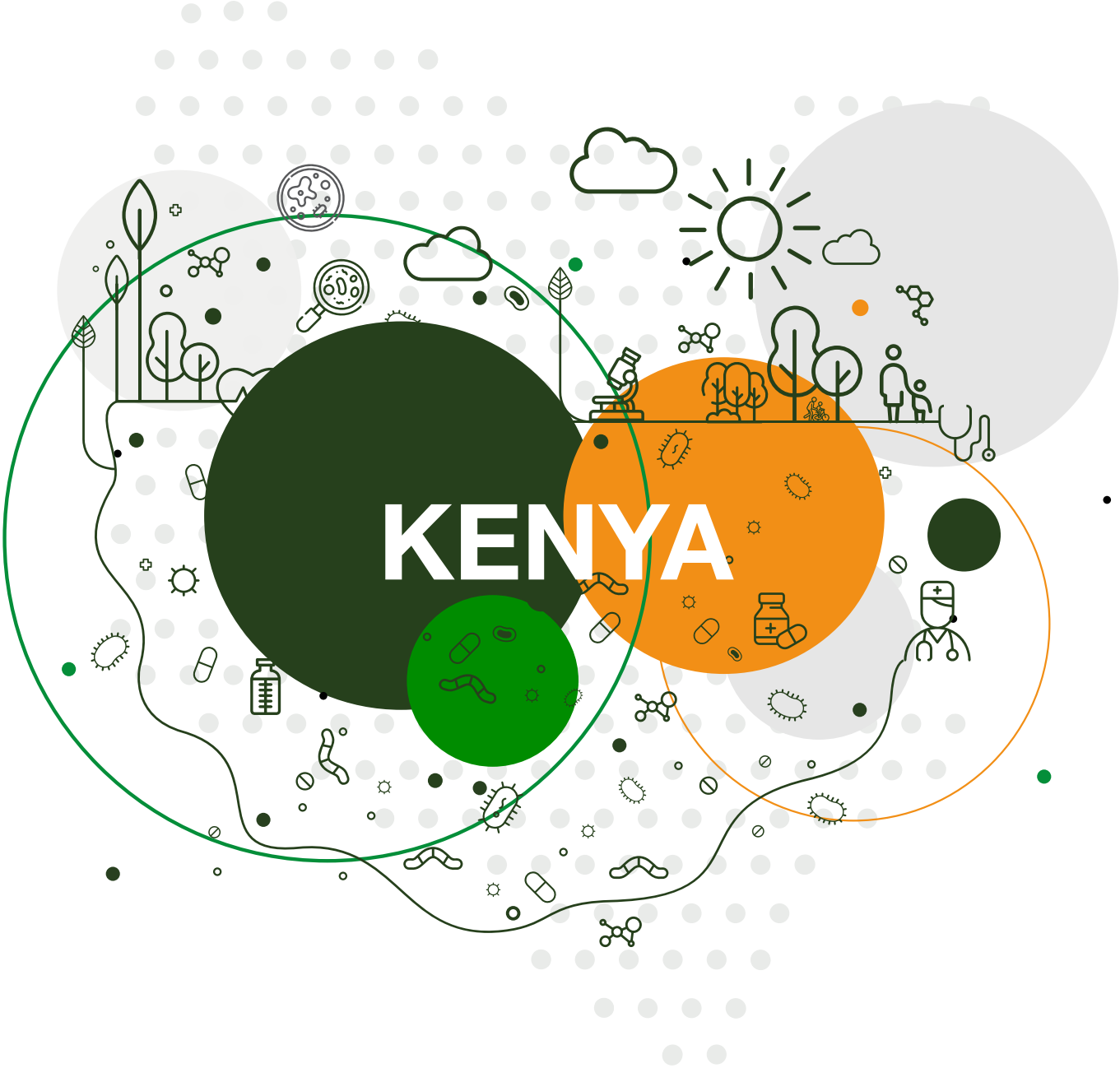
MAAP
Mapping AMR & AMU Partnership

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
EACSA
InSTEDD Innovative Support To Emergencies Diseases and Disasters
IQVIA
ONEHEALTH TRUST

Year: 2022

Kenya (2016-2018)

KENYA

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

ACDC	Africa Centres for Disease Control
AMC	Antimicrobial Consumption
AMR	Antimicrobial Resistance
AMRCC	Antimicrobial Resistance Coordinating Committee
AMU	Antimicrobial Use
ASLM	African Society for Laboratory Medicine
ASP	Antimicrobial Stewardship Programme
AST	Antibiotic Susceptibility Testing
ATC	Anatomical Therapeutic Chemical
AWaRe	Access, Watch, and Reserve
CAPTURA	Capturing Data on AMR Patterns and Trends in Use in Regions of Asia
CASFM	Comité de l'antibiogramme de la Société Française de Microbiologie
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
GAP	Global Action Plan
GHSI	Global Health Security
GLASS	Global Antimicrobial Resistance Surveillance System
GDP	Gross Domestic Product
HICC	Hospital Infection Control Committee
HIS	Hospital Information System
InSTEDD	Innovative Support to Emergencies, Diseases and Disasters
KIIs	Key Informant Interviews
KMSA	Kenya Medical Supplies Authority
LIS	Laboratory Information System
LMIC	Low- or Middle-Income Country
LQMS	Laboratory Quality Management System
MAAP	Mapping Antimicrobial resistance and Antimicrobial use Partnership
MEDS	Mission for Essential Drugs and Supplies
MoH	Ministry of Health
MRSA	Methicillin-resistant Staphylococcus aureus
MRSA	Methicillin-resistant Staphylococcus aureus
MTC	Medical Therapeutics Committee
NAP	National Action Plan
NCD	NNon-communicable disease(s)
NGO	Non-Governmental Organisation
OR	Odds Ratio
PPB	Pharmacy and Poisons Board
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
WHA	World Health Assembly
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, comprehensive and robust AMR, antimicrobial use (AMU), and antimicrobial consumption (AMC) data is lacking in many low- and middle- income countries (LMICs), 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 the MAAP consortium to implement the Regional Grant and aims to determine national AMR, AMC and AMU surveillance capacity, rates and trends and to assess the antimicrobial flow in Kenya during 2016-2018.

Kenya had approximately 1 037 laboratories in the national laboratory network during the study period, of which 64 reported capacity for bacteriology testing. Self-reports for functioning and quality compliance from 56 laboratories were assessed to determine AMR surveillance preparedness.

The reported AMR rates are based on the analysis of antimicrobial susceptibility results 0f 16 027 positive cultures obtained from 16 laboratories. High levels of resistance were noted for third-generation cephalosporins in the Enterobacterales (67-73%), carbapenem in Pseudomonas aeruginosa (36-51%) and methicillin in Staphylococcus aureus (40-52%). Antimicrobial-resistant infections were found to be more common in males and the elderly. All results should be interpreted cautiously because the participating laboratories were at different service levels and thus had varying testing capacities.

AMC is measured as the number 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 retrieved, but AMU data were not obtained due to the lack of a unique patient identifier and tracking systems across hospital departments. The average national total AMC consumption levels in Kenya between 2016-2018 were 8.8 defined daily doses (DDD) per 1 000 inhabitants per day (DID), ranging from 11 in 2016, 7.4 in 2017 and 8.1 in 2018. Antimicrobial utilisation by the World Health Organisation (WHO) Anatomical Therapeutic Chemical (ATC) classification was highest for penicillins with extended-spectrum (range 21.2% to 29.9%), followed by combinations of penicillins and beta-lactamase inhibitors (range 9.7% to 16.2%) and by combinations of sulfonamides and trimethoprim, including derivatives (range 7.7% to 16.4%).

The top five most consumed antimicrobials were amoxicillin, sulfamethoxazole/trimethoprim, ampicillin/cloxacillin, erythromycin and doxycycline. Together they accounted for > 58% of the total consumption share, suggesting a lack of variation. This consumption trend could potentially increase AMR. The AMC included antimicrobials from the 'Access' 70.4%, 'Watch' 29.6%, and 'Reserve' <0.1% categories. Between 2016-2018, the use of 'Access' category antibiotics exceeded the WHO minimum recommended consumption threshold of 60%. Nine combinations of two or more broad-spectrum fixed-dose combinations of antimicrobials were identified that were not recommended for clinical utility but were nevertheless consumed in Kenya. Of these FDCs, ampicillin/cloxacillin was most commonly consumed (mean DID of 0.7).

Drug resistance index (DRI) is a simple metric based on aggregate rates of resistance measured on a scale of 0-100, where 0 indicates fully susceptible while 100 indicates fully resistant. The DRI estimate was found to be moderately high at 56.2% (95% CI, 42.1–70.3%), implying low antibiotic effectiveness that threatens the effective management of infectious disease and calls for urgent policy intervention. The DRI estimate of Kenya suggests the need for inter-departmental collaborations, increased community awareness and improved stewardship practices to control AMR.

Policymakers and healthcare providers should note the following recommendations to strengthen AMR and AMC surveillance further to mitigate AMR in Kenya.

- 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 mapping exposes unmet needs and informs the laboratory network expansion plan
- Staff training on laboratory standards, common pathogens identification, and data management skills are essential for high-quality microbiology testing and reporting. Staff capacity building may be achieved by leveraging in-house expertise or outsourcing to external organisations or tertiary facilities
- Curating the correct data and generating evidence is essential to strengthening AMR surveillance. We recommend data collection through standardised formats at all levels (laboratories, clinics and pharmacies) and data analysis automation. We also recommend establishing a system of assigning permanent identification numbers for tracking patients
- Due to the limited number of facilities assessed, the MAAP consortium, per the WHO facility AMU assessment guide, recommends that future AMU and AMC surveillance attempts in the country be conducted through large-scale point prevalence surveys to give a nationally representative portrait of antimicrobials use in Kenya
- The consortium recommends that a comprehensive routine AMC data surveillance policy be developed. The policy should, at the minimum, stipulate AMC data reporting variables and routine data cleaning and reporting practices to minimise the time spent standardising and cleaning data before routine surveillance exercises
- To make future AMC surveillance more time and cost-efficient. Hospitals could consider switching to electronic systems and ensure such systems have capabilities to transfer data across systems and or produce user-friendly reports on AMC
- The consortium recommends that the country's Antimicrobial Resistance Coordinating Committee (AMRCC) consider introducing facility-level Antimicrobial Stewardship Programmes (ASPs) to regulate the use of broader spectrum antibiotics and educate prescribers on the importance of reserving these to maintain efficacy
- From the assessment, the top five antibiotics consumed within the 'Access' and 'Watch' categories were the majority of antibiotics consumed in each category. Such a consumption pattern could be postulated to be sub-optimal as evolutionary pressure driving resistance would be focused only on the narrow-band antibiotics consumed. The consortium, therefore, recommends that the country's ASP explores ways to ensure a wider spread in the consumption of antibiotics within each WHO Access, Watch, and Reserve (AWaRe) category
- The consortium recommends that an urgent survey be conducted by the Ministry of Health (MoH) and AMRCC to assess the availability of the 'Reserve' category antibiotics in the country. This survey may inform the subsequent review of the country's essential medicines list (EML) and treatment guidelines to include these vital antibiotics, if 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 to inform healthcare practitioners of the full spectrum of antimicrobials available in the county's EML

Overview

The Fleming Fund Grants Programme

The Fleming Fund Grants Programme, a United-Kingdom-sponsored initiative, aims to address the critical gaps in AMR surveillance in LMICs of Asia and sub-Saharan Africa.[1] The Programme includes Regional Grants, Country Grants, and the Fleming Fellowship Scheme. Mott MacDonald was the grant management firm.

The Fleming Fund Regional Grants Round 1 Programme

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

Problem statement

The quantum and quality of surveillance data are suboptimal in LMICs where AMR rates are typically lacking.[2] This data paucity hinders the assessment of the treatment efficacy and understanding of the drivers of resistance. It also impacts the adoption of appropriate policies to improve antimicrobial use, which impacts patient care. However, in most LMICs, some institutions (academic, research, public and private health facilities) have been collecting AMR data 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 assess 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 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 the spatiotemporal mapping of AMR and AMU across countries in each region and establish baselines. The programme was implemented by the 'Mapping Antimicrobial resistance and Antimicrobial use Partnership' (MAAP), a multi-organisational consortium of strategic and technical partners. The African Society for Laboratory Medicine (ASLM) was the lead grantee for the programme[3].

The MAAP's strategic partners included the ASLM, the Africa Centres for Disease Control and Prevention (ACDC), West African Health Organisation and 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). The ASLM oversaw the consortium's activities, ensured the fulfilment of ethical processes and completed the data-sharing agreements with the participating countries.

The MAAP collected and analysed each country's historical antimicrobial susceptibility, consumption and usage data for 2016-2018 to understand the regional AMR landscape. The MAAP's primary focus was to determine the resistance levels of the WHO-priority bacterial pathogens and other clinically important pathogens. The MAAP gathered, digitised, and collated the available AMR and AMC data between 2016 and 2018 using standardised data collection and analytical tools. The MAAP collected AMC information only instead of both AMU and AMC, based on collection feasibility.

The results of this analysis contribute to determining AMR and AMC baselines and trends, AMR drivers, and critical surveillance gaps. The study recommendations aim to increase the country's capacity for future AMR, AMC and AMU data collection, analysis and reporting.

Fourteen African countries across Western (Burkina Faso, Ghana, Nigeria, Senegal and Sierra Leone), Eastern (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 Kenya 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 Kenya, 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 and 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 AMC and AMU surveillance system status
- To quantify and evaluate the trends of AMC and AMU at the national-and pharmacy-level
- To assess the relationship between AMC and AMR through the DRI
- To assess the AMR drivers

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 in-country analysis of the current AMC and AMU surveillance status
- Total consumption of antimicrobials (defined daily dose), plus 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, highlight gaps and recommend measures for surveillance strengthening.

Key engagements and activities

The Regional Grants Round 1 engagement commenced with a kick-off meeting with the representatives from Mott MacDonald (Grant Managers), the MAAP consortium (for Africa Region) and the Capturing Data on AMR Patterns and Trends in Use in Regions of Asia (CAPTURA) consortium (for Asia Region). The meeting was held in Brighton, England, in February 2019. In April 2019, the MAAP convened a stakeholder consultation in Addis Ababa, Ethiopia, with representatives from the 14 participating African countries 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 the consortium and the countries, including representatives from the MoH, AMR coordinating committees, health facilities, laboratories, and pharmacies. These workshops were followed by site selection and data collection in each country. The technical partners analysed the data analysis, and the final results were shared at dissemination meetings (Figure 1).

