will the recipient present the results of data analysis (including maps) in any manner that would reveal the identity of individuals.

Appendix 2: Laboratory Eligibility Questionnaire

Question	Response
Part 1: Site Information	
1.1 What is the name of the laboratory?	
1.2 Between 2016 and 2018, did the laboratory routinely conduct antimicrobial susceptibility testing?	Yes / No
1.3 Is the laboratory willing to share 2016-2018 AST results with the MAAP consortium?	Yes / No
1.4 What is the address of the laboratory?	
1.5 What is the laboratory's level of service?	Reference- tier 3 or 4 / Regional/Intermediate / District or community / Other
1.6 What is the laboratory's affiliation?	Government/Ministry of Health / Private / Non-government organisation / Other
1.7 Is the laboratory co-located in a clinical facility?	Yes / No
1.8 Is a pharmacy co-located with the laboratory?	Yes / No
1.9 Did the laboratory serve as a national AMR surveillance site at any time between 2016 and 2018?	Yes / No
1.10 Is your country participating in the World Health Organisation's Global Antimicrobial Resistance Surveillance System (WHO GLASS)?	Yes / No
Part 2: Commodity and Equipment	
2.1 Did the laboratory have regular power supply with functional back up, in place at any time between 2016-18?	Yes / No
2.2 Did the laboratory have continuous water supply, in place at any time between 2016-18?	Yes / No
2.3 Did the laboratory have certified and functional biosafety cabinet, in place at any time between 2016-18?	Yes / No
2.4 Did the laboratory have automated methods for bacterial identification, in place at any time between 2016-18?	Yes / No
2.5 Did the laboratory have automated methods for antimicrobial susceptibility testing, in place at any time between 2016-18?	Yes / No
2.6 Did the laboratory test for mechanisms of antimicrobial resistance at any time between 2016-2018?	Yes / No
Part 3. Quality Assurance (QA), Accreditation and Certification	
3.1A Was the laboratory implementing quality management systems at any time between 2016-2018?	Yes / No
3.1B If you answered 'yes' to question 1A: What quality management tools did the laboratory utilize? (e.g., LQMS, SLIPTA, SLMTA, mentoring, others)	
3.2A Did the laboratory receive a quality certification at any time between 2016-2018?	Yes / No
3.2B If you answered 'yes' to question 2A: What kind of quality certification did the laboratory receive? (e.g., SLIPTA, College of American pathologists)	
3.2C If you answered 'yes' to question 2A: What was the laboratory's level of quality certification (e.g., star rating for SLIPTA certified laboratories)?	
3.3A Was the laboratory accredited by a national or international body at any time between 2016-2018?	Yes / No
3.3B If you answered 'yes' to question 3A: What was the name of the accreditation body/bodies?	

3.4	Did the laboratory participate in an inter laboratory comparison or external quality assessment (EQA) scheme for pathogen identification and AST at any time between 2016-18?	Yes		No	
3.5	Did the laboratory utilize reference strains to verify that stains, reagents, and media are working correctly at any time between 2016-18?	Yes		No	
3.6	Did the laboratory maintain records of QC results, at any time between 2016-18?	Yes		No	
3.7	Was there a quality focal person in your laboratory at any time between 2016-2018?	Yes		No	
3.8	Did the laboratory follow standard operating procedures (SOPs) on pathogen identification and AST methodology at any time between 2016-18?	Yes		No	
3.9	Did the laboratory comply with any standards (e.g., CLSI, EUCAST, others) for reporting AST results at any time between 2016-18?	Yes		No	

Part 4. Personnel and Training

4.1	Did the laboratory have at least one qualified microbiologist, in place at any time between 2016-18?	Yes		No	
4.2	Did the laboratory have a laboratory scientist/technologist /technician experienced in microbiology with skill set in bacteriology, in place at any time between 2016-18?	Yes		No	
4.3	Did the laboratory have up to date complete records on staff training and competence record for the microbiology tests they perform, in place at any time between 2016-18?	Yes		No	

Part 5. Specimen Management

5.1	Did the laboratory follow a defined standard operating procedure (SOP) for specimen collection and testing, at any time between 2016-18?	Yes		No	
5.2	Did the laboratory comply with specimen rejection criteria for rejecting inadequate specimens, at any time between 2016-18?	Yes		No	
5.3A	Does the laboratory have information on the average number of specimens processed for culture and sensitivity in 2018?	Yes		No	
5.3B	If you answered 'yes' to question 3A: What was the average number of specimens processed for bacterial culture in 2018?				
5.3C	If you answered 'yes' to question 3A: What was the average number of specimens that yielded bacterial growth and were processed for susceptibility tests, in 2018?				

<200	200-1000	1000-3000	>3000

Part 6. Laboratory Information System and Linkage to Clinical Data

6.1	Was a specimen (laboratory) identification number assigned to patient specimens received between 2016-18?	Yes		No	
6.2A	Was there a system/database to store patient data (demographic, clinical and specimen) at any time between 2016-18?	Yes		No	
6.2B	If you answered 'yes' to question 2A: What type of data was captured in the system/database?				
6.2C	If you answered 'yes' to question 2A: What was the format for storage of information?	Yes		No	
6.2D	If you answered 'yes' to question 2A: What is the location of this database, or where can this database be accessed from?				
6.3A	Were patient demographics and clinical information captured on test request forms at any time between 2016-18?	Yes		No	
6.3B	If you answered 'yes' to question 3A: Were test request forms submitted between 2016 and 2018 stored and retrievable?	Yes		No	

Note: For question 1.4, the exact address was preferred, however, the nearest landmark or street intersection was acceptable, where applicable; for questions 1.5 and 1.6, more than one response was possible and for the option 'other', the response was entered as plain text; for question 2.2 mechanisms of antimicrobial resistance can vary: common mechanisms are production of enzymes (extended spectrum beta lactamase, carbapenemase, etc.) and resistance genes (mecA gene in MRSA, etc.); for question 4.a, the qualified microbiologist should possess a postgraduate degree in microbiology (medical or non-medical); for question 6.2c, more than one response was possible and for the option 'other', responses were entered as plain text (i)

Of note, some countries received a version of the EQ which did not have the following two questions from part I: (i) Between 2016 and 2018, did the laboratory routinely conduct antimicrobial susceptibility testing? (ii) Is the laboratory willing to share 2016-2018 AST results with the MAAP consortium? However, AST capabilities were confirmed before the EQ evaluation, and the data sharing aspect of the process was already in place in agreements with the MoH.

Appendix 3: Laboratory Readiness Assessment

The EQ questions were scored for laboratory readiness as follows:

Part 1: Site Information (Maximum score=0)

	Question	Response				Scoring
1.1	What is the name of the laboratory?					None
1.2	Between 2016 and 2018, did the laboratory routinely conduct antimicrobial susceptibility testing?	Yes		No		None
1.3	Is the laboratory willing to share 2016-2018 AST results with the MAAP consortium?	Yes		No		None
1.4	What is the address of the laboratory?					None
1.5	What is the laboratory's level of service?					None
	Reference- tier 3 or 4	Regional/Intermediate	District or community	Other		
1.6	What is the laboratory's affiliation?					None
	Government/Ministry of Health	Private	Non-government organisation	Other		
1.7	Is the laboratory co-located in a clinical facility?	Yes		No		None
1.8	Is a pharmacy co-located with the laboratory?	Yes		No		None
1.9	Did the laboratory serve as a national AMR surveillance site at any time between 2016 and 2018	Yes		No		None
1.10	Is your country participating in the World Health Organisation's Global Antimicrobial Resistance Surveillance System (WHO GLASS)?	Yes		No		None

Part 2: Commodity and Equipment (Maximum score=6)

2.1	Did the laboratory have regular power supply with functional back up, in place at any time between 2016-18?	Yes		No		Score 1 for "Yes" and 0 for "No
2.2	Did the laboratory have continuous water supply, in place at any time between 2016-18?	Yes		No		Score 1 for "Yes" and 0 for "No
2.3	Did the laboratory have certified and functional biosafety cabinet, in place at any time between 2016-18?	Yes		No		Score 1 for "Yes" and 0 for "No
2.4	Did the laboratory have automated methods for bacterial identification, in place at any time between 2016-18?	Yes		No		Score 1 for "Yes" and 0 for "No
2.5	Did the laboratory have automated methods for antimicrobial susceptibility testing, in place at any time between 2016-18?	Yes		No		Score 1 for "Yes" and 0 for "No
2.6	Did the laboratory test for mechanisms of antimicrobial resistance at any time between 2016-2018?	Yes		No		Score 1 for "Yes" and 0 for "No

Part 3. Quality Assurance (QA), Accreditation and Certification (Maximum score=10)

3.1A	Was the laboratory implementing quality management systems at any time between 2016-2018?	Yes		No		Score 1 for "Yes" and 0 for "No
3.1B	If you answered 'yes' to question 1A: What quality management tools did the laboratory utilize? (e.g., LQMS, SLIPTA, SLMTA, mentoring, others)					Score 1 for "Yes" and 0 for "No
3.2A	Did the laboratory receive a quality certification at any time between 2016-2018?	Yes		No		Score 1 for "Yes" and 0 for "No
3.2B	If you answered 'yes' to question 2A: What kind of quality certification did the laboratory receive? (e.g., SLIPTA, College of American pathologists)					None
3.2C	If you answered 'yes' to question 2A: What was the laboratory's level of quality certification (e.g., star rating for SLIPTA certified laboratories)?					None
3.3A	Was the laboratory accredited by a national or international body at any time between 2016-2018?	Yes		No		Score 1 for "Yes" and 0 for "No
3.3B	If you answered 'yes' to question 3A: What was the name of the accreditation body/bodies?					None
3.4	Did the laboratory participate in an inter laboratory comparison or external quality assessment (EQA) scheme for pathogen identification and AST at any time between 2016-18?	Yes		No		Score 1 for "Yes" and 0 for "No
3.5	Did the laboratory utilize reference strains to verify that stains, reagents, and media are working correctly at any time between 2016-18?	Yes		No		Score 1 for "Yes" and 0 for "No

3.6	Did the laboratory maintain records of QC results, at any time between 2016-18?	Yes		No		Score 1 for "Yes" and 0 for "No
3.7	Was there a quality focal person in your laboratory at any time between 2016-2018?	Yes		No		Score 1 for "Yes" and 0 for "No
3.8	Did the laboratory follow standard operating procedures (SOPs) on pathogen identification and AST methodology at any time between 2016-18?	Yes		No		Score 1 for "Yes" and 0 for "No
3.9	Did the laboratory comply with any standards (e.g., CLSI, EUCAST, others) for reporting AST results at any time between 2016-18?	Yes		No		Score 1 for "Yes" and 0 for "No

Part 4. Personnel and Training (Maximum Score=3)

4.1	Did the laboratory have at least one qualified microbiologist, in place at any time between 2016-18?	Yes		No		Score 1 for "Yes" and 0 for "No
4.2	Did the laboratory have a laboratory scientist/technologist /technician experienced in microbiology with skill set in bacteriology, in place at any time between 2016-18?	Yes		No		Score 1 for "Yes" and 0 for "No
4.3	Did the laboratory have up to date complete records on staff training and competence record for the microbiology tests they perform, in place at any time between 2016-18?	Yes		No		Score 1 for "Yes" and 0 for "No

Part 5. Specimen Management (Maximum Score=3)

5.1	Did the laboratory follow a defined standard operating procedure (SOP) for specimen collection and testing, at any time between 2016-18?	Yes		No		Score 1 for "Yes" and 0 for "No
5.2	Did the laboratory comply with specimen rejection criteria for rejecting inadequate specimens, at any time between 2016-18?	Yes		No		Score 1 for "Yes" and 0 for "No
5.3A	Does the laboratory have information on the average number of specimens processed for culture and sensitivity in 2018?	Yes		No		Score 1 for "Yes" and 0 for "No
5.3B	If you answered 'yes' to question 3A: What was the average number of specimens processed for bacterial culture in 2018?					None
5.3C	If you answered 'yes' to question 3A: What was the average number of specimens that yielded bacterial growth and were processed for susceptibility tests, in 2018?					None
<200	200-1000	1000-3000	>3000			

Part 6. Laboratory Information System and Linkage to Clinical Data (Maximum Score=16)

6.1	Was a specimen (laboratory) identification number assigned to patient specimens received between 2016-18?	Yes		No		Score 1 for "Yes" and 0 for "No
6.2A	Was there a system/database to store patient data (demographic, clinical and specimen) at any time between 2016-18?	Yes		No		Score 1 for "Yes" and 0 for "No
6.2B	If you answered 'yes' to question 2A: What type of data was captured in the system/database?	Yes		No		Score 1 for "Yes" and 0 for "No
Patient demographic data (i.e., age, date of birth, gender, location)	Patient clinical data (i.e., primary/chief diagnosis, comorbidities, current antibiotic treatment)	Patient outcome				
6.2C	If you answered 'yes' to question 2A: What was the format for storage of information?					Score 1 for paper; 2 for mixed (E/P; E/P/O; others; mixed) and 3 for electronic (max score being 3)
Paper-based	Electronic (laboratory information system, hospital information system, other databases e.g., WHONET)	Other				
6.2D	If you answered 'yes' to question 2A: What is the location of this database, or where can this database be accessed from?					Score 1 for other; 2 for clinic and 3 for lab (max score being 6)
Laboratory	Clinical facility	Other				
6.3A	Were patient demographics and clinical information captured on test request forms at any time between 2016-18?	Yes		No		Score 1 for "Yes" and 0 for "No"
6.3B	If you answered 'yes' to question 3A: Were test request forms submitted between 2016 and 2018 stored and retrievable?	Yes		No		Score 1 for "Yes" and 0 for "No"

Appendix 4: Key AMR Variables

	Variables	Mandatory/Optional
Patient laboratory variables		
1	Patient code	Mandatory
2	Specimen type (name)	Mandatory
3	Specimen site	Mandatory
4	Date of specimen collection	Mandatory
5	Culture results – (no growth/contaminated/pathogen name)	Mandatory
6	AST Results	Mandatory
7	AST Standard	Mandatory
8	Resistance mechanism - if available	Optional
Patient demographic variables		
1	Patient code	Mandatory
2	Patient gender	Mandatory
3	Patient age or date of birth	Mandatory
4	Patient location	Mandatory
5	Patient department/specialty	Mandatory
6	Patient admission date	Optional
7	Patient discharge date	Optional
8	Patient level of education	Optional
9	Patient weight and height	Optional
10	Pregnancy status	Optional
11	Premature birth	Optional
12	Whether the patient was transferred from another clinical set-up?	Optional
Patient clinical/health variables		
1	Chief complaint	Mandatory
2	Primary diagnosis at admission	Mandatory
3	ICD code	Mandatory
4	Comorbidities	Optional
5	Whether antibiotics were prescribed to patient prior to sampling; antibiotic(s) name and duration	Optional
6	Was the patient on an indwelling medical device at time of sampling; type of device	Optional
7	Origin of infection - community acquired or hospital acquired	Optional
8	Patient outcome at discharge (recovered/deteriorated/dead/others)	Optional