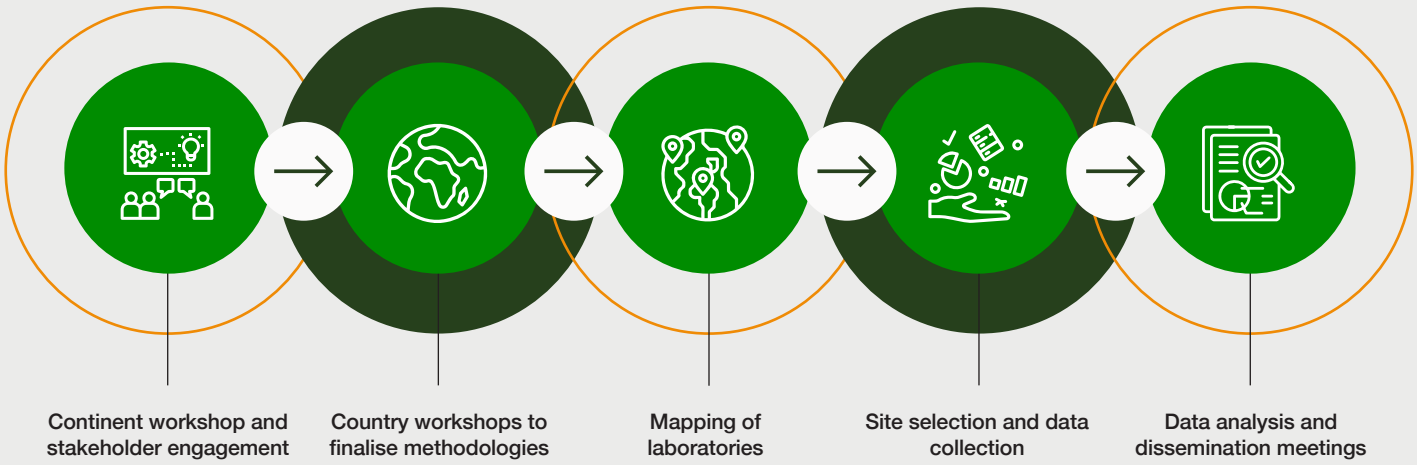


Figure 1: Key engagements and activities

Ethical issues and data sharing agreements

To ensure ethical conduct, confidentiality, regulated use and ownership of the data, a data-sharing agreement (DSA) was signed with the Ministry of Health and adhered to during the project. The DSA facilitated clear communication and established additional safeguards for managing the collected data (see AMR Appendix 1).

Country Profile

Health and demographic profile

As of 2020, Kenya had an estimated population of 53.8 million inhabitants with a life expectancy of 67 years. The country has a high infectious disease burden, with a TB incidence of 259 per 100 000 and an HIV prevalence of 4.2%. The country has a physician density rate of 0.16 per 1 000 inhabitants and a nurse density rate of 1.17 per 1 000 inhabitants. With a universal health coverage index of 56, Kenya appears to have an average coverage of essential medical services (Table 1).

Table 1: Health and demographic profile of Kenya

Characteristic	Kenya		Comparator values (most recent year)*		
	Year	Value	India	Argentina	United States
Population	2020	53 771 300	1 380 004 390	45 376 763	329 484 123
Life expectancy during the study period, total (years)	2020	67	70	77	79
Universal health coverage service index (0-100)	2019	56	61	67	83
GDP per capita (US dollars [$])	2020	1 878.6	1 927.7	8 579.0	63 593.4
Immunisation, DPT (% of children; ages 12-23 months)	2019	92.0	91.0	86.0	94.0
Incidence of tuberculosis (per 100 000 people)	2020	259.0	188.0	31.0	2.4
Prevalence of HIV, total (% of population; ages 15-49)#	2020	4.2	0.2*	0.4 2020	0.4 2019
Primary education (%)#	2016	99.7	94.6	98.6	100
Physician density (physicians per 1 000)#	2018	0.16	0.93	4.0	2.6
Nurse density (nurses and midwives per 1 000)#	2018	1.17	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 (sourced from the most recently available information between 2017-2020). GDP=Gross domestic product; DPT=Diphtheria, Pertussis and Tetanus

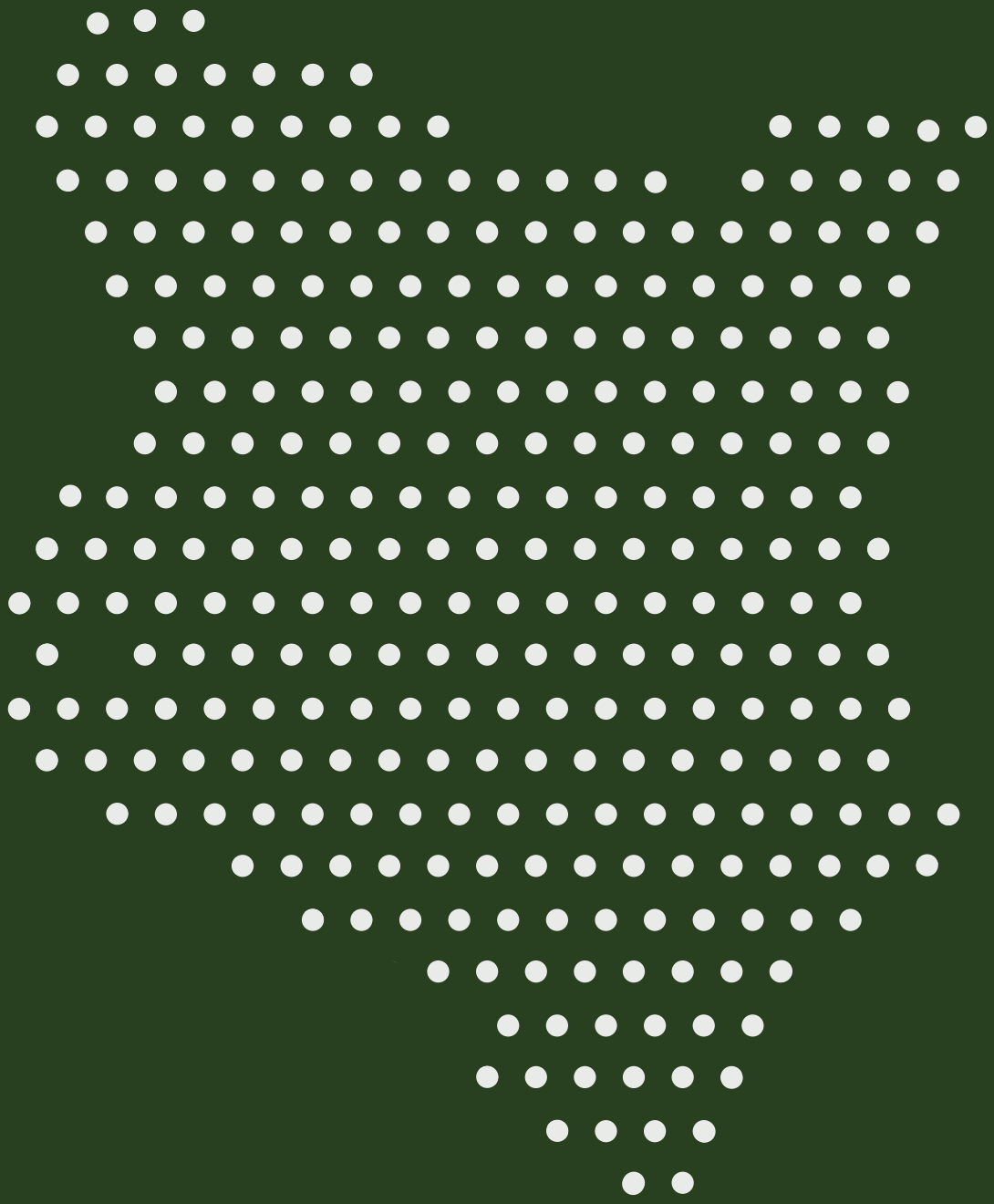
Abbreviations: GDP=gross domestic product

Policy frameworks

In May 2015, the World Health Assembly (WHA) 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] The GLASS provides standardised AMR data collection and analysis methodologies and encourages countries to share their data on the global surveillance platform. The GLASS has various modules and tools covering emerging AMR and AMC events and promotes the integration of AMR surveillance in the animal and environment sectors.

Kenya enrolled in the GLASS in May 2016[10] and has five surveillance sites in its national AMR surveillance system. However, Kenya has not submitted AMR data to GLASS as of the end of 2020.[11–13] Kenya has a National Policy on Prevention and Containment of Antimicrobial Resistance. [14] The policy aims to reduce the burden of AMR and promote the prudent use of antimicrobial agents to ensure that, for as long as possible, successful treatment and prevention of microbial diseases with effective, quality-assured, safe and accessible antimicrobials per the WHO GAP-AMR. Additionally, Kenya has a system for reporting AMR data to national authorities.

Part A: Antimicrobial Resistance



Section I: Laboratory assessment

Objective

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

Methodology

Initially, up to 16 laboratories (two reference, four private and ten public laboratories) were 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 questionnaire was administered to the identified laboratories to obtain site-specific details and assess 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 MoH and was not necessarily based on laboratory rankings.

Results

Mapping and selection of laboratories

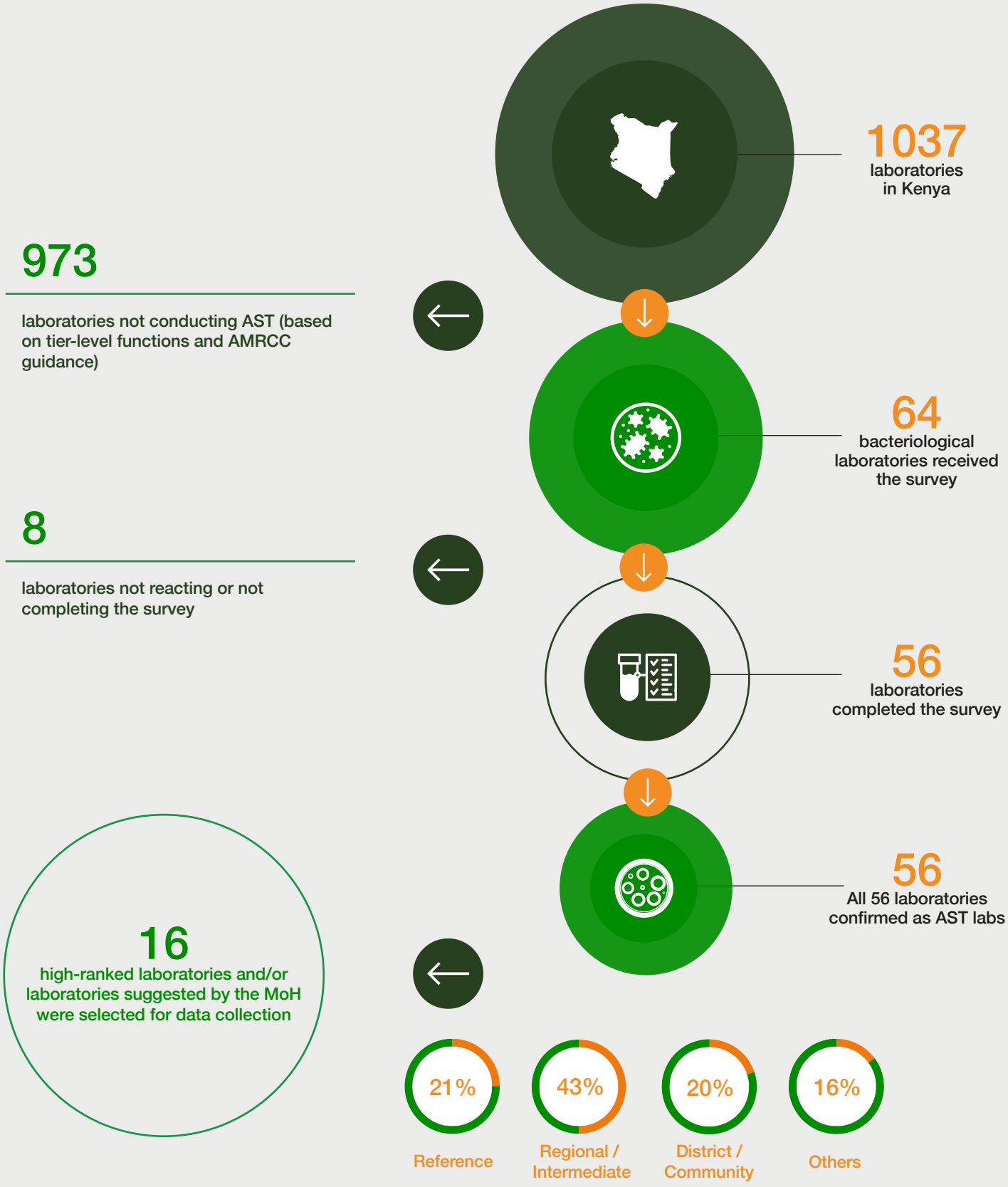
During the initial stages of in-country work in Kenya, 1 037 laboratories were mapped to the national laboratory network. An eligibility questionnaire was sent to 64 laboratories identified as having bacteriology testing capacity. Most of the 56 laboratories that responded to the questionnaire were affiliated with the government (Table 2, AMR Supplementary Table 1). The laboratory readiness scores of the surveyed laboratories varied widely (21.1–81.6%). Sixteen 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 of the 56 laboratories with bacteriology testing capacity in Kenya

Surveyed laboratories*	Laboratory readiness score (%)	Level of service	Affiliation
Selected			
Kisii Teaching and Referral Hospital Lab (Kisii)	81.6	Reference	Public
Mater Misericordia Hospital Laboratory (Mater)	78.9	Regional/ Intermediate	Private
Kitale Regional Public Health Laboratory (Kitale)	76.3	Reference	Public
Kenyatta National Hospital Microbiology Lab (Kenyatta)	76.3	Reference	Public
Bungoma County Referral Hospital Laboratory (Bungoma)	71.1	Reference	Public
Busia Regional/County Referral Hospital (Busia)	71.1	Regional/ Intermediate	Public
Nyeri County Hospital Referral Laboratory (Nyeri)	68.4	Reference	Public
Moi County Referral Hospital Laboratory (Moi County)	68.4	Regional/ Intermediate	Public
Wajir Regional Referral (Wajir)	68.4	Reference	Public
Moi Teaching and Referral Hospital Laboratory (Moi Teaching)	65.8	Reference	Private
MP Shah Laboratory (MP Shah)	65.8	Reference	Public
Thika Level 5 (Thika)	63.2	Regional/ Intermediate	Public
Coptic Hospital Laboratory (Coptic)	63.2	Reference	Other
Machakos Level 5 Referral Laboratory (Machakos)	63.2	Reference	Public
Meru Level 5 (Meru)	52.6	Reference	Public
Kilifi County Hospital Lab (Kilifi)	50	Regional/ Intermediate	Public