Laboratory-specific variables		
1	Laboratory's level of service (Reference- tier 3 or 4/ Regional/ Intermediate/ District/ Community/ Other	Mandatory
2	Laboratory's affiliation (Government/Ministry of Health/ Private/Non-government organisation/ Other)	Mandatory
3	Laboratory co-location with clinic/hospital/pharmacy	Mandatory
4	If laboratory served as a national AMR surveillance site at any time between 2016 and 2018?	Mandatory
5	Facility and Equipment related variables	Mandatory
6	Quality Assurance (QA), accreditation and certification related variables	Mandatory
7	Personnel and training related variables	Mandatory
8	Specimen management related variables	Mandatory
9	Laboratory information system and linkage to clinical data	Mandatory
Facility-specific variables (facility denotes co-located clinic/hospital or even from stand-alone laboratory as applicable; this information is obtained during phase of data collection)		
1	Ownership of facility (public/private/partnership/mission/military etc.)	Optional
2	Level of facility (primary, secondary, tertiary)	Optional
3	Facility co-location with pharmacy/lab	Optional
4	Number of inpatient beds in 2018 (and prior years as applicable)	Optional
5	Admissions in 2018 (and prior years as applicable)	Optional
6	Outpatients in 2018 (and prior years as applicable)	Optional
7	Presence of ID Department	Optional
8	No of ID physicians	Optional
9	No of ID nurses	Optional
10	Presence of AMS program	Optional
11	Frequency of AMS meetings	Optional
12	Presence of Medical therapeutic committee (MTC)	Optional
13	Frequency of MTC meet	Optional
14	Presence of HIC committee	Optional
15	Frequency of HIC meet	Optional
16	Number of bacterial cultures processed in 2018 (and prior years as applicable)	Optional
17	Number of fungal cultures processed in 2018 (and prior years as applicable)	Optional
18	Number of positive cerebrospinal fluid cultures in 2018 (and prior years as applicable)	Optional
19	Number of positive blood cultures in 2018 (and prior years as applicable)	Optional
20	Format for storing patient laboratory records	Optional
21	Format for storing patient clinical records	Optional

Appendix 5: WHO Priority Pathogens

Pathogen	Resistance	Priority
Acinetobacter baumannii	Carbapenem-resistant	Critical
Pseudomonas aeruginosa	Carbapenem-resistant	Critical
Enterobacterales*	Carbapenem-resistant, ESBL-producing	Critical
Enterococcus faecium	Vancomycin-resistant	High
Staphylococcus aureus	Methicillin-resistant, Vancomycin-intermediate and resistant	High
Helicobacter pylori	Clarithromycin-resistant	High
Campylobacter species	Fluoroquinolone-resistant	High
Neisseria gonorrhoeae	3rd generation Cephalosporin-resistant, Fluoroquinolone-resistant	High
Salmonellae	Fluoroquinolone-resistant	High
Shigella species	Fluoroquinolone-resistant	Medium
Streptococcus pneumoniae	Penicillin-non-susceptible	Medium
Hemophilus influenzae	Ampicillin-resistant	Medium

**Previously known as Enterobacteriaceae.*

Appendix 6: Other clinically important pathogens

Pathogen	Antimicrobial
Acinetobacter species*	Carbapenems Lipopeptides
Enterococcus species*	Aminoglycosides (high level) Vancomycin
E coli*	Carbapenems 3rd generation cephalosporins
H. influenzae*	Ampicillin 3rd generation cephalosporins
Klebsiella species*	Carbapenems 3rd generation cephalosporins
N. meningitidis*	Ampicillin 3rd generation cephalosporins
Pseudomonas species*	Carbapenems Lipopeptides
Salmonella species*	Fluoroquinolones Macrolides 3rd generation cephalosporins
Shigella species*	Fluoroquinolones Macrolides 3rd generation cephalosporins
Staphylococcus aureus*	Methicillin
Staphylococcus species* (other than S. aureus)	Methicillin
S. pneumoniae*	Penicillins Beta-lactam combinations Vancomycin Macrolides
Fungal pathogens**	(As per information available from countries)

*(ii) * from blood and CSF only; ** from all specimens*

Appendix 7: Pathogen Phenotype Definitions

Pathogen	Antimicrobial agent	Numerator	Denominator
Acinetobacter species	Lipopeptides (Colistin and Polymyxin B)	Any isolate that tested non-susceptible to colistin and polymyxin B	Any isolate that tested susceptible or non-susceptible to colistin and polymyxin B
Acinetobacter species	Carbapenems	Any isolate that tested non-susceptible to carbapenems	Any isolate that tested susceptible or non-susceptible to carbapenems
Campylobacter species	Fluoroquinolones	Any isolate that tested non-susceptible to fluoroquinolones	Any isolate that tested susceptible or non-susceptible to fluoroquinolones
Enterobacterales	3rd generation cephalosporins	Any isolate that tested non-susceptible to 3rd generation cephalosporins	Any isolate that tested susceptible or non-susceptible to 3rd generation cephalosporins
Enterobacterales	Carbapenems	Any isolate that tested non-susceptible to carbapenems	Any isolate that tested susceptible or non-susceptible to carbapenems
Enterobacterales	Fluoroquinolones	Any isolate that tested non-susceptible to fluoroquinolones	Any isolate that tested susceptible or non-susceptible to fluoroquinolones
Enterobacterales	Aminoglycosides	Any isolate that tested non-susceptible to aminoglycosides	Any isolate that tested susceptible or non-susceptible to aminoglycosides
Enterobacterales	Beta-lactam combinations including anti-pseudomonals	Any isolate that tested non-susceptible to beta-lactam combinations including anti-pseudomonals	Any isolate that tested susceptible or non-susceptible to beta-lactam combinations including anti-pseudomonals
Enterobacterales	Lipopeptides (Colistin and Polymyxin B)	Any isolate that tested non-susceptible to lipopeptides	Any isolate that tested susceptible or non-susceptible to lipopeptides
Enterobacterales	Ampicillin	Any isolate that tested non-susceptible to ampicillin	Any isolate that tested susceptible or non-susceptible to ampicillin
Enterobacterales	Sulfamethoxazole-Trimethoprim	Any isolate that tested non-susceptible to Sulfamethoxazole-Trimethoprim	Any isolate that tested susceptible or non-susceptible to Sulfamethoxazole-Trimethoprim
Enterobacterales	Macrolides	Any isolate that tested non-susceptible to macrolides	Any isolate that tested susceptible or non-susceptible to macrolides
Enterobacterales	Chloramphenicol	Any isolate that tested non-susceptible to chloramphenicol	Any isolate that tested susceptible or non-susceptible to chloramphenicol
Enterococcus species	Aminoglycosides (high level)	Any isolate that tested non-susceptible to aminoglycosides (high level)	Any isolate that tested susceptible or non-susceptible aminoglycosides (high level)
Enterococcus species	Quinopristin dalfopristin	Any isolate that tested non-susceptible to quinopristin dalfopristin	Any isolate that tested susceptible or non-susceptible to quinopristin dalfopristin
Enterococcus species	Vancomycin	Any isolate that tested non-susceptible to vancomycin	Any isolate that tested susceptible or non-susceptible to vancomycin
Enterococcus species	Ampicillin	Any isolate that tested non-susceptible to ampicillin	Any isolate that tested susceptible or non-susceptible to ampicillin
Haemophilus influenzae	Ampicillin	Any isolate that tested non-susceptible to ampicillin	Any isolate that tested susceptible or non-susceptible to ampicillin

Helicobacter pylori	Clarithromycin	Any isolate that tested non-susceptible to clarithromycin	Any isolate that tested susceptible or non-susceptible to clarithromycin
Neisseria gonorrhoeae	3rd generation cephalosporins	Any isolate that tested non-susceptible to 3rd generation cephalosporins	Any isolate that tested susceptible or non-susceptible to 3rd generation cephalosporins
Neisseria gonorrhoeae	Fluoroquinolones	Any isolate that tested non-susceptible to fluoroquinolones	Any isolate that tested susceptible or non-susceptible to fluoroquinolones
Pseudomonas species	Carbapenems	Any isolate that tested non-susceptible to carbapenems	Any isolate that tested susceptible or non-susceptible to carbapenems
Pseudomonas species	Aminoglycosides	Any isolate that tested non-susceptible to aminoglycosides	Any isolate that tested susceptible or non-susceptible to aminoglycosides
Pseudomonas species	Beta-lactam combinations (anti-pseudomonals)	Any isolate that tested non-susceptible to beta-lactam combinations (anti-pseudomonals)	Any isolate that tested susceptible or non-susceptible to beta-lactam combinations (anti-pseudomonals)
Pseudomonas species	Lipopeptides (Colistin and Polymyxin B)	Any isolate that tested non-susceptible to Colistin and Polymyxin B	Any isolate that tested susceptible or non-susceptible to Colistin and Polymyxin B
Pseudomonas species	Carbapenems	Any isolate that tested non-susceptible to carbapenems	Any isolate that tested susceptible or non-susceptible to carbapenems
Staphylococcus species	Methicillin	Any isolate that tested non-susceptible to penicillins (anti-staphylococcal) or cephamycins	Any isolate that tested susceptible or non-susceptible to penicillins (anti-staphylococcal) or cephamycins
Staphylococcus species (iii)	Vancomycin resistant (iv)	Any isolate that tested resistant to vancomycin (v)	Any isolate that tested susceptible or non-susceptible to vancomycin (vi)
Staphylococcus species	Vancomycin intermediate	Any isolate that tested intermediate to vancomycin	Any isolate that tested susceptible or non-susceptible to vancomycin
Staphylococcus species	Penicillins	Any isolate that tested non-susceptible to penicillins	Any isolate that tested susceptible or non-susceptible to penicillins
Staphylococcus species	Linezolid	Any isolate that tested non-susceptible to linezolids	Any isolate that tested susceptible or non-susceptible to linezolids
Streptococcus pneumoniae	Penicillins	Any isolate that tested non-susceptible to penicillins	Any isolate that tested susceptible or non-susceptible to penicillins
Gram-negatives*	3rd generation cephalosporins	Any isolate that tested non-susceptible to 3rd generation cephalosporins	Any isolate that tested susceptible or non-susceptible to 3rd generation cephalosporins
Gram-negatives*	Carbapenems	Any isolate that tested non-susceptible to carbapenems	Any isolate that tested susceptible or non-susceptible to carbapenems
Gram-negatives*	Lipopeptides (Colistin and Polymyxin B)	Any isolate that tested non-susceptible to Colistin and Polymyxin B.	Any isolate that tested susceptible or non-susceptible to Colistin and Polymyxin B.
Gram-positives*	Vancomycin	Any isolate that tested non-susceptible to vancomycin	Any isolate that tested susceptible or non-susceptible to vancomycin
Gram-positives*	Linezolid	Any isolate that tested non-susceptible to linezolids	Any isolate that tested susceptible or non-susceptible to linezolids

Note: Non-susceptible isolates include isolates which tested resistant or intermediate.

* Reflects pathogens for which only Gram stain identification was available (the number is exclusive of other pathogens identified at genus/species level).

Appendix 8: Pathogens and antimicrobials for AMR drivers and DRI

Pathogen	Antimicrobial
Acinetobacter baumannii	Aminoglycosides
Escherichia coli	Aminoglycosides
Klebsiella pneumoniae	Aminoglycosides
Pseudomonas aeruginosa	Aminoglycosides
Enterococcus faecalis	Aminoglycosides (High)
Enterococcus faecium	Aminoglycosides (High)
Enterococcus faecalis	Aminopenicillins
Enterococcus faecium	Aminopenicillins
Escherichia coli	Aminopenicillins
Acinetobacter baumannii	Carbapenems
Escherichia coli	Carbapenems
Klebsiella pneumoniae	Carbapenems
Pseudomonas aeruginosa	Carbapenems
Acinetobacter baumannii	Cephalosporins (3rd generation)
Escherichia coli	Cephalosporins (3rd generation)
Klebsiella pneumoniae	Cephalosporins (3rd generation)
Pseudomonas aeruginosa	Cephalosporins (3rd generation)
Acinetobacter baumannii	Fluoroquinolone
Escherichia coli	Fluoroquinolones
Klebsiella pneumoniae	Fluoroquinolones
Pseudomonas aeruginosa	Fluoroquinolones
Staphylococcus aureus	Methicillin
Pseudomonas aeruginosa	Beta-lactam combinations
Enterococcus faecalis	Vancomycin
Enterococcus faecium	Vancomycin

AMR Supplementary Tables

Supplementary Table 1: Level of service and affiliation of surveyed laboratories

Affiliation	Surveyed N=73 n (%)	Reference N = 3 n (%)	Regional/ Intermediate N =29 n (%)	District/ Community N = 41 n (%)	Unspecified N = 73 n (%)
Government	69 (94.52)	3 (100.0)	26 (89.7)	40 (97.6)	69 (94.52)
Private	4 (5.48)	0	3 (10.3)	1 (2.4)	4 (5.48)
NGO	0	0	0	0	0
Others	0	0	0	0	0

Supplementary Table 2: Assessment of preparedness for AMR surveillance

Parameters	Surveyed laboratories N=73 n (%)
Commodity and equipment status	
Regular power supply and functional back up	53 (72.6)
Continuous water supply	60 (82.2)
Certified and functional biosafety cabinets	26 (35.6)
Automated methods for pathogen identification	11 (15.1)
Automated methods for antimicrobial susceptibility testing	9 (12.3)
Methods for testing antimicrobial resistance mechanisms	30 (41.1)
QMS implementation	
Reported QMS Implementation	
• Reported QMS tool (n=44)	**50 (68.5)**
• LQMS	**17 (34.0)**
• SLIPTA	**5 (10.0)**
• SLMTA	**0 (0)**
• Mentoring	**5 (10.0)**
• Combination‡	**6 (12.0)**
• Others	**11 (22.0)**
Quality Certification	**13 (17.8)**
• Reported certification type (n=16)	
• SLIPTA	**6 (46.2)**
• College of American Pathologists	**0 (0)**
• Others	**7 (53.8)**
Accreditation	26 (35.6)
Participation in proficiency testing	27 (37.0)
Utilization of reference strains	37 (50.7)
Reported consistent maintenance of QC records	44 (60.3)
Designated focal quality person	59 (80.8)
Reported compliance to standard operating procedures	58 (79.5)
Reported compliance to antimicrobial susceptibility testing standards	42 (57.5)
Personnel and training status	
Presence of at least one qualified microbiologist	63 (86.3)
Presence of an experienced laboratory scientist/technologist	72 (98.6)
Up-to-date and complete records on staff training and competence	40 (54.8)
Specimen Management status	
Reported compliance to standard operating procedures on specimen collection and testing	71 (97.3)
Reported compliance to standard operating procedures on specimen rejection	67 (91.8)
Availability on average number of specimens processed for culture and sensitivity in year 2018	64 (87.7)
Laboratory Information System and Linkage to Clinical Data	
Assigned specimen (laboratory) identification number	67 (91.8)
Availability of system/database to store patient data	61 (83.6)
• System/database format (n=19)	
• Paper-based	45 (73.8)
• Electronic	1 (1.6)
• Mixed	15 (24.6)
Captured patients' demographics and clinical information on test request forms	56 (76.7)
• Retrievable test request forms (n=20)	38 (67.9)

**Data reflect laboratory functions between years 2016 - 2018; ‡ Combination refers to more than one option presented in the questionnaire (LQMS, SLIPTA, SLMTA and mentoring).*

Supplementary Table 3: Culture characteristics (yearly)