Not selected			
Aga Khan University Hospital	78.9	Other	Other
Malindi Sub County Hospital Laboratory	71.1	District/Community	Public
Kakamega County General Hospital Laboratory	65.8	Other	Public
The Amref Central Laboratory	65.8	Other	NGO
Webuye County Hospital Laboratory	65.8	Regional/Intermediate	Public
Kitui county referral hospital	63.2	Regional/Intermediate	Public
Kwale Sub County Hospital Laboratory	63.2	District/Community	Public
Naivasha Sub-County Laboratory	63.2	District/Community	Public
Maseno Mission Hospital Laboratory	63.2	District/Community	Other
Coast General Teaching and Referral Hospital	60.5	Regional/Intermediate	Public
Kisumu County Referral Hospital	60.5	Regional/Intermediate	Public
Jaramogi Oginga Odinga Teaching and Referral Hospital Laboratory	60.5	Regional/Intermediate	Public
Lodwar County and Referrer Hospital Laboratory	60.5	Regional/Intermediate	Public
Pcea Kikuyu Hospital Lab	60.5	Other	Other
Rift Valley Provincial General Hospital Laboratory	60.5	Regional/Intermediate	Public
Kericho County Referral Hospital Laboratory	57.9	Reference	Public
Kinango Sub-County Hospital Laboratory	57.9	District/Community	Public
Baringo County Referral Hospital Laboratory	57.9	Regional/Intermediate	Public
Embu level 5 Hospital laboratory	55.3	Regional/Intermediate	Public
Nanyuki Teaching and Referral Hospital Laboratory	55.3	Regional/Intermediate	Public
Nanyuki Cottage Hospital	55.3	Other	NGO
Lolondiani Subcounty Hospital Laboratory	52.6	District/Community	Public
Narok County Referral Hospital	52.6	Regional/Intermediate	Public
Longisa County Hospital Laboratory	52.6	Regional/Intermediate	Public
Butere County Hospital	50	District/Community	Public
J.M.Kariuki Memorial County Referral Hospital, Olkalou	50	Regional/Intermediate	Public
Taveta Sub-County Hospital Laboratory	50	District/Community	Public
Consolata Nkubu Hospital Laboratory	50	Other	Other
Muranga Level 5 Hospital	50	Regional/Intermediate	Public
Makueni County Referral Hospital Laboratory	47.4	Regional/Intermediate	Public
Gatundu L5 Hospital Laboratory	47.4	District/Community	Public
Msambweni County Referral Hospital Laboratory	44.7	Regional/Intermediate	Public
Miathene Sub-County Hospital	42.1	District/Community	Public
Catholic Hospital Wamba	42.1	Other	Private
Mbagathi Hospital Laboratory	39.5	Regional/Intermediate	Public
Maua Methodist Hospital	36.8	Other	Other
Outspan Hospital	36.8	Other	Private
Siaya County Referral Hospital Laboratory	31.6	Regional/Intermediate	Public
Kapkatet Hospital Laboratory	26.3	District/Community	Public
County Referral Hospital Chuka	21.1	Regional/Intermediate	Public

** Laboratory names are abbreviated.*



Abbreviations: AST=antibiotic susceptibility testing; AMRCC=antimicrobial resistance coordinating committee; MoH=Ministry of Health

Figure 2: Selection of laboratories in Kenya

Surveillance preparedness of surveyed laboratories

Based on self-reported information from 56 laboratories, laboratory function and quality compliance were assessed to understand their preparedness for AMR surveillance. Fifty laboratories had implemented QMS, and 28 laboratories had at least one qualified microbiologist on board. However, few laboratories were accredited (n=18) or used automated systems for pathogen identification (n=14) (Figure 3, AMR Supplementary Table 2). Since these findings may affect the laboratory data quality, the AMR rates presented in this report should be cautiously interpreted.

	Parameters			N (%)
Commodity and equipment status	Regular power supply and functional back up			54 (96.4)
	Continuous water supply			54 (96.4)
	Certified and functional biosafety cabinets			52 (92.9)
	Automated methods for pathogen identification			14 (25.0)
	Automated methods for AST			12 (21.4)
	Methods for testing AMR mechanisms			12 (21.4)
QMS implementation	Reported QMS Implementation			50 (89.3)
		Types of QMS	LQMS	2 (4.0)
			SLIPTA	21 (42.0)
			SLMTA	6 (12.0)
			Mentoring	0
			Combination‡	14 (28.0)
			Others	5 (10.0)
	Quality Certification			33 (58.9)
		Types of Quality certification	SLIPTA	16 (48.5)
			Col. of Am. Path	0
			Others	16 (48.5)
	Accreditation			18 (32.1)
	Participation in proficiency testing			29 (51.8)
	Utilisation of reference strains			32 (57.1)
	Reported consistent maintenance of QC records			37 (66.1)
	Designated focal quality person			52 (92.9)
	Reported compliance to standard operating procedures			53 (94.6)
	Reported compliance to AST standards			36 (64.3)
Personnel and training status	Presence of at least one qualified microbiologist			28 (50.0)
	Presence of an experienced laboratory scientist/technologist			49 (87.5)
	Up-to-date and complete records on staff training and competence			37 (66.1)
Specimen Management status	Reported compliance to SOPs on specimen collection and testing			54 (96.4)
	Reported compliance to SOPs on specimen rejection			54 (96.4)
	Average number of specimens processed for AST in 2018			54 (96.4)
LIS and Linkage to Clinical Data	Assigned specimen (laboratory) identification number			53 (94.6)
	Availability of system/database to store patient data			51 (91.1)
		Database format	Paper-based	26 (51.0)
			Electronic	10 (19.6)
			Mixed	15 (29.4)
	Captured patients' records on test request forms			51 (91.1)
			Retrievable	23 (45.1)

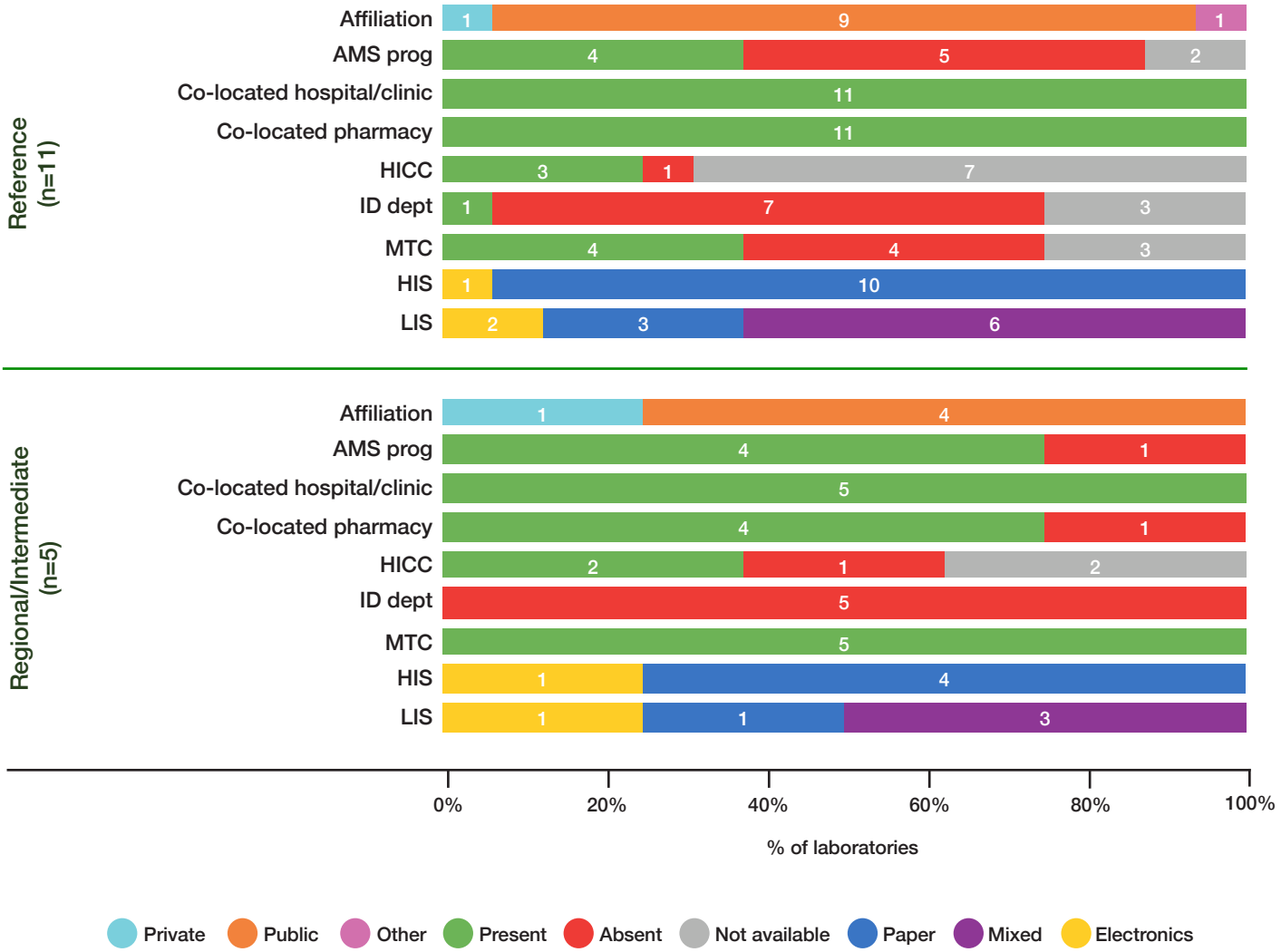
‡ Combination refers to more than one option presented in the questionnaire (laboratory quality management system (LQMS), stepwise laboratory improvement process towards accreditation (SLIPTA), strengthening laboratory management towards accreditation (SLMTA), and mentoring).

Abbreviations: AMR=antimicrobial resistance; AST=antibiotic susceptibility testing; LIS=laboratory information system; LQMS=laboratory quality management system; QMS=quality management system; QC=quality control; QMS=quality management system; SOP=standard operating procedure; Col. Of Am. Path.= College of American Pathologists

Figure 3: Laboratory preparedness for AMR surveillance assessment of the 56 selected laboratories with bacteriology testing capacity in Kenya

Profile of Selected Laboratories

All 16 selected laboratories were co-located with clinical facilities. Only one clinical facility had an infectious disease department, and only seven had ASP. The presence of medical therapeutic committees (MTC) and hospital infection control committees (HICC) varied (Figure 4). Nine laboratories had mixed (paper and electronic) LIS, but most hospitals used paper-based systems.



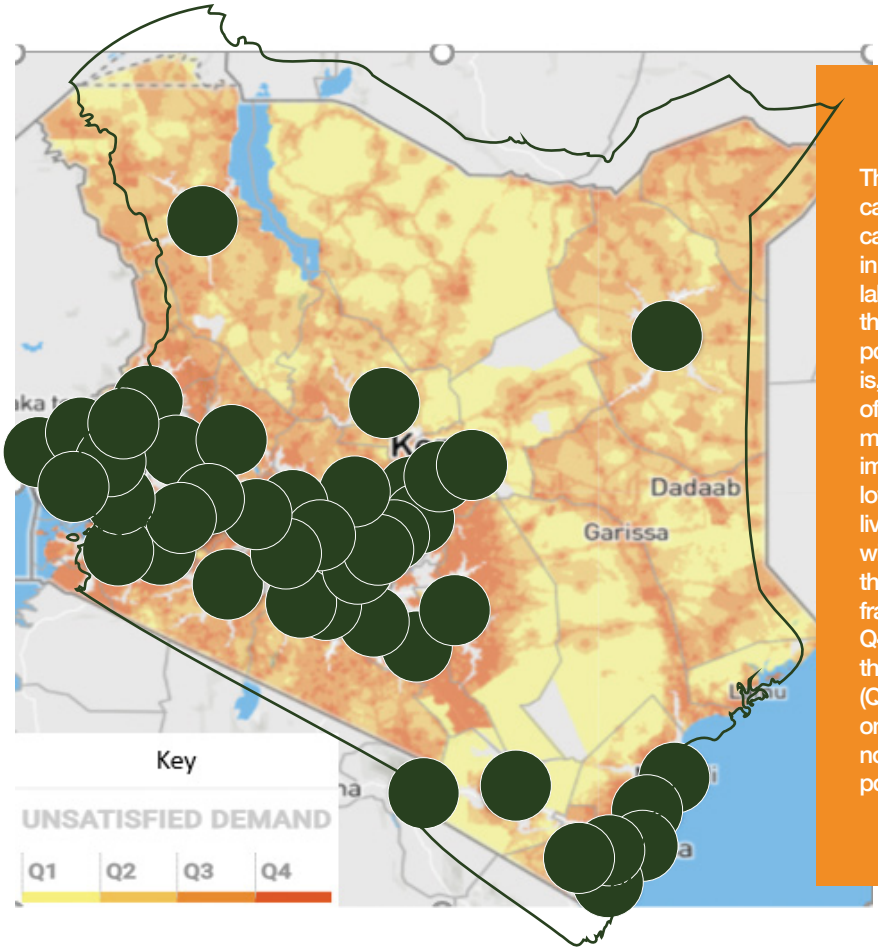
Abbreviations: AMS prog=antimicrobial stewardship programme; HICC=hospital infection control committee; HIS=hospital information system; ID dept=infectious diseases department; LIS=laboratory information system; MTC=medical therapeutics committee

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 and 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, Kenya had an estimated population of 53.77 million.



The laboratory population coverage 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 assumes 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 this definition, the overall unmet need. For ease of use, the unit of unmet need is represented on the map as 'pixels', i.e., the lowest base unit of a raster image. Each base component is ranked from the lowest to the highest, per the number of population living in the 'pixel' to visualise the geographical areas with the most critical unmet needs. The ranking is then divided into quartiles made of equal population fractions (from Q1 –the lowest population density to Q4 –the highest population density) corresponding to the different map colours (from yellow (Q1) to dark red (Q4) (Supplementary Figure 1). 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.

Supplementary Figure 1: Population coverage of selected AST laboratories in Kenya

In Kenya, the catchment population living within a one-hour travel time from the 56 participating AMR surveillance sites covers 82% of the population. Hence, the existing facilities do not cover 18% of the population. Regions with the highest absolute unmet need should be prioritised for capacity building to increase laboratory population coverage. New capacity should be introduced by upgrading an existing laboratory to start providing services or by constructing a new laboratory.

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 patients' culture (laboratory) results, clinical information, and antimicrobial usage (AMR Appendix 4). In clinics and hospitals where patient records are tracked between the laboratories and hospitals, patient demographics, clinical profile and antimicrobial usage information were collected for all positive blood and cerebrospinal fluid (CSF) cultures (Figure 5). Additionally, facility and national antimicrobial consumption (AMC) data were collected.

Figure 5: Data collection at a Kenyan facility

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 the 16 laboratories across the three years.

The MoH and IQVIA jointly recruited local field data collectors. As part of the consortium's activity, a capacity-building workshop was conducted to train the field staff on data collection and the use of the WHONET[16] and the specially developed MAAP tool for the secure transfer of collected data (Figure 6).