Variable		Valid			Positive			Positive with AS		
		2016	2017	2018	2016	2017	2018	2016	2017	2018
Annual Totals		**26896**	**32134**	**25518**	**7678**	**10640**	**8817**	**6532**	**9501**	**7930**
Pathogen type	bacteria	-	-	-	6715 (87.5)	9627 (90.5)	8005 (90.8)	6531 (100.0)	9485 (99.8)	7927 (100.0)
	fungi	-	-	-	963 (12.5)	1013 (9.5)	812 (9.2)	1 (0.0)	16 (0.2)	3 (0.0)
Age, years	Less than 1	3315 (12.3)	4218 (13.1)	2156 (8.4)	847 (11.0)	1372 (12.9)	613 (7.0)	833 (12.8)	1297 (13.7)	581 (7.3)
	1 to 17	6817 (25.3)	8728 (27.2)	4931 (19.3)	1542 (20.1)	2337 (22.0)	1023 (11.6)	1375 (21.1)	2174 (22.9)	977 (12.3)
	18 to 49	9433 (35.1)	10815 (33.7)	9088 (35.6)	2973 (38.7)	3591 (33.8)	2759 (31.3)	2305 (35.3)	2966 (31.2)	2358 (29.7)
	50 to 65	1548 (5.8)	2117 (6.6)	1512 (5.9)	457 (6.0)	798 (7.5)	498 (5.6)	404 (6.2)	762 (8.0)	464 (5.9)
	Above 65	1354 (5.0)	1971 (6.1)	1418 (5.6)	484 (6.3)	807 (7.6)	607 (6.9)	460 (7.0)	774 (8.1)	572 (7.2)
	Unknown Age	4429 (16.5)	4285 (13.3)	6413 (25.1)	1375 (17.9)	1735 (16.3)	3317 (37.6)	1155 (17.7)	1528 (16.1)	2978 (37.6)
Gender	Male	11851 (44.1)	14614 (45.5)	11085 (43.4)	2791 (36.4)	4402 (41.4)	3425 (38.8)	2638 (40.4)	4230 (44.5)	3292 (41.5)
	Female	15045 (55.9)	17519 (54.5)	14433 (56.6)	4887 (63.6)	6238 (58.6)	5392 (61.2)	3894 (59.6)	5271 (55.5)	4638 (58.5)
Laboratory	LAUTECH	641 (2.4)	2004 (6.2)	815 (3.2)	220 (2.9)	766 (7.2)	272 (3.1)	159 (2.4)	651 (6.9)	216 (2.7)
	Kubwa	2673 (9.9)	1770 (5.5)	1054 (4.1)	381 (5.0)	314 (3.0)	215 (2.4)	329 (5.0)	219 (2.3)	183 (2.3)
	Babcock	395 (1.5)	575 (1.8)	658 (2.6)	106 (1.4)	188 (1.8)	177 (2.0)	102 (1.6)	172 (1.8)	158 (2.0)
	Abuja	2371 (8.8)	4010 (12.5)	3208 (12.6)	428 (5.6)	922 (8.7)	655 (7.4)	278 (4.3)	804 (8.5)	572 (7.2)
	Muhammad Abdullahi	1537 (5.7)	1810 (5.6)	1236 (4.8)	702 (9.1)	842 (7.9)	636 (7.2)	556 (8.5)	657 (6.9)	498 (6.3)
	Port Harcourt	968 (3.6)	423 (1.3)	1265 (5.0)	305 (4.0)	109 (1.0)	433 (4.9)	251 (3.8)	100 (1.1)	386 (4.9)
	Bwari	1443 (5.4)	904 (2.8)	1298 (5.1)	514 (6.7)	218 (2.0)	286 (3.2)	305 (4.7)	119 (1.3)	250 (3.2)
	UTH Lagos	1328 (4.9)	1201 (3.7)	1109 (4.3)	609 (7.9)	365 (3.4)	410 (4.7)	593 (9.1)	362 (3.8)	400 (5.0)
	Niger Delta	437 (1.6)	640 (2.0)	567 (2.2)	171 (2.2)	272 (2.6)	295 (3.3)	152 (2.3)	246 (2.6)	272 (3.4)
	Ibadan	66 (0.2)	4713 (14.7)	205 (0.8)	7 (0.1)	2161 (20.3)	10 (0.1)	7 (0.1)	1928 (20.3)	8 (0.1)
	Ilorin	1799 (6.7)	1406 (4.4)	2327 (9.1)	319 (4.2)	462 (4.3)	674 (7.6)	220 (3.4)	441 (4.6)	590 (7.4)
	OAUTHC	1022 (3.8)	1328 (4.1)	550 (2.2)	235 (3.1)	303 (2.8)	114 (1.3)	225 (3.4)	276 (2.9)	99 (1.2)
	Maitama	1305 (4.9)	1315 (4.1)	1629 (6.4)	489 (6.4)	431 (4.1)	366 (4.2)	364 (5.6)	323 (3.4)	364 (4.6)
	Lapai	110 (0.4)	23 (0.1)	2 (0.0)	37 (0.5)	7 (0.1)	-	36 (0.6)	3 (0.0)	-
	Aminu Kanu	1253 (4.7)	1225 (3.8)	1055 (4.1)	59 (0.8)	134 (1.3)	50 (0.6)	32 (0.5)	127 (1.3)	49 (0.6)
	Mbarara	-	-	5810 (15.1)	-	-	2816 (19.3)	-	-	1442 (13.1)
	FMC Birnin	555 (2.1)	777 (2.4)	495 (1.9)	159 (2.1)	384 (3.6)	250 (2.8)	142 (2.2)	379 (4.0)	237 (3.0)
	Minna	1249 (4.6)	2437 (7.6)	1008 (4.0)	588 (7.7)	1049 (9.9)	401 (4.5)	588 (9.0)	1048 (11.0)	400 (5.0)
	UNTH Enugu	378 (1.4)	464 (1.4)	302 (1.2)	155 (2.0)	164 (1.5)	175 (2.0)	151 (2.3)	155 (1.6)	167 (2.1)
	Sinusi	103 (0.4)	433 (1.3)	206 (0.8)	24 (0.3)	143 (1.3)	75 (0.9)	24 (0.4)	137 (1.4)	74 (0.9)
	UCTH Calabar	594 (2.2)	517 (1.6)	92 (0.4)	184 (2.4)	173 (1.6)	22 (0.2)	151 (2.3)	160 (1.7)	17 (0.2)
	Murtala	-	165 (0.5)	3412 (13.4)	-	164 (1.5)	2265 (25.7)	-	164 (1.7)	2058 (26.0)
	FNPH Yaba	212 (0.8)	184 (0.6)	139 (0.5)	55 (0.7)	51 (0.5)	48 (0.5)	36 (0.6)	37 (0.4)	35 (0.4)
	FMC Bida	2248 (8.4)	1219 (3.8)	1108 (4.3)	816 (10.6)	396 (3.7)	436 (4.9)	789 (12.1)	392 (4.1)	377 (4.8)
	FMC Azare	3117 (11.6)	1622 (5.0)	1304 (5.1)	841 (11.0)	397 (3.7)	399 (4.5)	794 (12.2)	390 (4.1)	388 (4.9)
	FMC Abeokuta	1092 (4.1)	969 (3.0)	474 (1.9)	274 (3.6)	225 (2.1)	153 (1.7)	248 (3.8)	211 (2.2)	132 (1.7)

Supplementary Table 4: Specimen characteristics

Specimen Type	All years* N= 23 963 n (%)	2016 N = 6 532 n (%)	2017 N = 9 501 n (%)	2018 N = 7 930 n (%)
Abscess (abdominal)	1 (0)	-	1 (0)	-
Abscess/Discharge/Pus/Swab/Wound	4235 (17.7)	1022 (15.6)	1743 (18.3)	1470 (18.5)
Aspirate/discharge	204 (0.9)	43 (0.7)	90 (0.9)	71 (0.9)
Blood	6117 (25.5)	1588 (24.3)	3370 (35.5)	1159 (14.6)
Catheter (umbilical)	4 (0)	1 (0)	1 (0)	2 (0)
Catheter (unspecified)	75 (0.3)	10 (0.2)	32 (0.3)	33 (0.4)
Catheter (urinary)	8 (0)	4 (0.1)	1 (0)	3 (0)
CSF	209 (0.9)	74 (1.1)	76 (0.8)	59 (0.7)
Drain	1 (0)	-	-	1 (0)
Fluid (abdominal/peritoneal)	5 (0)	1 (0)	3 (0)	1 (0)
Fluid (amniotic)	2 (0)	2 (0)	-	-
Fluid (bile)	3 (0)	2 (0)	1 (0)	-
Fluid (dialysis)	1 (0)	-	-	1 (0)
Fluid (joint/synovial)	3 (0)	1 (0)	-	2 (0)
Fluid (pleural)	31 (0.1)	9 (0.1)	15 (0.2)	7 (0.1)
Fluid (scrotal)	2 (0)	1 (0)	1 (0)	-
Fluid (sinus)	11 (0)	1 (0)	7 (0.1)	3 (0)
Fluid (unspecified)	16 (0.1)	8 (0.1)	2 (0)	6 (0.1)
Genitourinary	4 (0)	-	3 (0)	1 (0)
Other	2 (0)	-	2 (0)	-
Respiratory-Lower	15 (0.1)	1 (0)	9 (0.1)	5 (0.1)
Respiratory-Upper	2347 (9.8)	460 (7)	786 (8.3)	1101 (13.9)
Scraping	1 (0)	-	-	1 (0)
Scraping (cornea)	1 (0)	-	-	1 (0)
Semen	356 (1.5)	146 (2.2)	81 (0.9)	129 (1.6)
Stool	745 (3.1)	254 (3.9)	266 (2.8)	225 (2.8)
Swab (cervical)	472 (2)	152 (2.3)	140 (1.5)	180 (2.3)
Swab (rectal)	2 (0)	1 (0)	-	1 (0)
Swab (urethral)	230 (1)	53 (0.8)	65 (0.7)	112 (1.4)
Swab (vaginal)	2373 (9.9)	653 (10)	666 (7)	1054 (13.3)
Swab/discharge (eye)	7 (0)	-	3 (0)	4 (0.1)
Swab/discharge (genital)	12 (0.1)	9 (0.1)	1 (0)	2 (0)
Swab/discharge (urethral)	7 (0)	2 (0)	1 (0)	4 (0.1)
Tissue/biopsy	24 (0.1)	4 (0.1)	13 (0.1)	7 (0.1)
Ulcer	11 (0)	-	8 (0.1)	3 (0)
Urine	6426 (26.8)	2030 (31.1)	2114 (22.3)	2282 (28.8)

**Indicates positive cultures with AST results*

Supplementary Table 5: Pathogen identification

Specimen Type	All years* N= 23 963 n (%)	2016 N = 6 532 n (%)	2017 N = 9 501 n (%)	2018 N = 7 930 n (%)
Pathogen				
Positive cultures with specific pathogen name	15427 (64.4)	3990 (61.1)	6476 (68.2)	4961 (62.6)
Acinetobacter baumannii	59 (0.2)	8 (0.1)	24 (0.3)	27 (0.3)
Acinetobacter haemolyticus	6 (0)	-	5 (0.1)	1 (0)
Acinetobacter lwoffii	8 (0)	2 (0)	2 (0)	4 (0.1)
Aeromonas caviae	2 (0)	-	2 (0)	-
Arcanobacterium haemolyticum	2 (0)	-	2 (0)	-
Burkholderia pseudomallei	2 (0)	1 (0)	-	1 (0)
Candida albicans	3 (0)	-	3 (0)	-
Chromobacterium violaceum	5 (0)	5 (0.1)	-	-
Citrobacter diversus	2 (0)	-	-	2 (0)
Citrobacter freundii	22 (0.1)	1 (0)	12 (0.1)	9 (0.1)
Corynebacterium diphtheriae	1 (0)	-	1 (0)	-
Cryptococcus neoformans	1 (0)	-	-	1 (0)
Enterobacter cloacae	26 (0.1)	-	23 (0.2)	3 (0)
Enterobacter gergoviae	2 (0)	-	1 (0)	1 (0)
Enterococcus faecalis	60 (0.3)	5 (0.1)	16 (0.2)	39 (0.5)
Escherichia coli	5274 (22)	1863 (28.5)	1722 (18.1)	1689 (21.3)
Escherichia fergusonii	1 (0)	-	-	1 (0)
Gardnerella vaginalis	4 (0)	-	-	4 (0.1)
Granulicatella adiacens	25 (0.1)	-	25 (0.3)	-
Haemophilus influenzae	11 (0)	1 (0)	7 (0.1)	3 (0)
Hafnia alvei	4 (0)	4 (0.1)	-	-
Klebsiella aerogenes	282 (1.2)	39 (0.6)	177 (1.9)	66 (0.8)
Klebsiella oxytoca	191 (0.8)	24 (0.4)	93 (1)	74 (0.9)
Klebsiella pneumoniae	1445 (6)	245 (3.8)	851 (9)	349 (4.4)
Lactobacillus fermentum	4 (0)	3 (0)	-	1 (0)
Listeria monocytogenes	1 (0)	-	1 (0)	-
Mannheimia haemolytica	2 (0)	-	2 (0)	-
Micrococcus luteus	1 (0)	-	-	1 (0)
Moraxella catarrhalis	7 (0)	3 (0)	1 (0)	3 (0)
Morganella morganii	30 (0.1)	5 (0.1)	11 (0.1)	14 (0.2)
Neisseria gonorrhoeae	6 (0)	3 (0)	2 (0)	1 (0)
Neisseria meningitidis	2 (0)	-	2 (0)	-

Paecilomyces lilacinus	8 (0)	-	8 (0.1)	-
Pantoea (enterobacter) agglomerans	5 (0)	-	3 (0)	2 (0)
Proteus hauseri	1 (0)	1 (0)	-	-
Proteus mirabilis	167 (0.7)	32 (0.5)	108 (1.1)	27 (0.3)
Proteus vulgaris	32 (0.1)	5 (0.1)	20 (0.2)	7 (0.1)
Providencia rettgeri	2 (0)	-	1 (0)	1 (0)
Providencia stuartii	4 (0)	1 (0)	3 (0)	-
Pseudomonas aeruginosa	925 (3.9)	189 (2.9)	513 (5.4)	223 (2.8)
Pseudomonas fluorescens	14 (0.1)	-	12 (0.1)	2 (0)
Pseudomonas stutzeri	1 (0)	1 (0)	-	-
Raoultella ornithinolytica	2 (0)	-	2 (0)	-
Salmonella enterica	3 (0)	1 (0)	1 (0)	1 (0)
Salmonella paratyphi	4 (0)	2 (0)	1 (0)	1 (0)
Salmonella typhi	57 (0.2)	8 (0.1)	44 (0.5)	5 (0.1)
Sebaldella termitidis	11 (0)	-	11 (0.1)	-
Serratia liquefaciens	3 (0)	-	3 (0)	-
Serratia marcescens	17 (0.1)	3 (0)	8 (0.1)	6 (0.1)
Staphylococcus arlettae	1 (0)	-	-	1 (0)
Staphylococcus aureus	5981 (25)	1426 (21.8)	2492 (26.2)	2063 (26)
Staphylococcus epidermidis	62 (0.3)	6 (0.1)	14 (0.1)	42 (0.5)
Staphylococcus haemolyticus	10 (0)	-	5 (0.1)	5 (0.1)
Staphylococcus saprophyticus	7 (0)	-	4 (0)	3 (0)
Staphylococcus vitulinus	5 (0)	-	-	5 (0.1)
Stenotrophomonas (xanthomonas) maltophilia	2 (0)	-	2 (0)	-
Streptococcus agalactiae	2 (0)	-	1 (0)	1 (0)
Streptococcus pneumoniae	108 (0.5)	22 (0.3)	78 (0.8)	8 (0.1)
Streptococcus pyogenes	40 (0.2)	2 (0)	28 (0.3)	10 (0.1)
Streptococcus viridans	452 (1.9)	76 (1.2)	128 (1.3)	248 (3.1)
Tatumella ptyseos	1 (0)	-	1 (0)	-
Yersinia enterocolitica	9 (0)	3 (0)	-	6 (0.1)
Positive cultures with non-specific pathogen name	8536 (35.6)	2542 (38.9)	3025 (31.8)	2969 (37.4)
Achromobacter Sp.	7 (0)	-	2 (0)	5 (0.1)
Acinetobacter Sp.	83 (0.3)	24 (0.4)	31 (0.3)	28 (0.4)
Alcaligenes Sp.	10 (0)	4 (0.1)	2 (0)	4 (0.1)
Anaerobes	1 (0)	1 (0)	-	-
Bacillus Sp.	5 (0)	2 (0)	1 (0)	2 (0)
Candida Sp.	2 (0)	-	1 (0)	1 (0)

Chromobacterium Sp.	3 (0)	2 (0)	1 (0)	-
Chryseomonas Sp.	1 (0)	1 (0)	-	-
Citrobacter Sp.	21 (0.1)	5 (0.1)	7 (0.1)	9 (0.1)
Clostridium Sp.	1 (0)	-	-	1 (0)
Corynebacterium Sp.	4 (0)	3 (0)	-	1 (0)
Cryptococcus Sp.	1 (0)	1 (0)	-	-
Eikenella Sp.	4 (0)	-	4 (0)	-
Enterobacter Sp.	59 (0.2)	24 (0.4)	16 (0.2)	19 (0.2)
Enterococcus Sp.	191 (0.8)	53 (0.8)	91 (1)	47 (0.6)
Haemophilus Sp.	6 (0)	5 (0.1)	-	1 (0)
Klebsiella Sp.	2637 (11)	737 (11.3)	822 (8.7)	1078 (13.6)
Listeria Sp.	1 (0)	1 (0)	-	-
Micrococcus Sp.	5 (0)	3 (0)	2 (0)	-
Neisseria Sp.	11 (0)	1 (0)	5 (0.1)	5 (0.1)
Non fermenting gram negative bacilli	39 (0.2)	35 (0.5)	-	4 (0.1)
Proteus Sp.	524 (2.2)	177 (2.7)	149 (1.6)	198 (2.5)
Providencia Sp.	24 (0.1)	2 (0)	15 (0.2)	7 (0.1)
Pseudallescheria Sp.	4 (0)	-	4 (0)	-
Pseudomonas Sp.	703 (2.9)	269 (4.1)	210 (2.2)	224 (2.8)
Salmonella Sp.	326 (1.4)	103 (1.6)	125 (1.3)	98 (1.2)
Sarcinosporon Sp.	1 (0)	-	-	1 (0)
Serratia Sp.	1 (0)	-	-	1 (0)
Shigella Sp.	28 (0.1)	16 (0.2)	7 (0.1)	5 (0.1)
Staphylococcus Sp.	2494 (10.4)	665 (10.2)	1142 (12)	687 (8.7)
Streptobacillus Sp.	1 (0)	1 (0)	-	-
Streptococcus Sp.	1089 (4.5)	230 (3.5)	363 (3.8)	496 (6.3)
Unspecified (Gram negative bacilli)	9 (0)	7 (0.1)	2 (0)	-
Unspecified (Gram negative bacteria)	1 (0)	-	1 (0)	-
Unspecified (Gram negative cocci)	3 (0)	3 (0)	-	-
Unspecified (Gram positive bacilli)	1 (0)	-	-	1 (0)
Unspecified (Gram positive cocci)	234 (1)	167 (2.6)	21 (0.2)	46 (0.6)
Yersinia Sp.	1 (0)	-	1 (0)	-
Brevibacterium Sp.	2 (0)	-	-	2 (0.1)
Candida Sp.	1 (0)	-	1 (0.1)	-
Citrobacter Sp.	161 (3.7)	50 (5.1)	65 (4)	46 (2.6)
Corynebacterium Sp.	3 (0.1)	-	3 (0.2)	-
Enterobacter Sp.	181 (4.1)	45 (4.6)	81 (5)	55 (3.1)

Enterococcus Sp.	53 (1.2)	6 (0.6)	15 (0.9)	32 (1.8)
Gardnerella Sp.	1 (0)	-	1 (0.1)	-
Haemophilus Sp.	1 (0)	-	1 (0.1)	-
Klebsiella Sp.	303 (6.9)	79 (8)	126 (7.8)	98 (5.5)
Morganella Sp.	5 (0.1)	-	4 (0.2)	1 (0.1)
Peptostreptococcus Sp.	1 (0)	-	1 (0.1)	-
Proteus Sp.	74 (1.7)	25 (2.5)	20 (1.2)	29 (1.6)
Providencia Sp.	6 (0.1)	2 (0.2)	3 (0.2)	1 (0.1)
Pseudomonas Sp.	115 (2.6)	52 (5.3)	37 (2.3)	26 (1.5)
Salmonella Sp.	15 (0.3)	3 (0.3)	5 (0.3)	7 (0.4)
Serratia Sp.	2 (0)	-	-	2 (0.1)
Shigella Sp.	1 (0)	-	1 (0.1)	-
Staphylococcus Sp.	493 (11.2)	73 (7.4)	245 (15.1)	175 (9.8)
Streptococcus Sp.	32 (0.7)	7 (0.7)	10 (0.6)	15 (0.8)
Unspecified (Gram negative bacilli)	12 (0.3)	6 (0.6)	5 (0.3)	1 (0.1)
Unspecified (Gram negative cocci)	1 (0)	1 (0.1)	-	-
Unspecified (Gram positive bacilli)	2 (0)	1 (0.1)	-	1 (0.1)
Unspecified (Gram positive cocci)	49 (1.1)	10 (1)	20 (1.2)	19 (1.1)
Yersinia Sp.	1 (0)	-	1 (0.1)	-
Serratia ficaria	13 (0)	4 (0)	4 (0)	5 (0)
Serratia fonticola	23 (0.1)	8 (0.1)	5 (0)	10 (0.1)
Serratia liquefaciens	31 (0.1)	8 (0.1)	15 (0.1)	8 (0.1)
Serratia marcescens	91 (0.3)	31 (0.3)	27 (0.2)	33 (0.3)
Serratia odorifera	48 (0.1)	17 (0.2)	21 (0.2)	10 (0.1)
Serratia plymuthica	22 (0.1)	10 (0.1)	8 (0.1)	4 (0)
Serratia rubidaea	1 (0)	-	1 (0)	-
Shewanella putrefaciens	2 (0)	1 (0)	1 (0)	-
Shigella boydii	14 (0)	5 (0.1)	6 (0.1)	3 (0)
Shigella dysenteriae	9 (0)	4 (0)	1 (0)	4 (0)
Shigella flexneri	2 (0)	-	-	2 (0)
Shigella sonnei	9 (0)	-	2 (0)	7 (0.1)
Sphingomonas paucimobilis	6 (0)	1 (0)	4 (0)	1 (0)
Staphylococcus arlettae	1 (0)	1 (0)	-	-
Staphylococcus aureus	2279 (7)	694 (7)	802 (7.1)	783 (6.9)
Staphylococcus capitis	1 (0)	1 (0)	-	-
Staphylococcus caprae	1 (0)	-	-	1 (0)
Staphylococcus chromogenes	1 (0)	-	1 (0)	-

Staphylococcus cohnii	1 (0)	-	1 (0)	-
Staphylococcus epidermidis	103 (0.3)	30 (0.3)	28 (0.2)	45 (0.4)
Staphylococcus gallinarum	1 (0)	-	-	1 (0)
Staphylococcus haemolyticus	23 (0.1)	5 (0.1)	6 (0.1)	12 (0.1)
Staphylococcus hominis	5 (0)	2 (0)	-	3 (0)
Staphylococcus pasteuri	1 (0)	1 (0)	-	-
Staphylococcus piscifermentans	3 (0)	-	1 (0)	2 (0)
Staphylococcus pseudintermedius	2 (0)	-	-	2 (0)
Staphylococcus saprophyticus	363 (1.1)	119 (1.2)	111 (1)	133 (1.2)
Staphylococcus schleiferi	132 (0.4)	33 (0.3)	28 (0.2)	71 (0.6)
Staphylococcus sciuri	7 (0)	2 (0)	1 (0)	4 (0)
Staphylococcus simulans	1 (0)	1 (0)	-	-
Staphylococcus warneri	4 (0)	-	3 (0)	1 (0)
Staphylococcus xylosus	16 (0)	3 (0)	1 (0)	12 (0.1)
Stenotrophomonas (xanthomonas) maltophilia	7 (0)	-	2 (0)	5 (0)
Streptococcus agalactiae	11 (0)	2 (0)	8 (0.1)	1 (0)
Streptococcus alactolyticus	1 (0)	1 (0)	-	-
Streptococcus anginosus	1 (0)	1 (0)	-	-
Streptococcus bovis	2 (0)	-	1 (0)	1 (0)
Streptococcus canis	2 (0)	2 (0)	-	-
Streptococcus dysgalactiae	1 (0)	1 (0)	-	-
Streptococcus ferus	1 (0)	-	1 (0)	-
Streptococcus gallolyticus	1 (0)	-	1 (0)	-
Streptococcus gordonii	1 (0)	1 (0)	-	-
Streptococcus milleri	10 (0)	3 (0)	4 (0)	3 (0)
Streptococcus mitis	5 (0)	3 (0)	2 (0)	-
Streptococcus oralis	2 (0)	1 (0)	-	1 (0)
Streptococcus parasanguinis	1 (0)	-	-	1 (0)
Streptococcus pneumoniae	37 (0.1)	18 (0.2)	11 (0.1)	8 (0.1)
Streptococcus pyogenes	11 (0)	1 (0)	6 (0.1)	4 (0)
Streptococcus salivarius	1 (0)	-	1 (0)	-
Streptococcus sanguinis	6 (0)	4 (0)	2 (0)	-
Streptococcus suis	1 (0)	-	-	1 (0)
Streptococcus thoraltensis	1 (0)	1 (0)	-	-
Streptococcus viridans	2 (0)	1 (0)	-	1 (0)
Trichophyton rubrum	1 (0)	-	1 (0)	-

Trichosporon asahii	2 (0)	-	-	2 (0)
Ureaplasma urealyticum	5321 (16.3)	1616 (16.3)	1950 (17.2)	1755 (15.5)
Vibrio metschnikovii	1 (0)	1 (0)	-	-
Yeast	2 (0)	2 (0)	-	-
Yersinia enterocolitica	6 (0)	-	3 (0)	3 (0)
Yersinia intermedia	1 (0)	-	1 (0)	-
Yersinia kristensenii	1 (0)	-	-	1 (0)
Yersinia pestis	1 (0)	-	1 (0)	-
Yersinia ruckeri	1 (0)	-	-	1 (0)
Positive cultures without specific pathogen name	3234 (9.9)	1063 (10.7)	938 (8.3)	1233 (10.9)
Achromobacter Sp.	1 (0)	-	-	1 (0)
Acidovorax Sp.	1 (0)	-	1 (0)	-
Acinetobacter Sp.	88 (0.3)	10 (0.1)	24 (0.2)	54 (0.5)
Aerococcus Sp.	1 (0)	-	1 (0)	-
Aeromonas Sp.	4 (0)	1 (0)	1 (0)	2 (0)
Aspergillus Sp.	1 (0)	-	-	1 (0)
Bacteroides Sp.	1 (0)	-	-	1 (0)
Campylobacter Sp.	1 (0)	1 (0)	-	-
Candida Sp.	1063 (3.3)	306 (3.1)	337 (3)	420 (3.7)
Chryseomonas Sp.	1 (0)	-	-	1 (0)
Citrobacter Sp.	20 (0.1)	4 (0)	9 (0.1)	7 (0.1)
Clostridium Sp.	1 (0)	1 (0)	-	-
Corynebacterium Sp.	6 (0)	1 (0)	2 (0)	3 (0)
Cryptococcus Sp.	3 (0)	-	1 (0)	2 (0)
Enterobacter Sp.	101 (0.3)	36 (0.4)	16 (0.1)	49 (0.4)
Enterococcus Sp.	87 (0.3)	25 (0.3)	44 (0.4)	18 (0.2)
Escherichia Sp.	2 (0)	1 (0)	1 (0)	-
Gardnerella Sp.	60 (0.2)	6 (0.1)	-	54 (0.5)
Geotrichum Sp.	1 (0)	1 (0)	-	-
Haemophilus Sp.	13 (0)	10 (0.1)	3 (0)	-
Klebsiella Sp.	218 (0.7)	106 (1.1)	43 (0.4)	69 (0.6)
Kluyvera Sp.	10 (0)	4 (0)	5 (0)	1 (0)
Leuconostoc Sp.	1 (0)	1 (0)	-	-
Listeria Sp.	3 (0)	-	1 (0)	2 (0)
Listonella Sp.	1 (0)	1 (0)	-	-
Micrococcus Sp.	2 (0)	2 (0)	-	-

Microsporum Sp.	1 (0)	-	1 (0)	-
Mobiluncus Sp.	1 (0)	1 (0)	-	-
Moraxella Sp.	1 (0)	-	-	1 (0)
Mycoplasma Sp.	39 (0.1)	3 (0)	-	36 (0.3)
Neisseria Sp.	6 (0)	1 (0)	1 (0)	4 (0)
Ochrobactrum Sp.	1 (0)	-	-	1 (0)
Other	6 (0)	6 (0.1)	-	-
Pantoea Sp.	99 (0.3)	28 (0.3)	42 (0.4)	29 (0.3)
Pasteurella Sp.	4 (0)	-	3 (0)	1 (0)
Photobacterium Sp.	1 (0)	-	-	1 (0)
Proteus Sp.	81 (0.2)	20 (0.2)	17 (0.1)	44 (0.4)
Providencia Sp.	11 (0)	2 (0)	3 (0)	6 (0.1)
Pseudomonas Sp.	93 (0.3)	34 (0.3)	28 (0.2)	31 (0.3)
Raoultella Sp.	2 (0)	1 (0)	1 (0)	-
Salmonella Sp.	216 (0.7)	46 (0.5)	81 (0.7)	89 (0.8)
Serratia Sp.	16 (0)	3 (0)	7 (0.1)	6 (0.1)
Shewanella Sp.	1 (0)	-	-	1 (0)
Shigella Sp.	106 (0.3)	23 (0.2)	53 (0.5)	30 (0.3)
Sphingobacterium Sp.	1 (0)	1 (0)	-	-
Staphylococcus Sp.	286 (0.9)	109 (1.1)	89 (0.8)	88 (0.8)
Stenotrophomonas Sp.	2 (0)	-	1 (0)	1 (0)
Streptobacillus Sp.	4 (0)	2 (0)	2 (0)	-
Streptococcus Sp.	351 (1.1)	106 (1.1)	104 (0.9)	141 (1.2)
Streptomyces Sp.	1 (0)	-	1 (0)	-
Trichosporon Sp.	1 (0)	-	-	1 (0)
Unspecified (Gram negative bacilli)	81 (0.2)	72 (0.7)	2 (0)	7 (0.1)
Unspecified (Gram negative bacteria)	91 (0.3)	77 (0.8)	-	14 (0.1)
Unspecified (Gram positive bacilli)	1 (0)	-	-	1 (0)
Unspecified (Gram positive bacteria)	5 (0)	4 (0)	-	1 (0)
Unspecified (Gram positive cocci)	30 (0.1)	4 (0)	13 (0.1)	13 (0.1)
Unspecified (Gram variable coccobacilli)	1 (0)	1 (0)	-	-
Ureaplasma Sp.	2 (0)	2 (0)	-	-
Yersinia Sp.	1 (0)	-	-	1 (0)