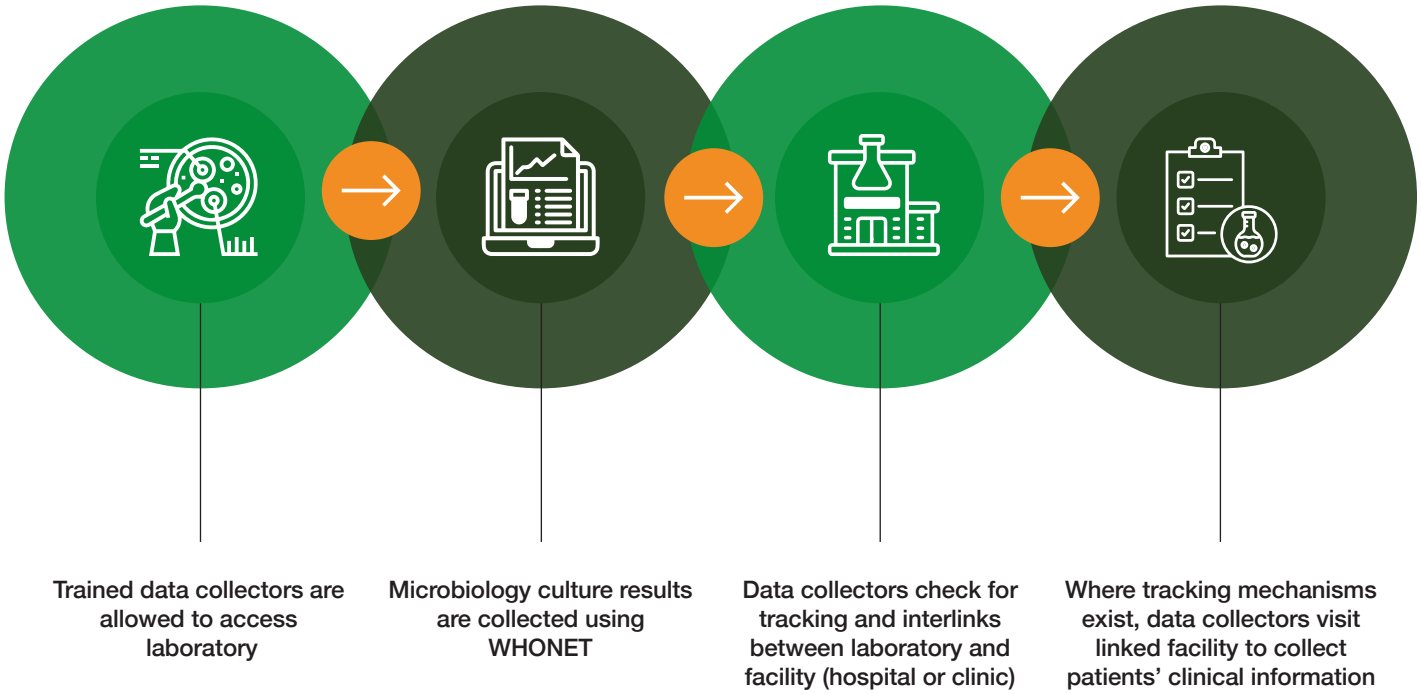


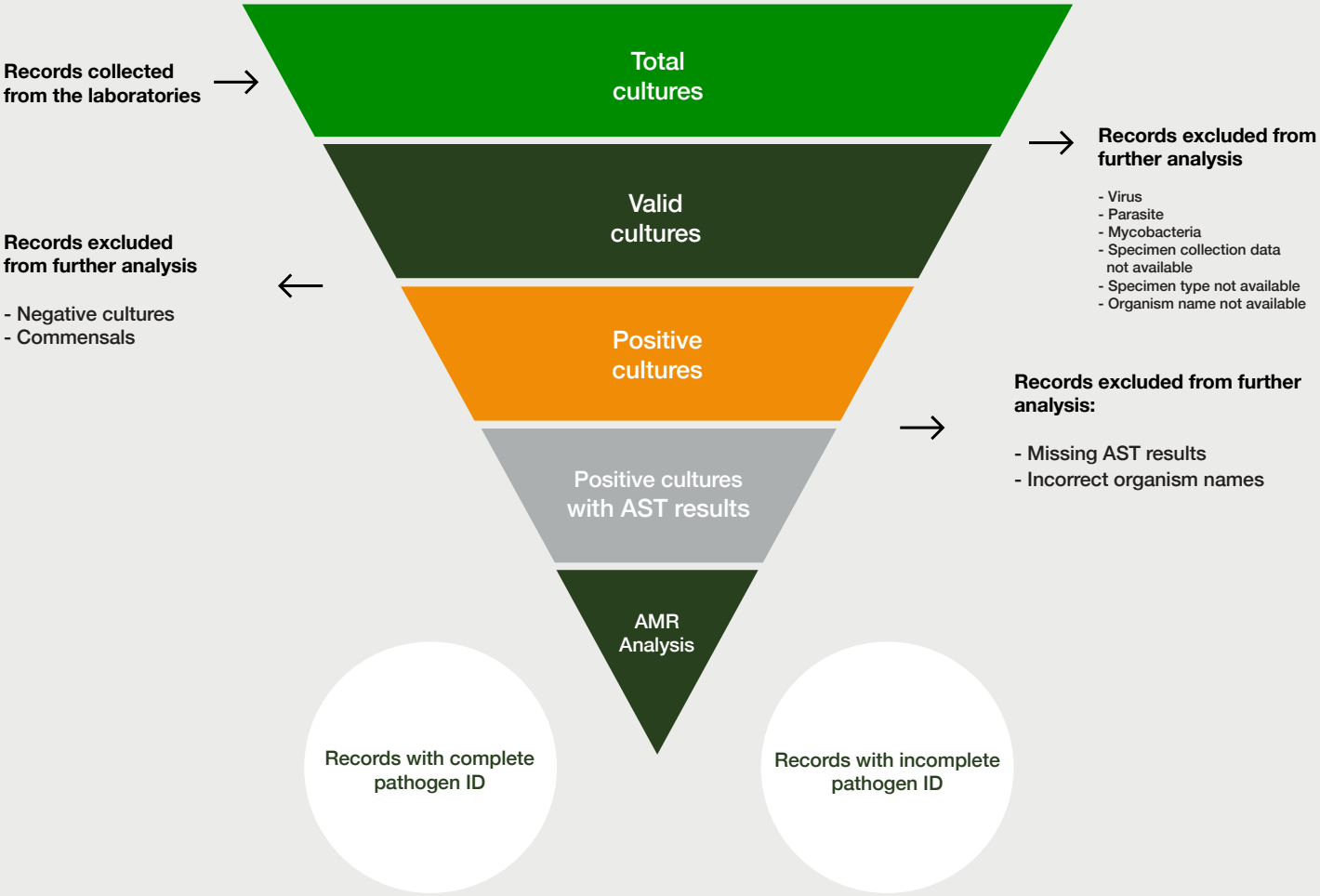
Figure 6: Steps of AMR data collection

Historical data from January 1, 2016, to December 31, 2018, were collected. The AMR data were initially captured through the WHONET, a free Windows-based database software programme developed for the management and analysis of microbiology laboratory data. The software allows the entry of clinical and microbiological data from routine diagnostic testing or research studies. The WHONET has a simple data file structure and output formats compatible with major databases, spreadsheets and 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 the WHONET, data were transferred into 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, tracking a patient across multiple visits was possible.

Data analysis

A preliminary data review was conducted to check for data completeness, accuracy, and redundancy. Data were summarised by 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 the subset of total cultures that had complete information on the specimen type, collection date and pathogen name. Valid positive cultures were cultures with pathogen growth reported, irrespective of the 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 8).
- **Level of pathogen identification:** Positive cultures with AST results were summarised based on the level of pathogen identification. Gram and genus-level identification were considered incomplete; 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).



Abbreviations: AMR=antimicrobial resistance; AST=antibiotic susceptibility testing; ID=identity

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 done for each study year.

Inappropriate testing: Positive cultures with AST results were assessed for compliance with AST standards. However, a comprehensive assessment of the AST results' validity was beyond the study's scope. Data were pooled across laboratories and assessed for each study year. The conventional AST standards are the Clinical and Laboratory Standards Institute (CLSI), the European Committee on Antimicrobial Susceptibility Testing (EUCAST) and Comité de l'antibiogramme de la Société Française de Microbiologie-E uropean Committee on Antimicrobial Susceptibility Testing (CASFM-EUCAST).

Clinical information: Positive cultures with AST results were summarised based on available clinical information, including diagnosis, infection origin (hospital- or community-acquired), an indwelling device and patient antimicrobial use. Data were quantified for each laboratory and assessed over the entire study period.

Specimen characteristics: Positive cultures with AST results were summarised per specimen type. 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 for evaluating each laboratory's data quality, as complete pathogen identification is essential 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 more than 75% species-level pathogens identification were awarded the highest score (4). Laboratories with less than 25% pathogen identification received the lowest score (1) (Table 3). Each study year was scored (i.e., 2016–2018), and then the average score for the years studied became 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

Since 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. Therefore, the maximum attainable data quality score was four, corresponding to an 'Excellent' rating (Table 4).

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

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

Table 4: Data quality rating

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

Results

Retrospective data from 2016–18 were collected from 16 laboratories and their healthcare facilities in Kenya.

1. Quantum of cultures and level of pathogen identification

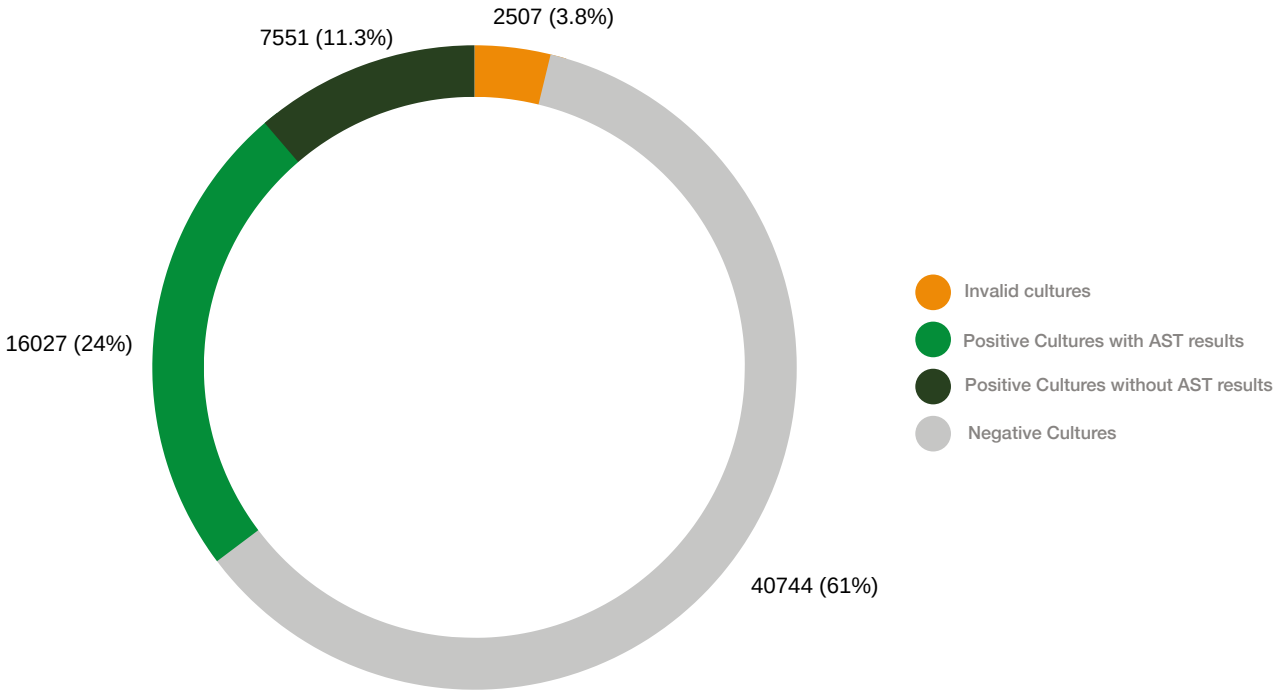
Data were retrieved for 66 835 total cultures, of which 64 328 were valid and 23 578 were positive. Of the positive cultures, AST results were available for 16 027 positive cultures, with the highest (n=6 278) coming from Kenyatta and the least (n=43) from Machakos (Figures 8 and 9). Not all pathogens were identified to the species level. Complete identifications were highest at the Kenyatta laboratory (99%) and lowest at the Moi Teaching laboratory (39%) (Table 5).

Table 5: Culture and AST data retrieved from 16 selected laboratories in Kenya, 2016 -2018

Variable (Columns) / Laboratory (Rows)	Total Cultures (N=66 835)	Valid Cultures N=64 328	Positive cultures N=23 578	Positive cultures with AST results N=16 027	Incomplete identity* N=3 458	Complete identity* N=12 569
Kisii	519	511 (98.5)	277 (54.2)	247 (89.2)	100 (40.5)	147 (59.5)
Mater	25 223	25 206 (99.9)	4 450 (17.7)	2 955 (66.4)	124 (4.2)	2 831 (95.8)
Kitale	664	660 (99.4)	270 (40.9)	253 (93.7)	41 (16.2)	212 (83.8)
Kenyatta	11 794	11 525 (97.7)	11 525 (100.0)	6 278 (54.5)	81 (1.3)	6 197 (98.7)
Bungoma	1 705	1 696 (99.5)	193 (11.4)	146 (75.6)	62 (42.5)	84 (57.5)
Busia	105	104 (99.0)	60 (57.7)	47 (78.3)	24 (51.1)	23 (48.9)
Nyeri	306	306 (100.0)	69 (22.5)	49 (71.0)	16 (32.7)	33 (67.3)
Moi County	916	915 (99.9)	306 (33.4)	295 (96.4)	114 (38.6)	181 (61.4)
Wajir	757	748 (98.8)	249 (33.3)	228 (91.6)	93 (40.8)	135 (59.2)
Moi Teaching	12 285	11 979 (97.5)	4 470 (37.3)	4 105 (91.8)	2 502 (61.0)	1 603 (39.0)
MP Shah	7 727	5 910 (76.5)	299 (5.1)	269 (90.0)	11 (4.1)	258 (95.9)
Thika	1 129	1 128 (99.9)	249 (22.1)	199 (79.9)	40 (20.1)	159 (79.9)
Coptic	1 570	1 565 (99.7)	360 (23.0)	280 (77.8)	10 (3.6)	270 (96.4)
Machakos	466	465 (99.8)	49 (10.5)	43 (87.8)	14 (32.6)	29 (67.4)
Meru	662	652 (98.5)	306 (46.9)	262 (85.6)	41 (15.6)	221 (84.4)
Kilifi	1 007	958 (95.1)	446 (46.6)	371 (83.2)	185 (49.9)	186 (50.1)

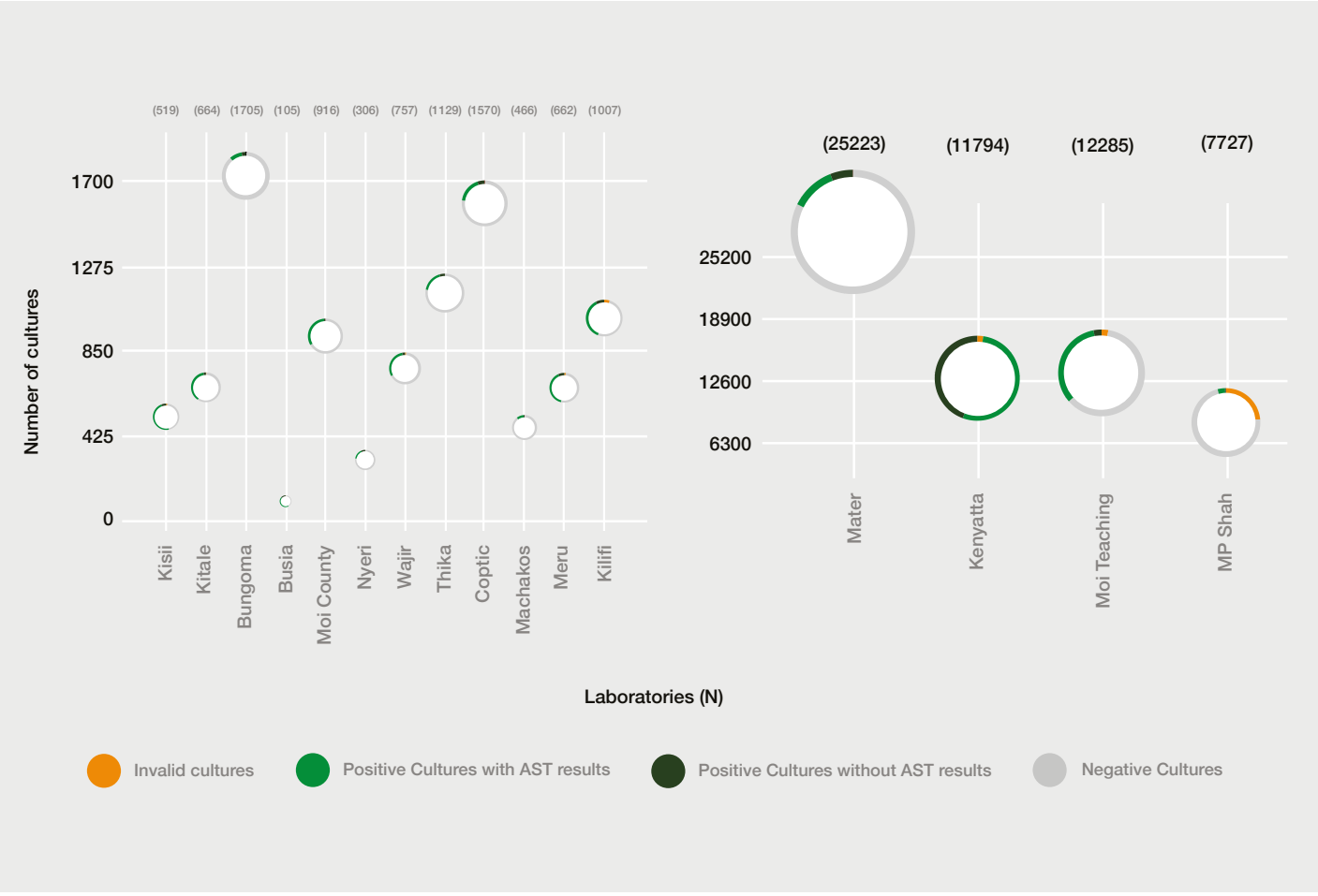
* Subsets of the category 'Positive cultures with AST results' where 'incomplete', it includes cultures with only Gram or genus-level identification; 'complete' includes cultures with species-level identification; — information not available

AST=Antibiotic Susceptibility Testing



Abbreviations: AST=antibiotic susceptibility testing

Figure 8: Quantum of cultures across all selected laboratories



AST=Antibiotic Susceptibility Testing

Figure 9: Quantum of cultures in each selected laboratory in Kenya, 2016-2018

2. Culture characteristics

Bacterial pathogens (15 971) were more commonly isolated from positive cultures than fungal pathogens. Information on age was missing from 24.7% of cultures, but where available, the data showed a patient-median age of 28 years (range: 0–90 years), with most of the cultures (5 495) obtained from patients 18–49 years old. Females (9 778) contributed more to the quantum of positive cultures with AST results. More data came from 2018 (9 813) than other years (Table 6, AMR Supplementary Table 3).

Table 6: Socio-demographic characteristics of positive cultures with AST results retrieved from 16 selected laboratories in Ghana, 2016 -2018

Characteristics	Positive cultures with AST results n=16 027 n (%)
Gender	
Male	6 249 (39.0)
Female	9 778 (61.0)
Age, years	
Less than 1	1 782 (11.1)
1 to 17	2 175 (13.6)
18 to 49	5 495 (34.3)
50 to 65	1 441 (9.0)
Above 65	1 178 (7.4)
Unknown age	3 956 (24.7)
Year of study	
2016	3 307 (20.6)
2017	2 907 (18.1)
2018	9 813 (61.2)
Pathogen	
Bacteria	15 971 (99.7)
Fungi	56 (0.3)

3. Inappropriate testing

The selected laboratories reported compliance with CLSI AST standards. However, while reviewing the AST results, inappropriate testing was noted.

Enterobacterales were tested with inappropriate agents such as vancomycin, penicillin G and oxacillin (Supplementary Figure 1a). Staphylococcus aureus was tested against vancomycin using the disk diffusion method (Supplementary Figure 1b).

4. Clinical information

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

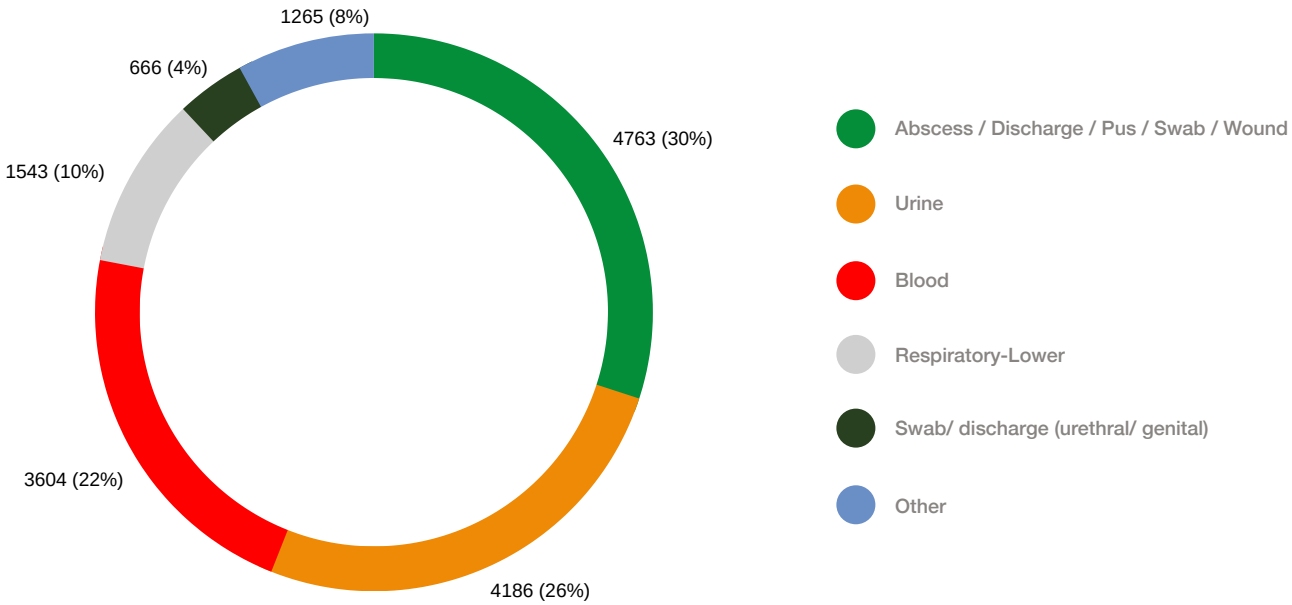
Table 7: Clinical characteristics of positive cultures with AST results retrieved from the 16 selected laboratories in Kenya, 2016 -2018

Laboratory	Positive cultures with AST results N=16 027	Diagnosis data	Infection origin data*	Indwelling device data	AMU data
Kisii	247	7	-	-	8
Mater	2 955	12	-	2	20
Kitale	253	-	-	-	-
Kenyatta	6 278	4 198	-	-	-
Bungoma	146	-	-	-	-
Busia	47	-	-	-	-
Nyeri	49	3	-	-	-
Moi County	295	-	-	-	-
Wajir	228	-	-	-	-
Moi Teaching	4 105	-	-	-	-
MP Shah	269	-	-	-	-
Thika	199	-	-	-	-
Coptic	280	1	1	-	-
Machakos	43	-	-	-	-
Meru	262	-	-	-	-
Kilifi	371	-	-	-	-

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

5. Specimen distribution

Purulent discharge, urine, and blood specimens accounted for most positive cultures in each study year (Figure 10, AMR Supplementary table 4).



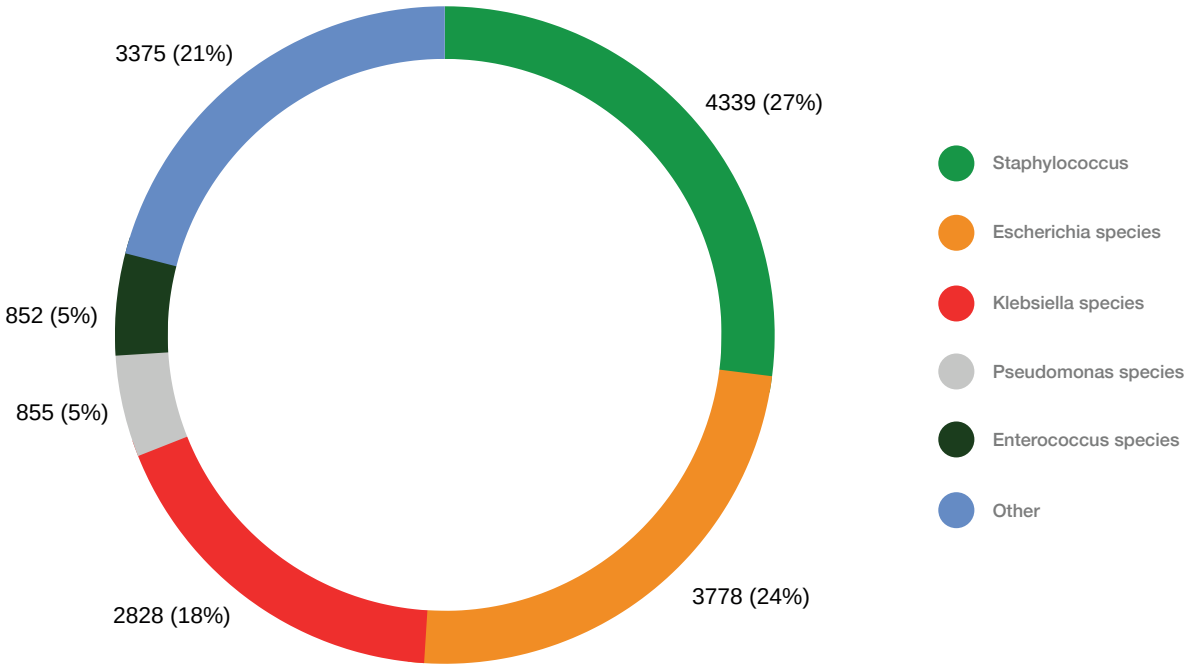
*** Others include all other specimens excluding the top five mentioned here**

Figure 10: Specimen-type distribution of positive cultures retrieved from 16 selected laboratories in Kenya, 2016 - 2018

6. Identified pathogens

Staphylococcus species (27.1%), Escherichia species (23.6%), and Klebsiella species (17.6%) largely contributed to the quantum of positive cultures (Figure 12).

In 2016, of the 3 307 positive cultures with AST results, Staphylococcus species (30.9%), Escherichia species (28.3%), and Klebsiella species (15.7%) were isolated the most. In 2017, of 2 907 positive cultures with AST results, Staphylococcus species (29.6%), Escherichia species (27.2%), and Klebsiella species (17.1%) were again the most reported. In 2018, information was available for many cultures (9 813), though pathogen distribution remained similar to previous years (AMR Supplementary Table 5).



* Others include all other pathogens excluding the top 5 mentioned here; inc. aureus=including S. aureus

Figure 11: Pathogens identified at selected facilities in Kenya, 2016-2018

7. Quality of data

The country data quality score of the 64 328 valid culture records obtained from the 16 laboratories in Kenya was 3.5, which is a 'good' data quality for AMR analysis. For individual laboratory data quality scores from each contributing laboratory (see AMR Supplementary Table 6).

Section III: AMR rates

Objective

1. To estimate the country-level AMR prevalence and trends for the WHO priority pathogens and other clinically important and frequently isolated pathogens
2. To enable spatiotemporal mapping of AMR and AMU data across countries

Methodology

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

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, determined by the proportion of non-susceptible isolates (i.e., either intermediate or resistant) over a year:

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

1. AMR rates were estimated for the WHO priority pathogens[17] with more than 30 tested isolates regardless of the specimen type (AMR Appendix 5). The AMR trends for the WHO priority pathogens were mapped depending on data availability.

In addition, AMR rates were estimated for:

2. Clinically important pathogens isolated from blood and cerebrospinal fluid (AMR Appendix 6)
3. Top three highly resistant bug-drug combinations (regardless of the specimen type)
4. 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 the resistance interpretations submitted by the laboratories. Where laboratories provided quantitative results (i.e., diameter measurements or minimum inhibitory concentrations), the interpretations were adjusted based on the updated breakpoints available on WHONET. Although the non-susceptibility interpretations were based on the results of the tested antimicrobials, they are represented at the antimicrobial class level wherever possible (AMR Appendix 7). The 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 isolated per patient per year, irrespective of AST profile and specimen characteristics (specimen source site or specimen type in the case of WHO priority pathogens) were included; this approach follows the CLSI M39A4 criteria.[18,19] Duplicates were removed 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 the AMR rates were calculated as the proportion of non-susceptible isolates.

AMR estimates statistics

Ninety-five percent confidence intervals (CIs) were calculated to quantify the uncertainty in the estimated resistance rates. Typically, AST data CIs have been constructed using the Wilson score method, a binomial calculation that assumes that all samples are independent.[20] However, there are likely correlations between data within each laboratory and between laboratories that draw from similar populations. Thus, the Wilson cluster robust CI method was employed where appropriate to account for the lack of data independence, such that each laboratory represented a cluster.[21]

These 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. AST result validation was beyond the study's scope; thus, data were taken at face value to assess resistance rates.