*Note: * indicates positive cultures with AST results; '-' means information was not available.*

Supplementary Table 6: Laboratory data scoring

Laboratory name	Laboratory data score (out of 4)			
	2016	2017	2018	Average
LAUTECH	4	4	4	4
Kubwa	3	3	4	3.3
BABCOCK	2	2	3	2.3
Abuja NH	4	4	4	4
Wase	2	2	2	2
UPTH	4	4	3	3.7
Bwari	3	3	4	3.3
LUTH	2	4	3	3
Niger Delta	3	3	2	2.7
Ibadan	4	4	3	3.7
Ilorin	4	4	4	4
OAUTHC	3	3	3	3
Maitama	3	3	3	3
Lapai	2	3	-	2.5
Aminu Kanu	3	3	3	3
FMC Birnin	1	3	2	2
Minna	2	1	1	1.3
UNTH Enugu	3	3	3	3
Sir MSS	2	2	2	2
UCTH	4	4	3	3.7
Murtala		3	3	3
FNPH Yaba	3	4	3	3.3
FMC Bida	4	4	4	4
FMC Azare	3	4	3	3.3
FMC Abeokuta	3	3	3	3

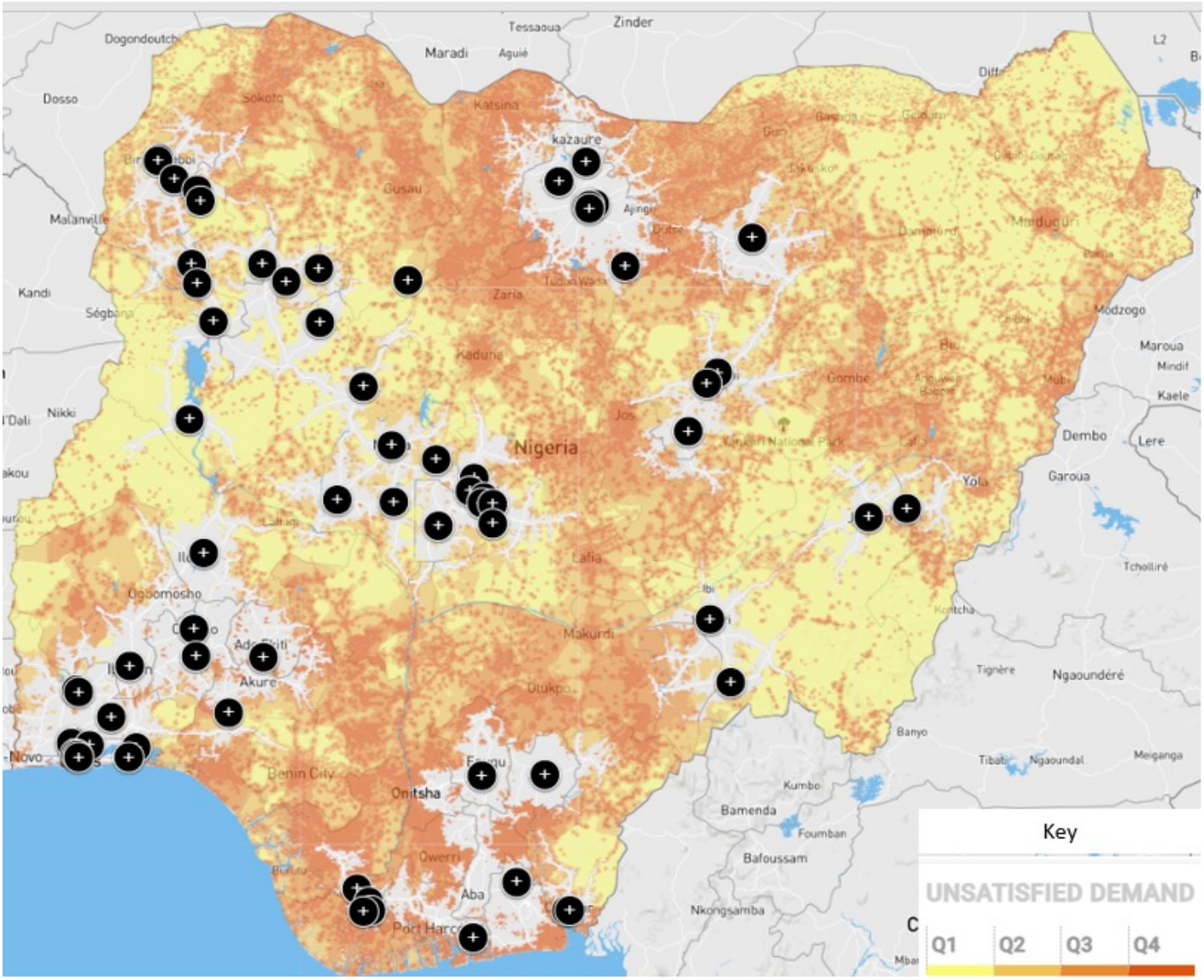
Supplementary Table 7: Univariate logistic regression analysis

Variable	Options	N	NS (%)	Crude OR (95% CI)	P-value
Gender	Female	2415	63.5	Ref	0.185
	Male	818	61.7	0.93 (0.83 – 1.04)	
Age, years	<1	109	58.7	0.77 (0.57 – 1.06)	0.1848
	1-17	439	64.2	0.98 (0.63 – 1.51)	
	18-49	1170	64.8	Ref	
	50-65	272	60.7	0.83 (0.66 – 1.07)	
	>65	221	67.0	1.10 (0.81 – 1.50)	

N-number of tested isolates; NS (%)-Proportion of non-susceptible isolates; Ref: Reference category

AMR Supplementary Figures

Supplementary Figure 1: Population coverage of laboratories



Supplementary Figure 2a: Inappropriate testing A

Organism Name	Antimicrobial Agent	Agent Code	Interpreted Results	Antimicrobial Susceptibility Method	Year
Escherichia coli	5-Fluorocytosine	FCT_ND1	R	Disk	2016
Escherichia coli	5-Fluorocytosine	FCT_ND1	S	Disk	2016
Klebsiella sp.	5-Fluorocytosine	FCT_ND1	S	Disk	2016
Escherichia coli	5-Fluorocytosine	FCT_ND1	S	Disk	2016
Cryptococcus sp.	Ceftriaxone	CRO_ND30	S	Disk	2016
Cryptococcus sp.	Levofloxacin	LVX_NDS	S	Disk	2016
Candida sp.	Amoxicillin	AMC_ND20	R	Disk	2017
Candida sp.	Gentamicin	GEN_ND10	R	Disk	2017
Paecilomyces lilacinus	Colistin	COL_ND10	R	Disk	2017
Paecilomyces lilacinus	Colistin	COL_ND10	R	Disk	2017
Sarcinosporon sp.	Cefuroxime	CXM_ND30	R	Disk	2018
Sarcinosporon sp.	Erythromycin	ERY_ND15	R	Disk	2018
Sarcinosporon sp.	Gentamicin	GEN_ND10	R	Disk	2018

Supplementary Figure 2b: Inappropriate testing B

Organism Name	Antimicrobial Agent	Agent Code	Interpreted Results	Antimicrobial Susceptibility Method	Year
Staphylococcus aureus	Vancomycin	VAN_ND30	R	Disk	2016
Staphylococcus aureus	Vancomycin	VAN_ND30	R	Disk	2016
Staphylococcus aureus	Vancomycin	VAN_ND30	R	Disk	2016
Staphylococcus aureus	Vancomycin	VAN_ND30	S	Disk	2017
Staphylococcus aureus	Vancomycin	VAN_ND30	S	Disk	2017
Staphylococcus aureus	Vancomycin	VAN_ND30	S	Disk	2017
Staphylococcus sp	Vancomycin	VAN_ND30	S	Disk	2018
Staphylococcus sp	Vancomycin	VAN_ND30	S	Disk	2018
Staphylococcus sp	Vancomycin	VAN_ND30	S	Disk	2018
Escherichia coli	Vancomycin	VAN_ND30	R	Disk	2016
Escherichia coli	Vancomycin	VAN_ND30	R	Disk	2016
Escherichia coli	Vancomycin	VAN_ND30	R	Disk	2016
Proteus mirabilis	Oxacillin	OXA_ND1	R	Disk	2017
Klebsiella aerogenes	Oxacillin	OXA_ND1	R	Disk	2017
Klebsiella sp	Oxacillin	OXA_ND1	R	Disk	2017
Escherichia coli	Penicillin G	PEN_ND10	R	Disk	2017
Klebsiella sp	Penicillin G	PEN_ND10	R	Disk	2017
Klebsiella aerogenes	Penicillin G	PEN_ND10	R	Disk	2018
Escherichia coli	Penicillin G	PEN_ND10	R	Disk	2018

Supplementary Figure 2c: Inappropriate testing C

Organism Name	Antimicrobial Agent	Agent Code	Interpreted Results	Antimicrobial Susceptibility Method	Year
Staphylococcus aureus	Vancomycin	VAN_ND30	R	Disk	2016
Staphylococcus aureus	Vancomycin	VAN_ND30	R	Disk	2016
Staphylococcus aureus	Vancomycin	VAN_ND30	R	Disk	2016
Staphylococcus aureus	Vancomycin	VAN_ND30	S	Disk	2017
Staphylococcus aureus	Vancomycin	VAN_ND30	S	Disk	2017
Staphylococcus aureus	Vancomycin	VAN_ND30	S	Disk	2017
Staphylococcus sp	Vancomycin	VAN_ND30	S	Disk	2018
Staphylococcus sp	Vancomycin	VAN_ND30	S	Disk	2018
Staphylococcus sp	Vancomycin	VAN_ND30	S	Disk	2018
Escherichia coli	Vancomycin	VAN_ND30	R	Disk	2016
Escherichia coli	Vancomycin	VAN_ND30	R	Disk	2016
Escherichia coli	Vancomycin	VAN_ND30	R	Disk	2016
Proteus mirabilis	Oxacillin	OXA_ND1	R	Disk	2017
Klebsiella aerogenes	Oxacillin	OXA_ND1	R	Disk	2017
Klebsiella sp	Oxacillin	OXA_ND1	R	Disk	2017
Escherichia coli	Penicillin G	PEN_ND10	R	Disk	2017
Klebsiella sp	Penicillin G	PEN_ND10	R	Disk	2017
Klebsiella aerogenes	Penicillin G	PEN_ND10	R	Disk	2018
Escherichia coli	Penicillin G	PEN_ND10	R	Disk	2018

AMC Appendices

Appendix 1: Key Informant Interview (KII) tool

(Contains ALL questions: However, during implementation, only specific questions were asked to suitable stakeholders)

Domestic Producers and Importers

1.1	What quantity/proportion of antibiotics are produced/manufactured (if any) within the country?	N/A
1.2	If domestically produced what manufactured quantity is later exported?	
1.3	What quantity/proportion of antibiotics are imported?	
1.4	What proportion (if any) are then re-exported?	

Procurement, Storage and Distribution

1.5	Are there any specific regulations regarding Procurement and/or storage of antibiotics?	Yes		No	

Public Sector

1.6	Who supplies to the public sector (names of the companies/organisations)?
1.7	What role (if any) does the Central Medical Stores play in the procurement, storage and distribution of antibiotics in the country?
1.8	What quantity/proportion of antibiotics is purchased by public healthcare facilities from central medical stores and what quantity/ proportion from wholesalers/other suppliers? (specify who these other suppliers are)
1.9	How do public facilities procure and receive their antibiotic supplies?

Private Sector

1.10	Who supplies to the private sector (names of the companies/organisations)?
1.11	What quantity/proportion of antibiotics is purchased by Private healthcare facilities from central medical stores and what quantity/ proportion from wholesalers/other suppliers? (specify who these other suppliers are)
1.12	How do private facilities procure and receive their antibiotic supplies?

Donor Funded Supply

1.13	Is there any donor support for procurement of antibiotics in the country?	Yes		No	
1.14	If yes to above, who are the donors and what are the procedures regarding import and distribution of donated antibiotics?				
1.15	Which sector(s) is supported with supplies procured through donor agencies?				
	Public Sector	Private			
1.16	If there is donor support, are antibiotics sourced locally or imported?				
1.17	Does the available donor data indicate specific country antibiotic consumption? Do these procurement mechanisms fit in with the countries regulatory systems and WHOs recommended surveillance practices? or are there challenges?				
1.18	What proportion/quantity of antibiotics are procured/supplied from donor programs; and using which mechanisms are such products procured e.g., WAMBO for The Global Fund, pooled procurement mechanisms etc.				
1.19	What are the requirements and procedures for suppliers to import/export antibiotics in the country?				

2. Data and Information Systems

2.1	What information systems are currently in use at **national level** for managing data on antibiotics?						
2.2	Are the systems manual or electronic?						
Manual				Electronic			
2.3	What type of information is captured using these systems? (e.g. generic names, dose strengths, formulations, pack size, brand names and volumes)						
Generic names		Dose strengths		Formulations		Pack size/ Volumes	
Brand names		Other:					
2.4	Does the country have a centralised data source for all antibiotics that are imported/exported?						
No		Yes, manual data system		Yes, electronic data system			
2.5	What are the available data sources to quantify antibiotic consumption at **facility level** (records from pharmacies, data from health insurance programs, prescribing records of physicians, dispensing records of pharmacists etc.)?						
2.6	What are the available data sources to quantify antibiotic consumption at **sub – national level** (records from pharmacies, data from health insurance programs, prescribing records of physicians, dispensing records of pharmacists etc.)?						
2.7	What are the available data sources to quantify antibiotic consumption at **the national level** (records from pharmacies, data from health insurance programs, prescribing records of physicians, dispensing records of pharmacists etc.)?						
2.8	What challenges (if any) are faced in terms of data availability on antibiotics?						
2.9	Do public sector healthcare providers have LMIS to monitor and retrieve data of logistics of antibiotics? How is it managed and what data does it gather and for what use?				Yes		No

3. Informal Supply Chains

3.1	Is there an estimate of the antibiotic black-market size in the country?
3.2	Are there any mechanisms utilized by relevant authorities to track and trace illegally imported antibiotics in the country?