Online data visualisation

The AMR data were aggregated at the national level, and definitions of resistance were harmonised across 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]). The RSN provides a simple approach for analysing AMR data: point-and-click editing tools allow the user to mine the data to answer complex questions, and the resulting analyses can be displayed as bar charts representing resistance over a period or line graphs showing changes over time (e.g., by month or year). The RSN will be made available to each participating country for at least one year following the end of the study.

Data were also uploaded to the CDDEP's ResistanceMap platform, a publicly available repository of aggregated country-level data.[22] Spatiotemporal analyses of 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 nonsusceptible isolates over each one-year interval. Across 2016–2018, the AMR rates for some organisms remained consistent; the rates for others varied. The highest AMR rates were observed for third-generation cephalosporin in the Enterobacterales (67–73%). The rates of carbapenem-resistant Enterobacterales (20–29%) and methicillin-resistant S. aureus (MRSA) (40–52%) were moderately high. Rates of carbapenem-resistant P. aeruginosa were also high (39–51%) (Table 8, Figures 12 and 13). Statistics for vancomycin-resistant and intermediate Staphylococcus species, including S. aureus, were not included.

Table 8: AMR rate estimates for WHO priority pathogens in Kenya, 2016-2018

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	8	7	-	2 (3 - 5)	9	9	-	4 (1 - 3)	11	11	-	3 (1 - 9)
Pseudomonas aeruginosa	Carbapenems	37	19 (51.4)	6.2-94.4	3 (10 - 16)	59	21 (35.6)	13.2-66.8	5 (1 - 28)	71	28 (39.4)	22.8-59	6 (1 - 40)
Enterobacter ales	Carbapenems	609	122 (20)	3.3-64.9	5 (8 -370)	655	133 (20.3)	4.3-58.8	7 (5 - 346)	612	180 (29.4)	11.4-57.4	8 (11 - 360)
Enterobacter ales	Cephalosporins (3rd generation)	1 307	933 (71.4)	34.9-92.1	11 (1 - 429)	1 267	846 (66.8)	35.8-87.8	13 (1 - 418)	1 332	974 (73.1)	49.2-88.4	14 (1 - 462)
Enterococcus faecium	Vancomycin	-	-	-	-	3	2	-	2 (1 - 2)	3	0	-	3 (1 - 1)
Haemophilus influenzae	Ampicillin	-	-	-	-	-	-	-	-	-	-	-	-
Helicobacter pylori	Clarithromycin	-	-	-	-	-	-	-	-	-	-	-	-
Neisseria gonorrhoeae	Cephalosporins (3rd generation)	5	0	-	1 (5)	4	0	-	1 (4)	6	0	-	1 (6)
Neisseria gonorrhoeae	Fluoroquinolones	8	1	-	1 (8)	4	1	-	1 (4)	9	1	-	2 (1 - 8)
Campylobacter species	Fluoroquinolones	-	-	-	-	-	-	-	-	-	-	-	-
Salmonella species	Fluoroquinolones	18	2	-	6 (1 - 7)	14	0	-	1 (14)	10	2	-	5 (1 - 5)
Shigella species	Fluoroquinolones	11	1	-	4 (1 - 6)	6	2	-	3 (1 - 4)	10	1	-	5 (1 - 4)
Staphylococcus aureus	Methicillin	75	35 (46.7)	21.8-73.3	7 (3 - 19)	75	39 (52)	29-74.2	9 (1 - 20)	58	23 (39.7)	25.2-56.2	10 (1 - 18)
Streptococcus pneumoniae	Beta-lactam combinations	-	-	-	-	1	0	-	1 (1)	1	1	-	1 (1)
Streptococcus pneumoniae	Penicillins	10	4	-	3 (2 - 4)	4	2	-	2 (1 - 3)	7	4	-	3 (2 - 3)

N=the number of tested isolates; n=the 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 the same genus are grouped as one entity.

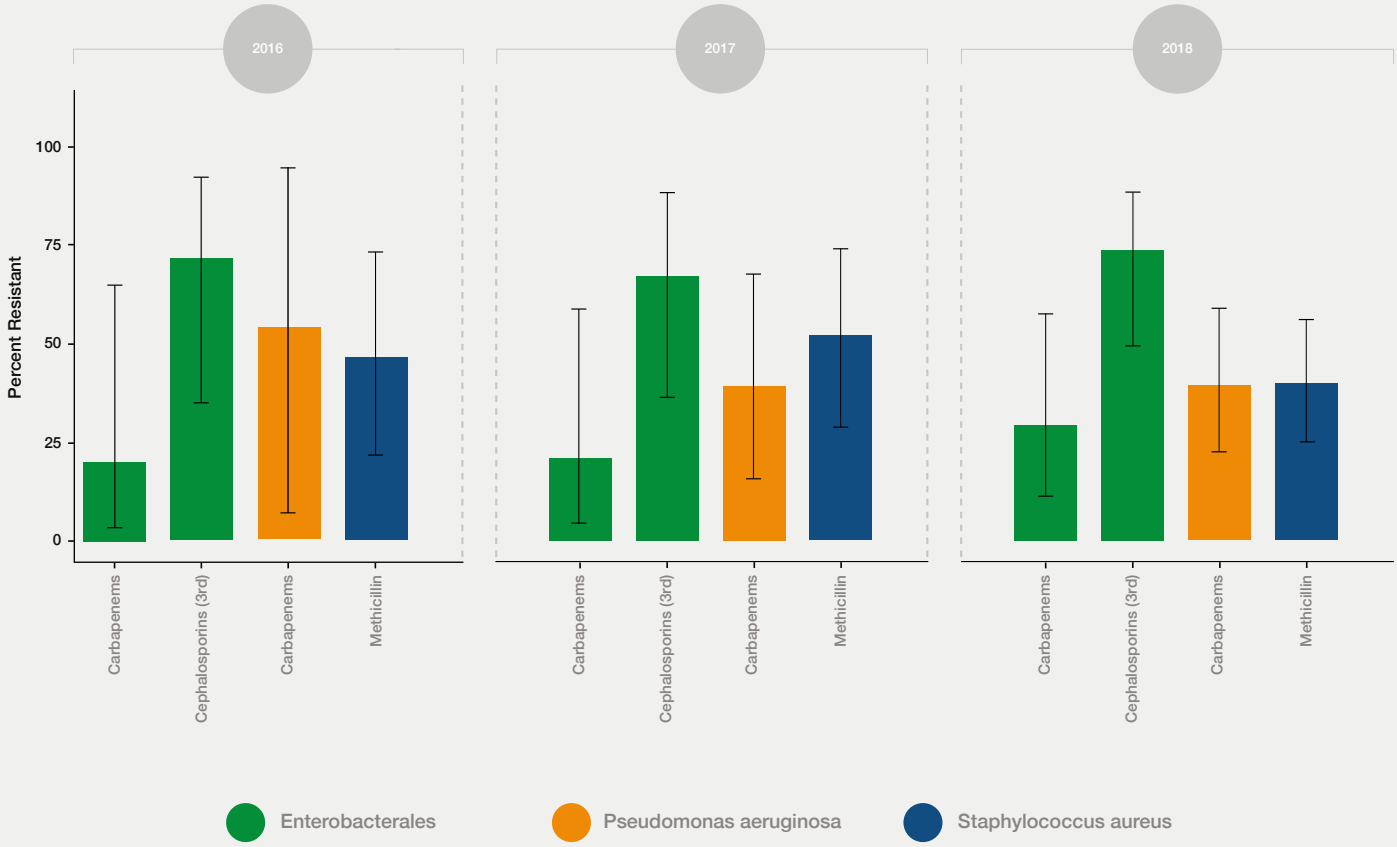
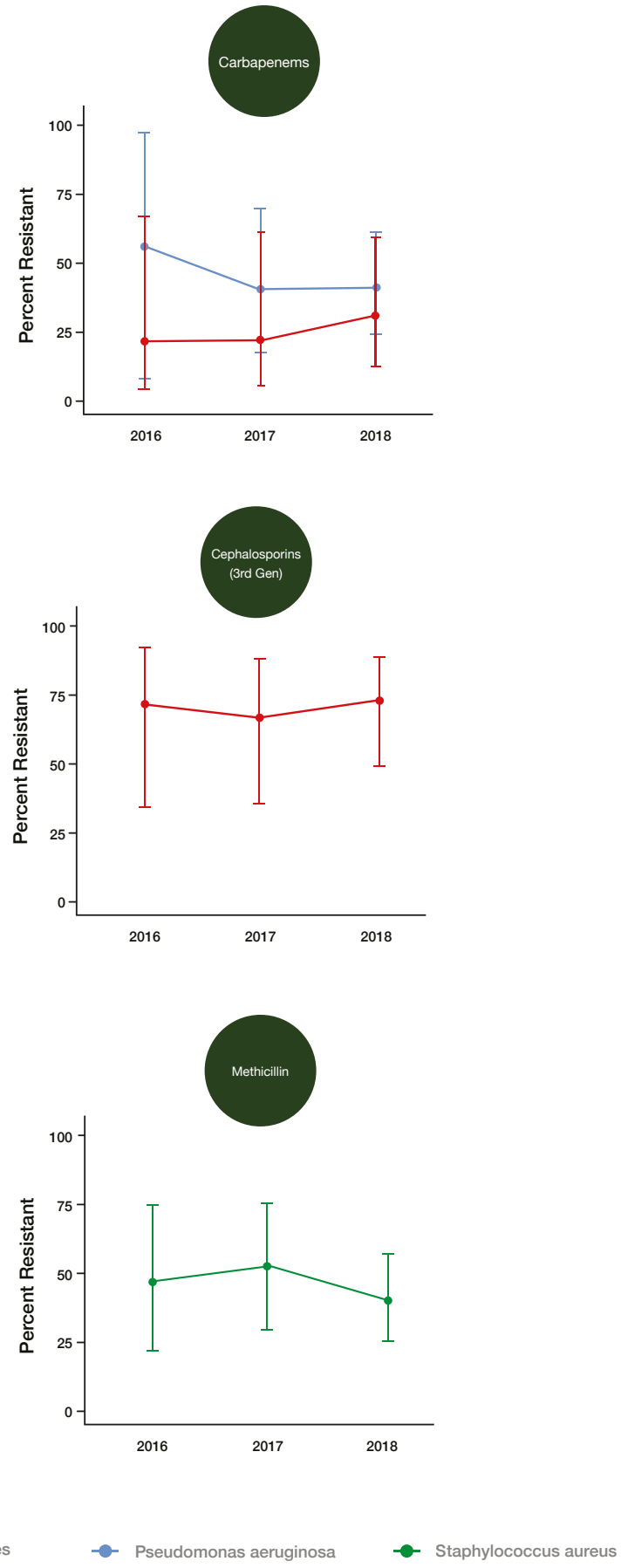


Figure 12: AMR rate estimates for selected WHO priority pathogens isolated by 16 selected facilities in Kenya, 2016-2018



3rd Gen=Third generation

Figure 13: AMR trends of selected WHO priority pathogens isolated by the 16 selected laboratories in Kenya, 2016 -2018

(ii) AMR rates for other pathogens of clinical importance

Analysis of the AST data from blood and CSF isolates revealed very high rates of third-generation cephalosporin-resistant Klebsiella species (93% in 2016, 75% in 2017, and 91% in 2018), followed by carbapenem-resistant Acinetobacter species (22% in 2017) and then by carbapenem-resistant Klebsiella species (5–10% during 2016-18) (Table 9).

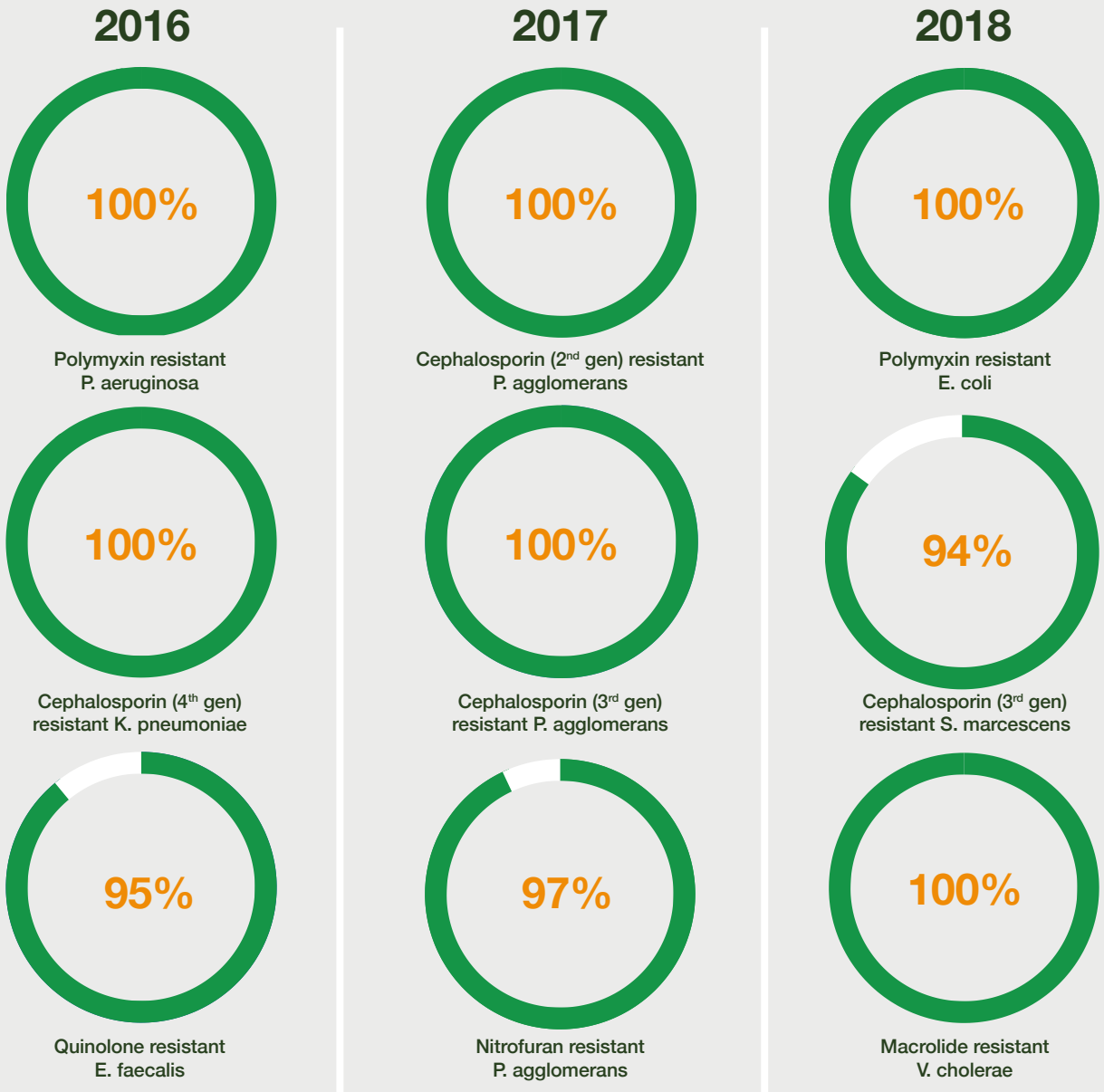
Table 9: AMR rate estimates for other clinically important pathogens identified at 16 selected laboratories in Kenya, 2016 -2018*