Appendix 2: Eligibility questionnaire for pharmacies

Purpose:
To determine eligibility of community pharmacies for data collection Antimicrobial Consumption (AMC)

Instructions

Pre-requisite for administering the Questionnaire:
List of public hospitals/ private facilities where the laboratories are situated/ where eligibility of laboratories is being tested
Contact details of pharmacy situated within/ connected to the above public/ private hospital
Mode of administering the Questionnaire:
Administered over email and/ or over the phone

Eligibility questionnaire for Community Pharmacies:

A. General information				
1. What is the name and complete address of your pharmacy?				
2. Does the pharmacy house a laboratory?	Yes		No	
3. Does the pharmacy have relevant certification/ accreditation (in example by the pharmacy and poison board etc.)	Yes		No	
4. Did the pharmacy have the following in place at any time between 2016-18?				
4.1 At least one Pharmacist	Yes		No	
4.2 At least one pharmacy technician	Yes		No	
4.3 Are there SOPs in place for entering issues / sales of antibiotics?	Yes		No	
B. Antibiotic Consumption Data				
1. Are the following data at the pharmacy stored electronically? (State Y/N for each)				
2. Sales of antibiotics to patients/customers	Yes		No	
3. Purchases (from wholesalers/distributors/open markets etc.)	Yes		No	
4. Current stock in hand of antibiotics (at end of month)	Yes		No	
5. No electronic records are maintained	Yes		No	
6. If answer is YES to Q5, how far back in time do the electronic records exist (indicate start month and year – for 2018, 2017 and 2016 for each of the below)?				
7. Sales to patients/customers	Month:			
	Year:			
8. Purchases (from wholesalers/distributors/open markets etc.)	Month:			
	Year:			
9. Current stock in hand of medicines (at end of each month)	Month:			
	Year:			
10. As a follow up to Q6, is it possible to extract historical data (for 2018, 2017, 2016 or part thereof) in excel, CSV or any other format from electronic pharmacy system? (State Y/N for each)				
11. Sales to patients, customers and/ or Prescriptions	Yes		No	
12. Purchases (from wholesalers/distributors/open markets etc.)	Yes		No	
13. Current stock of medicines (at end of each month)	Yes		No	
14. If answer is NO to Q5, does the pharmacy manually hold paper-based data for medicines? (State Y/N for each)				
15. Sales to patients/customers	Yes		No	

16. Purchases from wholesalers/distributors etc.	Yes		No	
17. Current stock in hand of medicines	Yes		No	
18. How far back in time do the manual/ paper-based records exist for the following (indicate start month and year – for 2018, 2017 and 2016 for each of the below)?				
19. Sales to patients/customers	Month:			
	Year:			
20. Purchases (from wholesalers/distributors/open markets etc.)	Month:			
	Year:			
21. Current stock in hand of medicines	Month:			
	Year:			
22. What records can be used for historical data extraction for antibiotic sales? (State Y/N for each option)				
23. Sales invoices / prescriptions to customers/patients (sell-out)	Yes		No	
24. Supplier invoices received by pharmacy (sell-in)	Yes		No	
25. Any other (please state)	Yes		No	
26. What kind of stock control system does the pharmacy store maintain? (State Y/N for each option)				
27. Issues/ sales book	Yes		No	
28. Stock card/Bin Card	Yes		No	
29. Electronic	Yes		No	
30. Any other (please state)	Yes		No	
31. In case of dispensing antibiotics to patients, can the pharmacy trace if there was a prescription?	Yes		No	

Based on historical data, will it be possible to obtain month-wise disaggregated data for the following fields for 2018, 2017 and 2016?	In the table below just indicate Y/N to understand availability of the kind of data – DO NOT fill actual data for now

Antibiotic Name	Form* (Tablets, Vials, Capsules, Syrup etc.)	Strength* (in MG)	Pack* size	Manufacturer	Data available for- No. of units DISPENSED in a month	Data available for- No. of units PURCHASED in a month	Data available for- Stock in Hand end of each month
AMOXICILLIN	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N
		Y/N	Y/N	Y/N	Y/N	Y/N	Y/N
		Y/N	Y/N	Y/N	Y/N	Y/N	Y/N
	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N
	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N
	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N

* A single antibiotic may come in different forms, with different strength and in different pack sizes. Idea here is to understand whether consumption / purchase data can be made available at the pharmacy for each of the different form-strength-pack size combinations. For instance, Amoxicillin 'Capsules' (form) '250 mg' (strength) '100' (pack size) will be one row, and so on.

Stock out status of antibiotics (State Y/N to each of the below statements)				
a. Is there often a stock-out of antibiotics at the pharmacy?	Yes		No	
b. If yes to a, is a record of the stocked-out antibiotics maintained?	Yes		No	
c. In case some antibiotic is out of stock or not available, how do patients purchase that medicine generally?	Yes		No	
d. Purchase from the public hospital pharmacy	Yes		No	
e. Purchase from nearby other private pharmacy	Yes		No	
f. Purchase from private pharmacy near their residence	Yes		No	
g. Purchase from the market	Yes		No	

Appendix 3: Harmonised list of antimicrobials to be included in data collection

Appendix 3: Harmonised list of antimicrobials to be included in data collection

Antimicrobial name	WHO ATC Index	A/W/R/U category
Acetyl Kitasamycin	J01	U
Acetylspiramycin	J01	W
Alatrofloxacin	J01	U
Amoxicillin/Ampicillin	J01	U
Amoxicillin/Cloxacillin	J01	U
Amoxicillin/Dicloxacillin	J01	U
Amoxicillin/Flucloxacillin	J01	U
Amoxicillin/Metronidazole	J01	U
Amoxicillin/Sulbactam	J01	A
Ampicillin/Cloxacillin	J01	U
Ampicillin/Dicloxacillin	J01	U
Ampicillin/Flucloxacillin	J01	U
Ampicillin/Oxacillin	J01	U
Ampicillin/Sulbactam	J01	A
Ampicillin/Sultamicillin	J01	A
Antofloxacin	J01	W
Astromicin	J01	W
Balofloxacin	J01	W
Benzylpenicillin/Phenoxymethylpenicillin	J01	A
Benzylpenicillin/Phenoxymethylpenicillin/Streptomycin	J01	U
Benzylpenicillin/Streptomycin	J01	U
Bleomycin A5	J01	U
Cefadroxil/Clavulanic Acid	J01	A
Cefathiamidine	J01	A
Cefepime/Sulbactam	J01	U
Cefepime/Tazobactam	J01	U
Cefixime/Azithromycin	J01	U
Cefixime/Cefpodoxime	J01	U
Cefixime/Clavulanic Acid	J01	W
Cefixime/Cloxacillin	J01	U
Cefixime/Dicloxacillin	J01	U
Cefixime/Levofloxacin	J01	U
Cefixime/Linezolid	J01	U
Cefixime/Moxifloxacin	J01	U
Cefixime/Ofloxacin	J01	U

Cefixime/Sulbactam	J01	U
Cefoperazone/Sulbactam	J01	U
Cefoperazone/Tazobactam	J01	U
Cefoselis	J01	R
Cefotaxime/Sulbactam	J01	U
Cefpodoxime/Azithromycin	J01	U
Cefpodoxime/Cloxacillin	J01	U
Cefpodoxime/Dicloxacillin	J01	U
Cefpodoxime/Levofloxacin	J01	W
Cefpodoxime/Ofloxacin	J01	W
Ceftazidime/Avibactam	J01	R
Ceftazidime/Sulbactam	J01	U
Ceftazidime/Tazobactam	J01	U
Ceftazidime/Tobramycin	J01	U
Ceftizoxime/Tazobactam	J01	U
Ceftolozane	J01	R
Ceftriaxone/Sulbactam	J01	U
Ceftriaxone/Tazobactam	J01	U
Ceftriaxone/Vancomycin	J01	U
Cefuroxime/Clavulanic Acid	J01	W
Cefuroxime/Linezolid	J01	U
Cefuroxime/Sulbactam	J01	U
Cephalosporin C	J01	U
Ciclacillin	J01	U
Erythromycin Stearate	J01	U
Erythromycin Stinoprate	J01	U
Etimicin	J01	W
Furbenicillin	J01	W
Guamecycline	J01	U
Imipenem	J01	U
Kitasamycin	J01	U
Lenampicillin	J01	U
Levofloxacin/Azithromycin	J01	W
Levofloxacin/Metronidazole	J01	U
Meleumycin	J01	U
Meropenem/Sulbactam	J01	U
Norvancomycin	J01	W
Novobiocin	J01	U

Ofloxacin/Azithromycin	J01	U
Panipenem	J01	W
Piperacillin/Sulbactam	J01	U
Piperacillin/Tazobactam	J01	W
Pivampicillin/Pivmecillinam	J01	U
Polymyxin M	J01	R
Sulfadoxine/Trimethoprim	J01	U
Sulfalene/Trimethoprim	J01	U
Sulfamethizole/Trimethoprim	J01	A
Sulfamethoxypyridazine/Trimethoprim	J01	U
Demeclocycline	J01AA01	U
Doxycycline	J01AA02	A
Chlortetracycline	J01AA03	W
Lymecycline	J01AA04	W
Metacycline	J01AA05	W
Oxytetracycline	J01AA06	W
Tetracycline	J01AA07	A
Minocycline	J01AA08	W, R (IV)
Rolitetracycline	J01AA09	U
Penimepicycline	J01AA10	U
Clomocycline	J01AA11	U
Tigecycline	J01AA12	R
Eravacycline	J01AA13	R
Chloramphenicol	J01BA01	A
Thiamphenicol	J01BA02	A
Ampicillin	J01CA01	A
Pivampicillin	J01CA02	A
Carbenicillin	J01CA03	W
Amoxicillin	J01CA04	A
Carindacillin	J01CA05	U
Bacampicillin	J01CA06	A
Epicillin	J01CA07	U
Pivmecillinam	J01CA08	A
Azlocillin	J01CA09	W
Mezlocillin	J01CA10	W
Mecillinam	J01CA11	A
Piperacillin	J01CA12	W
Ticarcillin	J01CA13	W
Metampicillin	J01CA14	U

Talampicillin	J01CA15	U
Sulbenicillin	J01CA16	W
Temocillin	J01CA17	W
Hetacillin	J01CA18	U
Aspoxicillin	J01CA19	U
Benzylpenicillin	J01CE01	A
Phenoxymethylpenicillin	J01CE02	A
Propicillin	J01CE03	U
Azidocillin	J01CE04	U
Pheneticillin	J01CE05	W
Penamecillin	J01CE06	A
Clometocillin	J01CE07	A
Benzathine phenoxymethylpenicillin	J01CE10	U
Dicloxacillin	J01CF01	A
Cloxacillin	J01CF02	A
MeticillinMethicillin	J01CF03	U
Oxacillin	J01CF04	A
Flucloxacillin	J01CF05	A
Nafcillin	J01CF06	A
Sulbactam	J01CG01	U
Tazobactam	J01CG02	U
Ampicillin/Clavulanic Acid	J01CR01	A
Amoxicillin/Clavulanic Acid	J01CR02	A
Ticarcillin/Clavulanic Acid	J01CR03	W
Sultamicillin	J01CR04	A
Cefalexin	J01DB01	A
Cefaloridine	J01DB02	U
Cefalotin	J01DB03	A
Cefazolin	J01DB04	A
Cefadroxil	J01DB05	A
Cefazedone	J01DB06	A
Cefatrizine	J01DB07	A
Cefapirin	J01DB08	A
Cefradine	J01DB09	A
Cefacetrile	J01DB10	A
Cefroxadine	J01DB11	A
Ceftezole	J01DB12	A
Cefoxitin	J01DC01	W
Cefuroxime	J01DC02	W

Cefamandole	J01DC03	W
Cefaclor	J01DC04	W
Cefotetan	J01DC05	W
Cefonicid	J01DC06	W
Cefotiam	J01DC07	W
Loracarbef	J01DC08	U
Cefmetazole	J01DC09	W
Cefprozil	J01DC10	W
Ceforanide	J01DC11	W
Cefminox	J01DC12	W
Cefbuperazone	J01DC13	W
Flomoxef	J01DC14	W
Cefotaxime	J01DD01	W
Ceftazidime	J01DD02	W
Cefsulodin	J01DD03	U
Ceftriaxone	J01DD04	W
Cefmenoxime	J01DD05	W
Latamoxef	J01DD06	W
Ceftizoxime	J01DD07	W
Cefixime	J01DD08	W
Cefodizime	J01DD09	W
Cefetamet	J01DD10	W
Cefpiramide	J01DD11	W
Cefoperazone	J01DD12	W
Cefpodoxime	J01DD13	W
Ceftibuten	J01DD14	W
Cefdinir	J01DD15	W
Cefditoren	J01DD16	W
Cefcapene	J01DD17	W
Cefteram	J01DD18	W
Cefotaxime/Clavulanic Acid	J01DD51	W
Ceftazidime/Clavulanic Acid	J01DD52	W
Ceftazidime/Clavulanic Acid	J01DD52	W
Cefoperazone/Clavulanic Acid	J01DD62	W
Ceftriaxone/Clavulanic Acid	J01DD63	W
Cefpodoxime/Clavulanic Acid	J01DD64	W
Cefepime	J01DE01	W
Cefpirome	J01DE02	R

Cefozopran	J01DE03	R
Aztreonam	J01DF01	R
Carumonam	J01DF02	U
Meropenem	J01DH02	W
Ertapenem	J01DH03	W
Doripenem	J01DH04	W
Biapenem	J01DH05	W
Tebipenem Pivoxil	J01DH06	W
Imipenem/Cilastatin	J01DH51	W
Meropenem/Vaborbactam	J01DH52	R
Panipenem/Betamipron	J01DH55	U
Ceftobiprole Medocaril	J01DI01	R
Ceftaroline Fosamil	J01DI02	R
Faropenem	J01DI03	W
Ceftolozane/Tazobactam	J01DI54	U
Ceftolozane/Clavulanic Acid	J01DI54	R
Trimethoprim	J01EA01	A
Brodimoprim	J01EA02	U
Iclaprim	J01EA03	U
Sulfaisodimidine	J01EB01	U
Sulfamethizole	J01EB02	U
Sulfadimidine	J01EB03	U
Sulfapyridine	J01EB04	U
Sulfafurazole	J01EB05	U
Sulfanilamide	J01EB06	U
Sulfathiazole	J01EB07	U
Sulfathiourea	J01EB08	U
Sulfamethoxazole	J01EC01	U
Sulfadiazine	J01EC02	U
Sulfamoxole	J01EC03	U
Sulfadimethoxine	J01ED01	U
Sulfalene	J01ED02	U
Sulfametomidine	J01ED03	U
Sulfametoxydiazine	J01ED04	U
Sulfamethoxypyridazine	J01ED05	U
Sulfaperin	J01ED06	U
Sulfamerazine	J01ED07	U
Sulfaphenazole	J01ED08	U

Sulfamazone	J01ED09	U
Trimethoprim/Sulfamethoxazole	J01EE01	A
Sulfadiazine/Trimethoprim	J01EE02	A
Sulfametrole/Trimethoprim	J01EE03	A
Sulfamoxole/Trimethoprim	J01EE04	A
Sulfadimidine/Trimethoprim	J01EE05	U
Sulfadiazine/Tetroxoprim	J01EE06	U
Sulfamerazine/Trimethoprim	J01EE07	U
Erythromycin	J01FA01	W
Spiramycin	J01FA02	W
Midecamycin	J01FA03	W
Oleandomycin	J01FA05	W
Roxithromycin	J01FA06	W
Josamycin	J01FA07	W
Troleandomycin	J01FA08	U
Clarithromycin	J01FA09	W
Azithromycin	J01FA10	W
Miocamycin	J01FA11	U
Rokitamycin	J01FA12	U
Dirithromycin	J01FA13	W
Flurithromycin	J01FA14	U
Telithromycin	J01FA15	W
Solithromycin	J01FA16	U
Clindamycin	J01FF01	A
Lincomycin	J01FF02	W
Pristinamycin	J01FG01	W
Quinupristin/Dalfopristin	J01FG02	R
Streptomycin	J01GA01	A
Streptoduocin	J01GA02	U
Tobramycin	J01GB01	W
Gentamicin	J01GB03	A
Kanamycin	J01GB04	A
Neomycin	J01GB05	W
Amikacin	J01GB06	A
Netilmicin	J01GB07	W
Sisomicin	J01GB08	W
Dibekacin	J01GB09	W
Ribostamycin	J01GB10	W
Isepamicin	J01GB11	W

Arbekacin	J01GB12	W
Bekanamycin	J01GB13	U
Ofloxacin	J01MA01	W
Ciprofloxacin	J01MA02	W
Pefloxacin	J01MA03	W
Enoxacin	J01MA04	W
Temafloxacin	J01MA05	U
Norfloxacin	J01MA06	W
Lomefloxacin	J01MA07	W
Fleroxacin	J01MA08	W
Sparfloxacin	J01MA09	W
Rufloxacin	J01MA10	W
Grepafloxacin	J01MA11	U
Levofloxacin	J01MA12	W
Trovafloxacin	J01MA13	U
Moxifloxacin	J01MA14	W
Gemifloxacin	J01MA15	W
Gatifloxacin	J01MA16	W
Prulifloxacin	J01MA17	W
Pazufloxacin	J01MA18	W
Garenoxacin	J01MA19	W
Sitafloxacin	J01MA21	W
Tosufloxacin	J01MA22	W
Delafloxacin	J01MA23	W
Rosoxacin	J01MB01	U
Nalidixic acid	J01MB02	U
Piromidic Acid	J01MB03	U
Pipemidic Acid	J01MB04	U
Oxolinic Acid	J01MB05	U
Cinoxacin	J01MB06	U
Flumequine	J01MB07	W
Nemonoxacin	J01MB08	U
Cefuroxime/Metronidazole	J01RA03	U
Spiramycin/Metronidazole	J01RA04	W
Levofloxacin/Ornidazole	J01RA05	U
Cefepime/Amikacin	J01RA06	U
Azithromycin/Fluconazole/Secnidazole	J01RA07	U
Tetracycline/Oleandomycin	J01RA08	U
Ofloxacin/Ornidazole	J01RA09	U

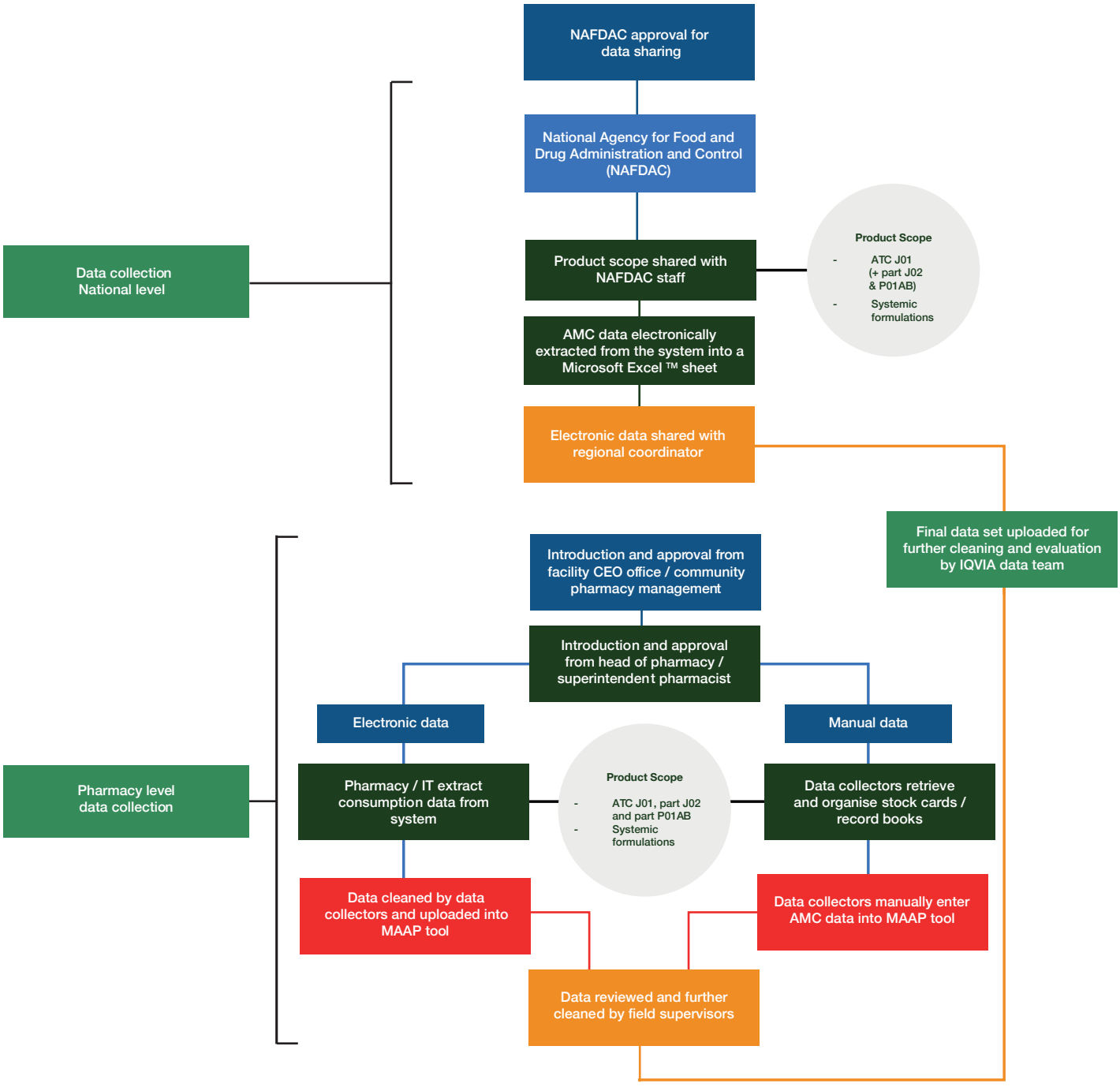
Ciprofloxacin/Metronidazole	J01RA10	U
Ciprofloxacin/Tinidazole	J01RA11	U
Ciprofloxacin/Ornidazole	J01RA12	U
Norfloxacin/Tinidazole	J01RA13	U
Vancomycin	J01XA01	W
Teicoplanin	J01XA02	W
Telavancin	J01XA03	R
Dalbavancin	J01XA04	R
Oritavancin	J01XA05	R
Colistin	J01XB01	R
Polymyxin B	J01XB02	R
Fusidic Acid	J01XC01	W
Metronidazole	J01XD01	A
Tinidazole	J01XD02	U
Ornidazole	J01XD03	U
Nitrofurantoin	J01XE01	U
Nifurtoinol	J01XE02	U
Furazidine	J01XE03	U
Fosfomycin	J01XX01	R
Xibornol	J01XX02	U
Clofoctol	J01XX03	W
Spectinomycin	J01XX04	A
Linezolid	J01XX08	R
Daptomycin	J01XX09	R
Bacitracin	J01XX10	U
Tedizolid	J01XX11	R
Amphotericin B	J02AA01	N/A
Fluconazole	J02AC01	N/A
Itraconazole	J02AC02	N/A
Voriconazole	J02AC03	N/A
Posaconazole	J02AC04	N/A
Isavuconazole	J02AC05	N/A
Flucytosine	J02AX01	N/A
Caspofungin	J02AX04	N/A
Micafungin	J02AX05	N/A
Anidulafungin	J02AX06	N/A

Key - A: Access W: Watch R: Reserve U: Uncategorised

Appendix 4: Key AMC specific variables

	Variables	Mandatory or Optional
	Antimicrobial consumption specific	
1	Site Name /Pharmacy name	Mandatory
2	Date of transaction	Mandatory
3	Antibiotic Name	Mandatory
4	Antibiotic Identification Number	Optional
5	Antibiotic strength	Mandatory
6	Antibiotic Strength Units	Mandatory
7	Form	Mandatory
8	Pack size	Mandatory
10	Brand	Mandatory
11	Quantity Issued IN/OUT	Mandatory
12	Balance (after a transaction is complete)	Mandatory
13	Date of data entry (data capture date by data collectors)	Optional
14	Date of data review (data review date by data manager or regional coordinator)	Optional
15	Recipient facility	Optional
16	Recipient unit	Optional

Appendix 5: Data collection process flowchart



**CENAME: National Centre for the Supply of Drugs and Essential Consumables - Nigeria*

Appendix 6: Description of AMC analysis methodology

Defined Daily Dose (DDD) AMC Analysis:
DDD's were calculated as follows:

$$\text{Number of DDDs} = \frac{\text{Total milligrams used}}{\text{DDD value in milligrams*}}$$

***WHO approved DDDs for antibiotics:**

Where total grams of the antimicrobial used is determined by summing the amount of active ingredient across the various formulations (different strengths of tablets, or capsules, syrup formulations) and pack sizes.

Once AMC is converted to standard DDDs, the data is further analysed into the below standard units: DDDs/1000 inhabitants/day (DID): used to calculate total AMC for the Nigeria population at a national level; includes all age and gender groups and used the known population numbers as the denominator (obtained from the Worldometer Population Database). The below formula summarises how this calculation was done:

The below formula summarizes how this calculation was done:

DDD/1000 Inhabitants/day =

$$\frac{\text{Utilization in DDDs} \times 1000}{(\text{Number of inhabitants*}) \times (\text{Number of days in the period of data collection})}$$

*Nigeria population estimated for 2016-2019 obtained from: https://www.worldometers.info/world-population/Nigeria-population/

DDD equivalent: used to calculate AMC at site level (presented as a percentage) and used WHO DDD as the denominator. The below formulas indicate how this was done:

DDD equivalent (%) =

$$\frac{\text{Total milligrams consumed/purchased} \times 100}{\text{WHO DDD*}}$$

*WHO approved DDDs for antibiotics:

WHO Anatomical Therapeutic Chemical (ATC) classification

Definition of the classification of the medicines in groups at five different levels:

Level 1: Indicates the anatomical main group, it is represented by a letter. For antimicrobials, the main group is 'J', which represented Anti-infectives for systemic use. It should be noted that there are antimicrobials that are classified in other main groups.

Level 2: Indicates the therapeutic subgroups and is represented by a number. For example: J01 groups together Antibacterial for systemic use.

Level 3: Classifies the pharmacological subgroup, e.g., J01C is Beta (β)-lactam antibacterial, Penicillins and J01F lists Macrolides, Lincosamides and Streptogramins

Level 4: Further defines the group by pharmacological subgroup, e.g., J01CA is Penicillins with extended spectrum and J01FA is Macrolides

Level 5: Is the chemical substance, e.g., J01CA01 is ampicillin and J01FA10 s azithromycin

WHO Access, Watch and Reserve (AWaRe) AMC Analysis:

Description of the AWaRe categories below:

Access: This group includes antibiotics that generally have a narrow spectrum of activity against microbes and are active against a wide range of common infections. The Access group represent first and second choice antibiotics for the empiric treatment of most common infectious syndromes. They offer the best therapeutic value, while minimizing the potential for resistance. The distribution of antibiotics in this group includes Beta (β)–lactam (52.63%), followed by aminoglycosides (15.78%), macrolides (5.26%), and tetracyclines (5.26%). 'Access' group compromises of 48 antibiotics; 19 of which are included in the WHO's EML.

Watch: These antibiotics generally have a broader spectrum of activity against microbes and are to be used sparingly as first or second choice treatment options for specified infectious syndromes; they are indicated for specific, limited number of infective syndromes or patient groups. These medicines are also preferred over 'Access' antibiotics in serious infections. β-lactams (54.54%) constitute the larger share of the 'Watch' group antibiotics followed by macrolides (18.18%), aminoglycosides (9.09%), and carbapenems (9.09%). 'Watch' group compromises of 110 antibiotics; 11 of which are included in the WHO's EML. 'Watch' group antibiotics should be prioritised as key targets of stewardship programs and monitoring.

Reserve: Should strictly be considered as the last-resort option. They should be used only in the most severe circumstances when all other alternatives have failed i.e., in life-threatening infections due to multi-drug resistant bacteria. The 'Reserve' group is majorly constituted of polymyxin (28.57%) followed by β-lactams (14.28%) and aminoglycosides (14.28%). 'Reserve' group compromises of 22 antibiotics; 7 of which are included in the WHO's EML. The use of antibiotics in this group should be closely monitored and prioritised as targets for AMS to ensure their continued effectiveness.