		2016				2017				2018			
Pathogen	Antibiotic, class	N	n (%)	95% CI	Labs# (range)	N	n (%)	95% CI	Labs# (range)	N	n (%)	95% CI	Labs# (range)
Acinetobacter species	Carbapenems	24	10	-	3 (1 - 19)	51	11 (21.6)	12.1-35.4	4 (1 - 47)	24	13	-	3 (1 - 22)
Acinetobacter species	Lipopeptides	-	-	-	-	-	-	-	-	-	-	-	-
Enterococcus species	Aminoglycosides (high level)	19	1	-	2 (1 - 18)	2	0	-	1 (2)	2	1	-	1 (2 - 2)
Enterococcus species	Vancomycin	26	3	-	3 (1 - 22)	16	4	-	3 (3 - 8)	27	5	-	4 (1 - 22)
H. influenzae	Ampicillin	-	-	-	-	-	-	-	-	-	-	-	-
H. influenzae	3rd generation cephalosporins	-	-	-	-	-	-	-	-	-	-	-	-
Klebsiella species	Carbapenems	163	8 (4.9)	1-20.6	3 (1 - 145)	149	10 (6.7)	1-33.7	4 (3 - 116)	87	9 (10.3)	3-30.4	4 (3 - 70)
Klebsiella species	Cephalosporins (3rd generation)	202	188 (93.1)	79.1-97.9	3 (8 - 161)	154	116 (75.3)	61.3-85.5	4 (6 - 119)	116	105 (90.5)	80.5-95.7	6 (1 - 80)
N. meningitidis	Ampicillin	-	-		-	-	-	-	-	-	-	-	-
N. meningitidis	Cephalosporins (3rd generation)	-	-	-	-	1	0	-	1 (1)	-	-	-	-
Pseudomonas species	Carbapenems	7	1	-	2 (3 - 4)	8	2	-	3 (1 - 5)	7	5	-	1 (7)
Pseudomonas species	Lipopeptides	-	-	-	-	-	-	-	-	-	-	-	-
Salmonella species	Fluoroquinolones	-	-	-	-	-	-	-	-	-	-	-	-
Salmonella species	Macrolides	-	-	-	-	-	-	-	-	-	-	-	-
Salmonella species	3rd generation cephalosporins	-	-	-	-	-	-	-	-	-	-	-	-
Staphylococcus aureus	Methicillin	-	-	-	-	-	-	-	-	-	-	-	-
Staphylococcus species	Methicillin	25	11	-	2 (5 - 20)	22	14	-	2 (1 - 21)	17	15	-	2 (1 - 16)
S. pneumoniae	Penicillins	4	1	-	1 (4)	2	1	-	2 (1)	-	-	-	-
S. pneumoniae	Beta-lactam combinations	-	-	-	-	1	0	-	1 (1)	-	-	-	-
S. pneumoniae	Macrolides	4	1	-	1 (4 - 4)	2	0	0	2 (1 - 1)	-	-	4	1
S. pneumoniae	Vancomycin	4	0	-	1 (4)	3	0	-	2 (1 - 2)	-	-	-	-

* From blood and CSF; N = number of tested isolates; n = number of non-susceptible isolates; %n and %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 available data, very high resistance (100%) was estimated for P. aeruginosa to polymyxins, K. pneumoniae to fourth-generation cephalosporins, E. coli to polymyxins, and P. agglomerans to second- and third-generation cephalosporins (Figure 14).



Pathogen nomenclature is shown as reported by laboratories; antimicrobials are reported at the class level.

Figure 14: Top five highly resistant pathogens isolated by the 16 selected laboratories in Kenya, 2016 -2018

(iv) AMR rates for fungal pathogens

The available AST data on fungal isolates were 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., The following patient and country-level factors were considered to determine the association between AMR and its potential drivers:

- **Patient-level factors:** demographics (age, gender), diagnosis, comorbidities, antimicrobial usage, presence of an indwelling medical 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, gross domestic product (GDP) per capita, physician and nurse densities, disease prevalence and antibiotic consumption in DDD per 1 000 inhabitants (the country-level associations are presented separately at a regional/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 DRI methodology guided the choice of pathogens and antimicrobials (see Part C).

Statistical analysis

An initial data exploration was conducted 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, and only those 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 the robust standard error was used to construct CIs for the AMR rates.

Pearson's correlation analysis was performed to explore the association between the country factors (continuous variables) and AMR; the correlation was reported at the continental level.

All results should be interpreted with caution because they were derived from data aggregated from facilities and laboratories with varying capabilities.

Results

The possible association of three variables, namely, age, gender and diagnosis, with AMR was evaluated. Information on other patient factors was unavailable or inadequate for analysis. The data availability of these variables was: age, 80.4%; gender, 83.8%; and diagnosis, 18.4%. The univariate logistic regression analysis revealed that the male patients were more likely to have a resistant infection (OR 1.27, 95% CI 1.10 – 1.5) as well as people aged above 65 years compared to the other age groups (OR 1.32, 95% CI 1.07 – 1.42) (Supplementary Table 7).

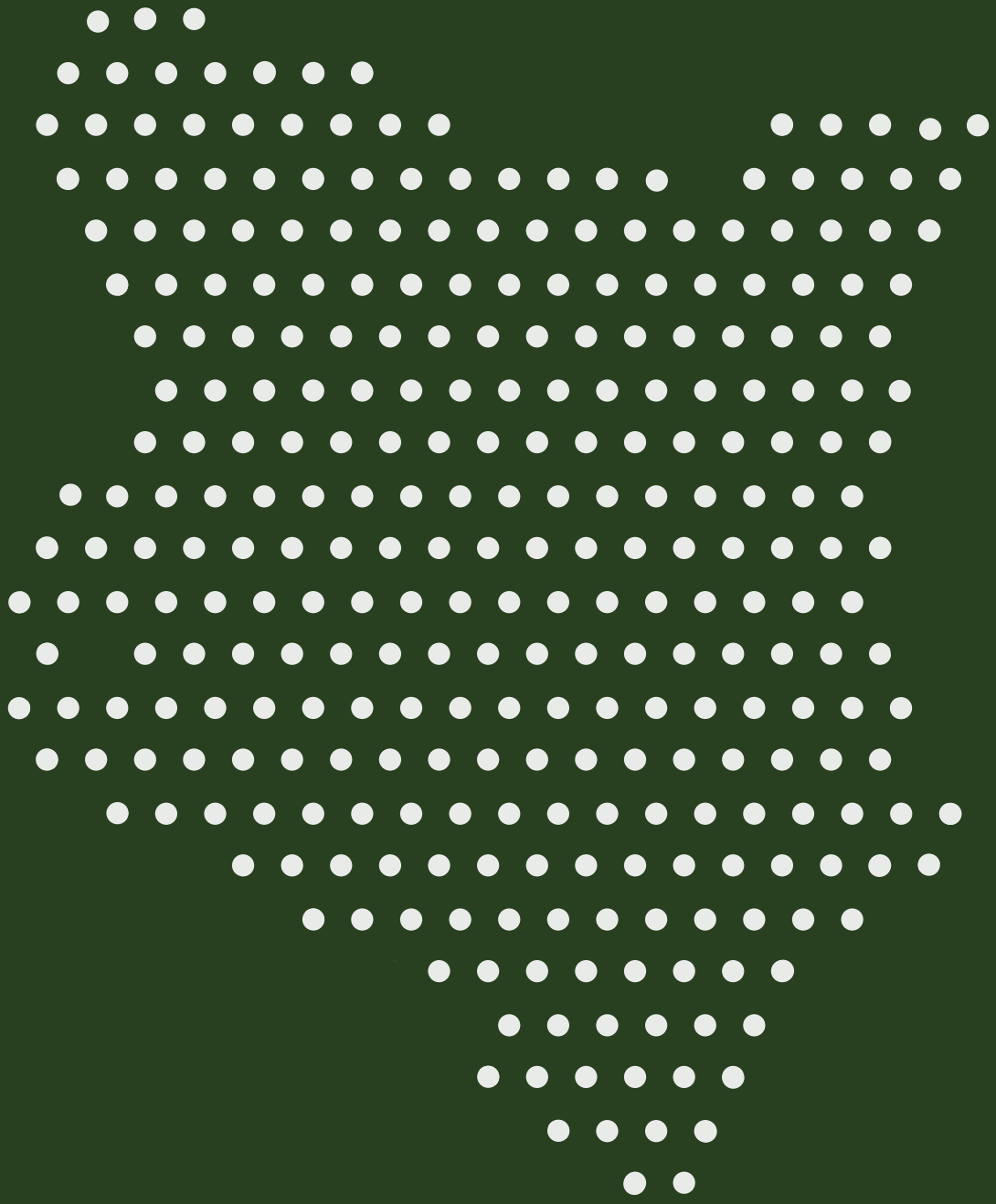
Age and gender were included in the multiple logistic regression analysis model based on the set criteria. When adjusting for age, the male patients were more likely to have resistant infections (OR 1.26, 95% CI 1.12 – 1.42). Similarly, when adjusting for gender, patients aged above 65 years were more likely to have resistant infections (OR 1.24, 95% CI 1.01 – 1.52) (Table 10).

Table 10: Demographic drivers of AMR in Kenya, 2016 -2018

Variable	Options	N	NS (%)	Adjusted OR (95% CI)	P-value
Gender	Female	4914	41.74	**Reference category**	
	Male	3414	47.95	**1.26 (1.12–1.42)**	0.000
Age	<1	441	46.94	1.14 (0.87–1.53)	0.191
	1-17	1639	43.62	0.99 (0.85–1.15)	0.880
	18-49	4291	42.55	Reference category	
	50-65	1162	47.25	1.15 (0.87–1.53)	0.322
	>65	795	49.18	**1.24 (1.01–1.52)**	0.006

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

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 use exerts selective pressure by inhibiting the growth of susceptible microorganisms while favouring the growth of resistant ones, consequently accelerating the development of AMR.[23,24] Therefore, close surveillance on how the antimicrobials are utilised is a key step for stewardship programmes to stem the threat of AMR. The surveillance mechanisms recommended by the WHO include monitoring AMC and AMU and are in line with the MAAP's aim to expand the volume of AMR and AMC/AMU data available across Africa and the country's National Action Plan (2017-2022) on AMR prevention and containment.[25]

Definition of AMC and AMU

AMC is defined as the number of antimicrobials used within a specified setting (e.g., national, hospital, or community healthcare facility level) over a specified period. The AMC is calculated from aggregated data, such as import, wholesaler, insurance, or facility dispensing or procurement data sources, while AMU tracks whether antimicrobials are prescribed appropriately for the right infections and according to treatment guidelines. AMC and AMU are terminologies that are sometimes incorrectly used interchangeably. It is therefore prudent to further clarify that AMC data describe quantities of antimicrobials dispensed (e.g., at national stores or pharmacies), whereas AMU data describes how and why antimicrobials are used (i.e., whether the required laboratory tests and clinical assessments were conducted before prescription, whether the right antimicrobial was prescribed at the correct strength and frequency and for the appropriate duration to treat the right indication as per country guidelines and whether the patient correctly and completely consumed the prescribed antimicrobial).[26]

Link between the antimicrobial usage and AMR

The unwarranted use of antimicrobials contributes to the development of AMR and explains the link or association between antimicrobial use and AMR. This association implies that a reduction in the unnecessary consumption of antimicrobials could, in turn, affect resistance rates.[23] Inappropriate antimicrobials use refers to the use of the wrong type of antimicrobial and or at the wrong dose, frequency, duration and or for the wrong indication. The past few decades have seen a global increase in antimicrobial consumption and a consumption shift towards broad-spectrum and last-resort antimicrobials, particularly in LMICs. These shifts are due to improved access and increased economic strength within some of these countries. However, AMR can also develop due to a lack of access to antimicrobials, leading to the prolonged use of a particular antimicrobial over a long time, and thus selective pressure favours microbes that evade these predominantly used antimicrobials. This is often the picture in many LMICs where inequities in access to antimicrobials persist.[27] This complicated picture demonstrates the need for the research and development of new agents that counteract emerging AMR and also strongly supports the need for the appropriate use and ensured access to available antimicrobials.

An AMC surveillance system is paramount for obtaining an elaborate and complete picture of the link between AMC/AMU and AMR in Kenya, identifying prevalent gaps and targeting interventions promoting rational antimicrobial use. In this regard, one of MAAP's key objectives was to evaluate the ability to conduct an AMC and AMU data collection and analysis in Kenya 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 setting up 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

Optimising the correct usage of antimicrobials is one of the strategic objectives of the WHO GAP to ensure the successful treatment of infectious diseases in patients.[8] For the successful implementation of the above objective, there is a need to understand a country's pattern of antimicrobial use and consumption quantities. At present, there are only a few published reports on AMC surveillance and AMU in Africa.[28-32] The process of obtaining AMC/AMU data equips the country with local information on various problems that exist with antimicrobial use and allows for monitoring the accessibility of antimicrobials. Obtaining AMC/AMU data permits the continuous local assessment of correlations between antimicrobial usage and emerging local AMR that informs proper mitigation policies and activities. Data obtained from the local surveillance exercises also presents the opportunity to inform stewardship programmes better. Therefore, the MAAP set out to quantify consumption and analyse AMC and AMU trends at selected facilities and the national level, to better inform the design of future stewardship programmes and policies that will optimise antimicrobials' use in Kenya. In addition, this analysis provides the country with a baseline to measure the impact and success of future implemented interventions.

The aim of this work

1. Describe the current in-country antimicrobial flow, AMC status and AMU surveillance system in Kenya

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

Section II: AMC or AMU surveillance status

Objective

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

Methodology

Data sources

The national AMC data for Kenya was obtained from IQVIA and included data from the central medical store (CMS) –Kenya Medical Supplies Authority (KMSA) and the private sector (private-for-profit distributors and wholesalers) (AMC Appendix 1 for the tool used). In Kenya, the total pharmaceutical market comprises a private-sector market of approximately 40% and a public-sector market of approximately 60%, of which the public-sector market includes private-not-for-profit distributors and wholesalers.

Under the guidance of the Kenya AMRCC, the MAAP recruited and obtained data from twice as many pharmacies as the selected AST laboratories (i.e. a total of 32 pharmacies). Pharmacy-level AMC data were obtained from the pharmacies that were co-located in the same facility with AST laboratories (n=16) (AMC Appendix 2 for the tool used). Also, AMC data were to be collected from the community pharmacies (n=16) that the co-located pharmacies nominated due to their proximity to the AST laboratories and their status as the community-preferred patient medicine purchase sites or the backup prescription fulfilment source in the case of stock-outs in the main hospital pharmacy. Additionally, the availability of retrospective data from 2016-2018 and willingness to share the data were key criteria for selection.