Appendix 7: National AMC by Antimicrobial molecules

ATC Class Rank	AWaRe category	Molecule	2016	2017	2018	Mean DDD
			DDD/1000 inhabitant-days (%*)			
J01 Class		Total	3,923,651.77 (100)	3,608,010.16 (100)	3839,752.45 (100)	3,790,471.46
1	Access	Amoxicillin/ Clavulanic Acid	496,856 (12.7)	577,166.98 (16)	538,068.48 (14)	537,363.82
2	Watch	Cefuroxime	488,184.25 (12.4)	505,447.25 (14)	471,337.5 (12.3)	488,323
3	Watch	Ciprofloxacin	316,023.75 (8.1)	487,185.13 (13.5)	486,471.63 (12.7)	429,893.5
4	Access	Amoxicillin	421,614.43 (10.7)	354,071.5 (9.8)	380,048.83 (9.9)	385,244.92
5	Access	Doxycycline	219,478 (5.6)	166,352 (4.6)	728,300 (19)	371,376.67
6	Watch	Ceftriaxone	725,834 (18.5)	185,749.25 (5.1)	85,171 (2.2)	332,251.42
7	Access	Gentamicin	265,024.67 (6.8)	133,197.67 (3.7)	116,279.33 (3)	171,500.56
8	Watch	Erythromycin	78,709.5 (2)	206,739.4 (5.7)	192,793.5 (5)	159,414.13
9	Uncategorized	Ampicillin/Cloxacillin	167,541.25 (4.3)	167,551.85 (4.6)	136,181.2 (3.5)	157,091.43
10	Watch	Levofloxacin	115,940 (3)	181,843 (5)	127,609 (3.3)	141,797.33
11	Watch	Cefixime	130,995.25 (3.3)	128,055.25 (3.5)	93,099 (2.4)	117,383.17
12	Watch	Azithromycin	69,916.67 (1.8)	106,355.33 (2.9)	119,780.42 (3.1)	98,684.14
13	Watch	Ofloxacin	72,123.75 (1.8)	78,971 (2.2)	83,892 (2.2)	78,328.92
14	Access	Metronidazole	67,909.33 (1.7)	49,809.33 (1.4)	51,587.33 (1.3)	56,435.33
15	Access	Sulfamethoxazole/ Trimethoprim	69,395.75 (1.8)	48,073.25 (1.3)	39,091.23 (1)	52,186.74
16	Uncategorized	Ofloxacin/Ornidazole	11,305 (0.3)	67,580 (1.9)	29,814.5 (0.8)	36,233.17
17	Watch	Clarithromycin	47,457 (1.2)	30,784 (0.9)	29,835 (0.8)	36,025.33
18	Access	Tetracycline	21,464.25 (0.5)	25,985 (0.7)	13,913.5 (0.4)	20,454.25
19	Watch	Cefpodoxime proxetil	15,421 (0.4)	22,424.75 (0.6)	23,294.5 (0.6)	20,380.08
20	Uncategorized	Ciprofloxacin/Tinidazole	11,775 (0.3)	14,665 (0.4)	15,760 (0.4)	14,066.67
21	Uncategorized	Cefixime/Clavulanic Acid	13,085 (0.3)	9,098.5 (0.3)	9,410 (0.2)	10,531.17
22	Access	Cefalexin	12,298 (0.3)	3,284.75 (0.1)	5,473.38 (0.1)	7,018.71
23	Access	Clindamycin	6,434.67 (0.2)	7,814.25 (0.2)	5,168.21 (0.1)	6,472.38
24	Watch	Streptomycin	15,283 (0.4)	3,050 (0.1)	970 (0)	6,434.33
25	Watch	Meropenem	3,255.33 (0.1)	4,852.33 (0.1)	5,597.17 (0.1)	4,568.28
26	Watch	Lincomycin	4,299.44 (0.1)	4,363.5 (0.1)	4,251.67 (0.1)	4,304.87
27	Access	Nitrofurantoin	1,320 (0)	1,680 (0)	8,716.5 (0.2)	3,905.5
28	Uncategorized	Azithromycin/Fluconazole/ Secnidazole	3,641 (0.1)	3,257 (0.1)	4,350 (0.1)	3,749.33
29	Access	Ampicillin	4,836.38 (0.1)	2,216.25 (0.1)	3,641.25 (0.1)	3,564.63
30	Access	Chloramphenicol	4,271.25 (0.1)	2,950.83 (0.1)	2,341.67 (0.1)	3,187.92
31	Watch	Sparfloxacin	3,008 (0.1)	2,334 (0.1)	3,784 (0.1)	3,042
32	Access	Phenoxymethylpenicillin	5,357.75 (0.1)	2,823.25 (0.1)	182 (0)	2,787.67
33	Uncategorized	Ampicillin/Flucloxacillin	4,882 (0.1)	1,110 (0)	1,973 (0.1)	2,655
34	Uncategorized	Ceftriaxone/Sulbactam	2,240 (0.1)	2,811.5 (0.1)	2,720.5 (0.1)	2,590.67
35	Uncategorized	Cefuroxime/ Clavulanic Acid	4,775 (0.1)	1,260 (0)	315 (0)	2,116.67

36	Access	Ampicillin/Sulbactam	1,657.17 (0)	2,353.5 (0.1)	2,244.17 (0.1)	2,084.94
37	Watch	Pefloxacin	2,212 (0.1)	2,181 (0.1)	1,858 (0)	2,083.67
38	Watch	Ceftazidime	2,860.94 (0.1)	1,670.25 (0)	1,446.06 (0)	1,992.42
39	Uncategorized	Tinidazole	644.27 (0)	2,292.53 (0.1)	2,939.2 (0.1)	1,958.67
40	Watch	Cefotaxime	2,100.75 (0.1)	1,200.5 (0)	1,877.25 (0)	1,726.17
41	Access	**Cloxacillin**	**3,800 (0.1)**	**0 (0)**	**0 (0)**	**1,266.67**
42	Access	Benzylpenicillin	1,360.83 (0)	1,177 (0)	408.67 (0)	982.17
43	Uncategorized	Levofloxacin/Ornidazole	0 (0)	300 (0)	2,600 (0.1)	966.67
44	Access	**Amikacin**	**1,213.5 (0)**	**1,153.5 (0)**	**252 (0)**	**873**
45	Access	Flucloxacillin	1,307.5 (0)	418.5 (0)	590 (0)	772
46	Uncategorized	Ofloxacin/Tinidazole	0 (0)	2,080 (0.1)	175 (0)	751.67
47	Watch	Moxifloxacin	1,215 (0)	528 (0)	360 (0)	701
48	Uncategorized	Neomycin	1,050 (0)	50 (0)	400 (0)	500
49	Watch	Gemifloxacin	965 (0)	235.34 (0)	226 (0)	475.45
50	Watch	Cefdinir	565 (0)	195 (0)	390 (0)	383.33
51	Uncategorized	Amoxicillin/Flucloxacillin	40 (0)	62.5 (0)	929.5 (0)	344
52	Watch	Vancomycin	309 (0)	434.25 (0)	247 (0)	330.08
53	Access	Procaine benzylpenicillin	60 (0)	324 (0)	573 (0)	319
54	Uncategorized	Ceftriaxone/Tazobactam	15 (0)	30 (0)	576.5 (0)	207.17
55	Watch	Piperacillin/Tazobactam	89.14 (0)	261.43 (0)	203.57 (0)	184.71
56	Watch	Norfloxacin	65 (0)	0 (0)	150 (0)	71.67
57	Watch	Cefepime	118 (0)	12.5 (0)	0 (0)	43.5
58	Reserve	Tigecycline	0 (0)	100 (0)	25 (0)	41.67
59	Access	Cefadroxil	36 (0)	21 (0)	0 (0)	19
60	Watch	Oxytetracycline	0 (0)	0 (0)	20 (0)	6.67
61	Uncategorized	Cefoperazone/Sulbactam	0 (0)	0 (0)	17.5 (0)	5.83
62	Uncategorized	Cefpodoxime proxetil/ Clavulanic Acid	0 (0)	0 (0)	17.5 (0)	5.83
63	Watch	Minocycline	12 (0)	0 (0)	0 (0)	4
64	Access	Cefazolin	0 (0)	8.33 (0)	0 (0)	2.78
65	Access	Spectinomycin	0 (0)	6.67 (0)	0 (0)	2.22
66	Watch	Imipenem/Cilastatin	0 (0)	1.25 (0)	3.75 (0)	1.67
67	Access	Benzathine benzylpenicillin	0 (0)	0 (0)	0.5 (0)	0.17
J02 Class		Total	30,388.63 (100)	25,058.88 (100)	23,128.88 (100)	26,192.12
1	Uncategorized	Fluconazole	9,411.63 (31)	7,619.88 (30.4)	13,843.88 (59.9)	10,291.79
2	Uncategorized	Ketoconazole	18,050 (59.4)	9,850 (39.3)	1,380 (6)	9,760
3	Uncategorized	Itraconazole	2,927 (9.6)	7,561 (30.2)	7,835 (33.9)	6,107.67
4	Uncategorized	Voriconazole	0 (0)	28 (0.1)	70 (0.3)	32.67
P01AB Class		Total	553,177.3 (100)	813,281 (100)	621,511.6 (100)	662,656.63
1	Access	Metronidazole	547,969.1 (99.1)	806,528.8 (99.2)	613,501.2 (98.7)	655,999.7
2	Uncategorized	Tinidazole	3,428.5 (0.6)	6,025.5 (0.7)	7,340.5 (1.2)	5,598.17
3	Uncategorized	Secnidazole	1,779.7 (0.3)	726.7 (0.1)	669.9 (0.1)	1,058.77

**Antibiotics marked as 'uncategorised' have not been awarded a category within the 2019 WHO AWaRe database*

Appendix 8: Breakdown of national AMC by ATC classes

	% consumption		
ATC class	2016	2017	2018
Tetracyclines	5.3%	4.3%	16.6%
Fluoroquinolones	11.3%	16.9%	15.7%
Combinations of penicillins, incl. Beta-lactamase inhibitors	14.9%	16.8%	15.2%
Nitroimidazole derivatives	12.2%	18.3%	13.8%
Second-generation cephalosporins	10.9%	11.4%	10.5%
Penicillins with extended spectrum	9.5%	8.0%	8.6%
Macrolides	4.4%	7.7%	7.6%
Third-generation cephalosporins	19.8%	7.9%	4.9%
Aminoglycosides	6.2%	3.1%	2.6%
Imidazole derivatives	1.9%	1.4%	1.2%
Combinations of antibacterials	0.6%	2.0%	1.2%
Combinations of sulfonamides and trimethoprim, incl. derivatives	1.5%	1.1%	0.9%
Triazole derivatives	0.3%	0.3%	0.5%
Lincosamides	0.2%	0.3%	0.2%
Nitrofuran derivatives	<0.1%	<0.1%	0.2%
Carbapenems	0.1%	0.1%	0.1%
First-generation cephalosporins	0.3%	0.1%	0.1%
Amphenicols	0.1%	0.1%	0.1%
Beta-lactamase sensitive penicillins	0.2%	0.1%	<0.1%
Beta-lactamase resistant penicillins	0.1%	<0.1%	<0.1%
Other aminoglycosides	<0.1%	<0.1%	<0.1%
Glycopeptides	<0.1%	<0.1%	<0.1%
Fourth-generation cephalosporins	<0.1%	<0.1%	<0.1%
Other antibacterials	<0.1%	<0.1%	<0.1%

Appendix 9: Breakdown of antibiotic documented and their inclusion in the WHO EML and National EML

Standardised Molecule Name	WHO AWaRe Categorisation	WHO ATC Code	WHO EML	National EML	Documented Data
Amikacin	Access	J01GB06	Y	N	Y
Amoxicillin	Access	J01CA04	Y	Y	Y
Amoxicillin/Clavulanic Acid	Access	J01CR02	Y	Y	Y
Amoxicillin/Flucloxacillin		J01CR50	N	N	Y
Amphotericin-B		J02AA01	N	Y	N
Ampicillin	Access	J01CA01	Y	N	Y
Ampicillin/Cloxacillin		J01CR50	N	N	Y
Ampicillin/Flucloxacillin		J01CR50	N	N	Y
Ampicillin/Sulbactam	Access	J01CR01	N	N	Y
Azithromycin	Watch	J01FA10	Y	Y	Y
Azithromycin/Fluconazole/ Secnidazole		J01RA07	N	N	Y
Benzathine benzylpenicillin	Access	J01CE08	Y	Y	Y
Benzylpenicillin	Access	J01CE01	Y	Y	Y
Cefadroxil	Access	J01DB05	N	N	Y
Cefalexin	Access	J01DB01	Y	N	Y
Cefazolin	Access	J01DB04	Y	N	Y
Cefdinir	Watch	J01DD15	N	N	Y
Cefepime	Watch	J01DE01	N	N	Y
Cefiderocol	Reserve	J01DI04	Y	N	N
Cefixime	Watch	J01DD08	Y	N	Y
Cefixime/Clavulanic Acid		J01DD--	N	N	Y
Cefoperazone/Sulbactam		J01DD62	N	N	Y
Cefotaxime	Watch	J01DD01	Y	N	Y
Cefpodoxime proxetil	Watch	J01DD13	N	N	Y
Cefpodoxime proxetil/ Clavulanic Acid		J01DD64	N	N	Y
Ceftazidime	Watch	J01DD02	Y	N	Y
Ceftazidime/avibactam	Reserve	J01DD52	Y	N	N
Ceftriaxone	Watch	J01DD04	Y	Y	Y
Ceftriaxone/Sulbactam		J01DD63	N	N	Y
Ceftriaxone/Tazobactam		J01DD63	N	N	Y
Cefuroxime	Watch	J01DC02	Y	Y	Y
Cefuroxime/Clavulanic Acid		J01DC--	N	N	Y
Chloramphenicol	Access	J01BA01	Y	N	Y
Ciprofloxacin	Watch	J01MA02	Y	Y	Y
Ciprofloxacin/Tinidazole		J01RA11	N	N	Y
Clarithromycin	Watch	J01FA09	Y	Y	Y
Clindamycin	Access	J01FF01	Y	Y	Y
Cloxacillin	Access	J01CF02	Y	Y	Y
Colistin	Reserve	J01XB01	Y	N	N
Doxycycline	Access	J01AA02	Y	Y	Y

Erythromycin	Watch	J01FA01	N	Y	Y
Flucloxacillin	Access	J01CF05	N	Y	Y
Fluconazole		J02AC01	N	Y	Y
Fosfomycin (IV)	Reserve	J01XX01	Y	N	N
Gemifloxacin	Watch	J01MA15	N	N	Y
Gentamicin	Access	J01GB03	Y	Y	Y
Imipenem/Cilastatin	Watch	J01DH51	N	N	Y
Itraconazole		J02AC02	N	N	Y
Ketoconazole		J02AB02	N	N	Y
Levofloxacin	Watch	J01MA12	N	Y	Y
Levofloxacin/Ornidazole		J01RA05	N	N	Y
Lincomycin	Watch	J01FF02	N	N	Y
Linezolid	Reserve	J01XX08	Y	N	N
Meropenem	Watch	J01DH02	Y	N	Y
Meropenem/vaborbactam	Reserve	J01DH52	Y	N	N
Metronidazole	Access	P01AB01, J01XD01	Y	Y	Y
Minocycline	Watch	J01AA08	N	N	Y
Moxifloxacin	Watch	J01MA14	N	N	Y
Nitrofurantoin	Access	J01XE01	Y	Y	Y
Norfloxacin	Watch	J01MA06	N	N	Y
Ofloxacin	Watch	J01MA01	N	N	Y
Ofloxacin/Ornidazole		J01RA09	N	N	Y
Ofloxacin/Tinidazole		J01RA--	N	N	Y
Oxytetracycline	Watch	J01AA06	N	N	Y
Pefloxacin	Watch	J01MA03	N	N	Y
Phenoxymethylpenicillin	Access	J01CE02	Y	Y	Y
Piperacillin/Tazobactam	Watch	J01CR05	Y	N	Y
Plazomicin	Reserve	J01GB14	Y	N	N
Polymyxin-B	Reserve	J01XB02	Y	N	N
Procaine benzylpenicillin	Access	J01CE09	Y	N	Y
Secnidazole		P01AB07	N	N	Y
Sparfloxacin	Watch	J01MA09	N	N	Y
Spectinomycin	Access	J01XX04	Y	N	Y
Streptomycin	Watch	J01GA01	N	N	Y
Sulfamethoxazole/ Trimethoprim	Access	J01EE01	Y	Y	Y
Tetracycline	Access	J01AA07	N	Y	Y
Tigecycline	Reserve	J01AA12	N	N	Y
Tinidazole		P01AB02	N	Y	Y
Trimethoprim	Access	J01EA01	Y	N	N
Vancomycin	Watch	J01XA01	Y	Y	Y
Voriconazole		J02AC03	N	N	Y

Appendix 10: AMC data collection and expired drug and losses tool

AMC Data Collection Tool

Product Name
Pack Size_Value
Pack Size_Unit
Strength Num_Value
Strength Num_Unit
Strength Denom_Value
Strength Denom_Unit
ATC5
Combi-nation
Route
Salt
Volume

Expired Drug and Losses Tool

Country
Pharmacy Name
Date of Transaction
Antibiotic Name
Strength Value
Strength Unit
Form
Pack Size
Brand
Quantity

MAAP
Mapping AMR & AMU Partnership

The Fleming Fund
Regional Grants

UKaid
from the British people

African Union

AFRICA CDC
Centres for Disease Control and Prevention
Safeguarding Africa's Health

ASLM
AFRICAN SOCIETY FOR LABORATORY MEDICINE

CEDERO
ECOWAS

InSTEDD
Innovative Support To Emergencies Diseases and Disasters

IQVIA

ONEHEALTH
TRUST