In addition to the AMC data collected, AMU data were to be obtained for the (n=16) hospital pharmacies, and this was to be retrieved from the facility prescription or patient medical records. To clarify, community pharmacies, 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. The definition excludes unregulated and informal medicine dispensers. Hospital pharmacies are the pharmacies located within a hospital providing medicinal products to the hospital's in and out-patients.

Data collection scope

The MAAP purposively aimed to collect data on J01 (antibiotics for systemic use) consumption trends. The J01 medicines are one of the WHO core monitoring Anatomical Therapeutic Chemical (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 (AMC Appendix 3 for the full list of selected antimicrobials in Kenya). The P01AB and J02 ATC antimicrobials are part of the WHO core and optional monitored medicine classes for AMC surveillance.[33] The AMC data for these medicine categories were collected from January 2016 to December 2018.

Data collection

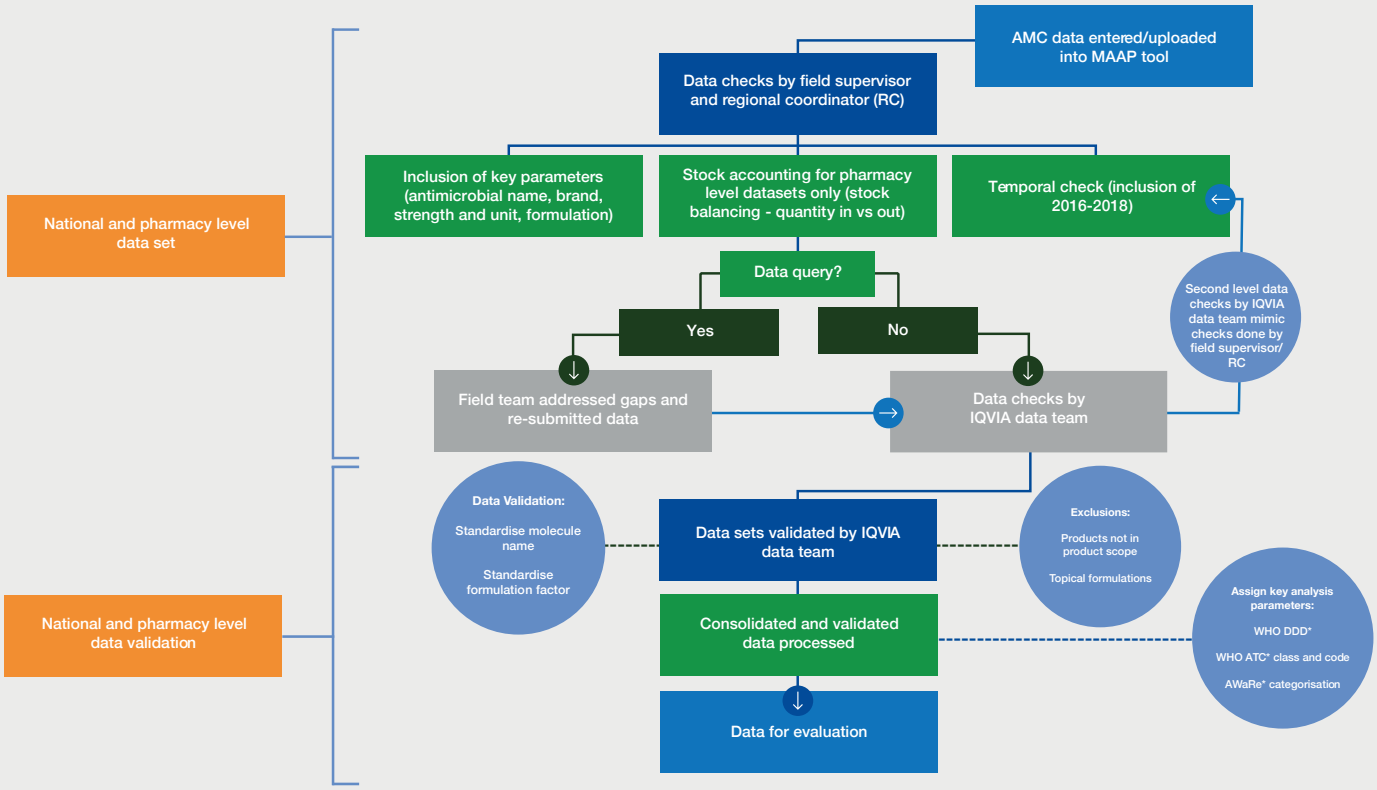
The IQVIA™ AMC dataset for the period between 2016-2018 was provided to the regional coordinator in the form of a Microsoft Excel sheet. The data collection team reviewed and cleaned data in an Excel™ sheet, which was then transferred securely through the MAAP tool that captured all of the medicines by their standard molecule 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 electric pharmacy-level data, the trained MAAP data collectors either extracted the consumption data from the facility's health information system (HIS) into a Microsoft Excel™ sheet. Within facilities without electronic HIS, abstracted data from stock record cards and manually entered into the MAAP tool. The data teams reviewed and cleaned the electronic datasets and then transferred them securely through the MAAP tool to the central data processing and analysis team (AMC Appendix 5).

The MAAP also planned to collect AMU data in pharmacies co-located within the same clinical facilities as the AST laboratories and clinical services to assess the appropriateness of consumed antimicrobials. Data to be captured included patient characteristics and medical condition for which the antimicrobial was prescribed and the appropriateness of the prescription per the national guidelines. Appropriateness of prescription assessed the conduct of relevant laboratory tests and clinical assessment done prior to prescription and assessed the dose, strength, frequency and duration of the prescription.

Data cleaning and validation

The data received from the KEMSA and wholesalers/distributors by the Kenya IQVIA™ data team for the national-level dataset were separately pre-processed. First, the raw data collected were coded, and then IQVIA's standard attributes were linked to the data using reference product master files and price master lists specific to Kenya. The processed data were then validated (AMC Appendix 6). Once the MAAP received the IQVIA dataset, the national-and pharmacy-level AMC data were subjected to data validation checks to ensure accuracy and consistency. Here, pharmacy and national AMC data were subjected to secondary and tertiary checks by field supervisors, regional coordinators and the IQVIA data team (Figure 15).



*DDD Defined Daily Dose - *ATC - Anatomical Therapeutic Chemical *AWaRe - Access, Watch and Reserve

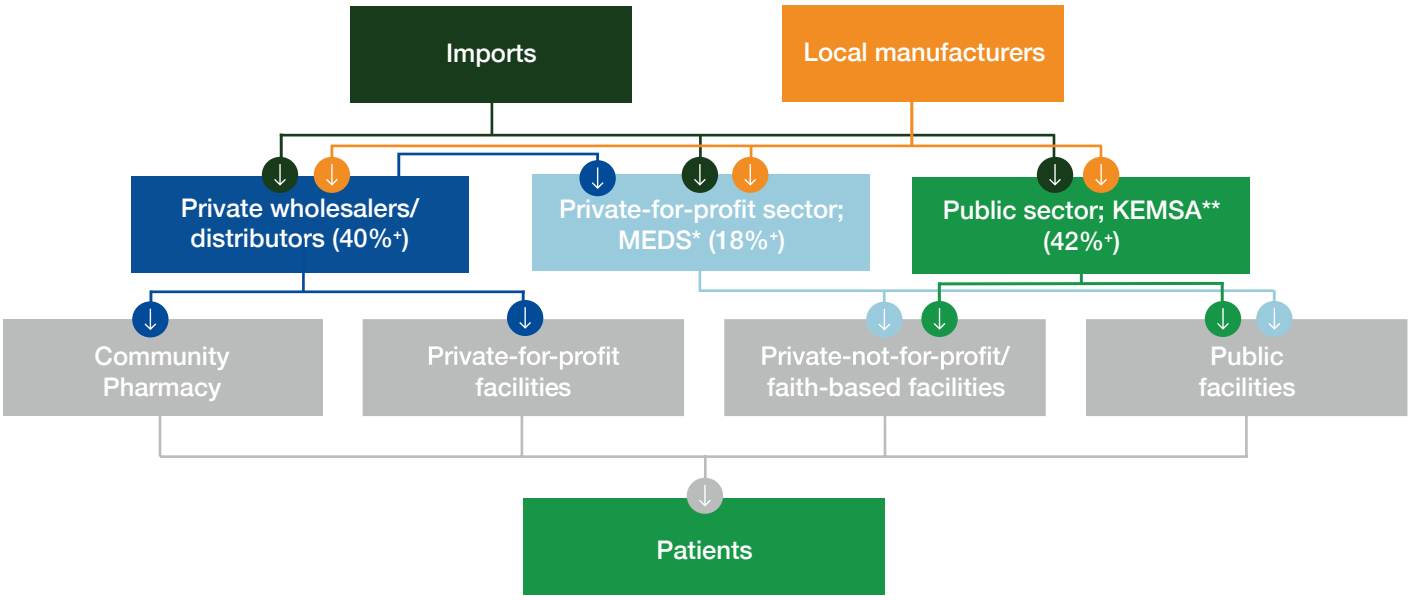
Abbreviation: RC= regional coordinator;

Figure 15: The data checks and validation process for national- and pharmacy-level AMC data collected from selected facilities in Kenya, 2016-2018

Results

Flow of antimicrobials in the country

Three key informant interviews (KIIs) of stakeholders in Kenya from the national AMRCC, regulatory body – Pharmacy and Poisons Board (PPB) and the public sector national CMS – (also known as the KEMSA) were conducted. In Kenya, medicines are both locally manufactured and imported; therefore, accounting for the national AMC requires capturing data from both sources. After importation or local production, medicines are distributed to hospitals, pharmacies and other retail outlets by private for-profit wholesalers, private-not-for-profit distributors (i.e., Mission for Essential Drugs and Supplies) and the national public CMS (i.e., KEMSA); who in turn then pass along the antimicrobials to the community pharmacies, private for-profit and non-profit facilities and public health facilities. These latter recipients of medicines then issue the antimicrobials to patients (Figure 16).



* MEDS - Mission for Essential Drugs and Supplies
**KEMSA - Kenya Mediacl Supplies Authority
+Approximate percentage of the total antimicrobial market

A dotted line indicates supplies are not mainstream

Figure 16: Antimicrobial circulation routes to the patients in Kenya, 2016-2018

Regulation of antimicrobials consumption

In Kenya, the PPB regulates all importation and manufacturing conditions for medicines manufacture and local retailing.[14] The antimicrobials for human consumption are regulated under the Kenya Pharmacy and Poisons Act, 2012. The act stipulates that antibiotics can only be dispensed with a prescription and that the sales records are to be kept in an antibiotic register (National Council for Law Reporting, 2012). The overuse and misuse of antimicrobials significantly contribute towards the emergence of Antimicrobial Resistance (AMR). Therefore, to address the above issues and other gaps, the country developed a National Action Plan (NAP) on AMR (2017-2022) that seeks to further build regulations around AMC to curb AMR.[15]

Availability of data for AMU surveillance

Attempts were made to obtain AMU data from participating pharmacies that were co-located with AST laboratories in facilities offering clinical services (n=15). However, no AMU data were obtained during the MAAP data collection because of the nature of the data sources. The participating pharmacies used stock issuance record cards that did not track the specific medicines received by each. Thus, the MAAP was thus unable to retrieve the AMU data from the selected health facilities in Kenya. The AMU variables included patient characteristics and indication for the antimicrobial prescription and the appropriateness of prescription per the national guidelines, including conducting relevant laboratory test(s) and clinical assessment(s) before prescribing and assessing dose, strength, frequency, and duration of the prescription.

Availability of data for AMC surveillance

National-level data

The national AMC data were obtained from the IQVIA™ Kenya datasets as sourced from the KEMSA and wholesalers/distributors (excluding the private-not-for-profit Mission for Essential Drugs and Supplies (MEDS) AMC dataset and approximately 20% of other wholesalers/distributors). The IQVIA™ datasets included approximately 80% of the private-sector market data and 70% of the public-sector market data. Therefore, the data collected and analysed (2016-2018) from the IQVATM Kenya dataset represents approximately 70% coverage of total consumed antimicrobials in Kenya.

Facility-level data

Data was collected in 25 of the 32 targeted community and AST-laboratory-co-located pharmacies. The 25 selected pharmacies comprised ten community and 15 hospital pharmacies. Of the remaining seven targeted pharmacies, six community pharmacies were unwilling to share their AMC data and were therefore excluded from the data collection. One recruited AST laboratory co-located hospital pharmacy was unable to share their data with MAAP after numerous attempts were made. Of the recruited 15 AST-laboratory-co-located hospital pharmacies, 13 were in public government hospitals, while two were in private/faith-based hospitals. The public hospitals consisted of two level 4 hospitals (13%), ten level 5 (67%) and three level 6 (20%). Of the community pharmacies, all ten were stand-alone community retail pharmacies. The MAAP could not assess facility-level data representativeness as the total number of hospital/community pharmacies in Kenya is unknown.

The necessary variables for pharmacy-level data were collected from the stock cards or electronic records of 18 pharmacies. However, there were instances where strength or pack size information was missing from the stock cards for a few line items/transactions in each of the visited facilities. These information gaps were filled by revisiting the facilities and gathering information from the facility staff or through secondary desk research using the available product details. Of the 25 hospital and community pharmacies, the MAAP was able to collect data across three years in 24 pharmacies. Only one participating community pharmacy did not have archived data for the 2016-2017 period.

Only one hospital pharmacy out of (n=25) recruited pharmacies indicated that it was actively reporting AMC data centrally (Table 11).

Table 11: Characteristics of the 25 recruited community and hospital pharmacies in Kenya, 2016-2019

	Pharmacy Name	Level of Service#	Affiliation	Region	Record keeping*	Pharmacy system directly linked to patient records *†	AMC reporting*
Hospital pharmacies (co-located with AST laboratories) ~	Bungoma County Referral Hospital Pharmacy	5	Public	Bungoma	Manual	Partially	No
	Busia County Referral Hospital Pharmacy	4	Public	Busia	Manual	No	No
	Kenyatta National Hospital Pharmacy	6	Public	Nairobi	Manual/ Electronic	No	Yes
	Kilifi County Referral Hospital Pharmacy	4	Public	Kilifi	Manual	No	No
	Kisii County Referral Hospital Pharmacy	6	Public	Kisii	Manual/ Electronic	Yes	No
	Kitale County Referral Hospital Pharmacy	5	Public	Kitale	Manual/ Electronic	Partially	No
	Machakos County Referral Hospital Pharmacy	5	Public	Machakos	Manual/ Electronic	No	No
	Meru Teaching Referral Hospital Pharmacy	5	Public	Meru	Manual	No	No
	Moi County Referral Hospital Pharmacy	5	Public	Taita Taveta	Manual	No	No
	Private Hospital◊	5	Private	Nairobi	Electronic	Yes	No
	Nyeri County Referral Hospital Pharmacy	5	Public	Nyeri	Manual	No	No
	Thika County Referral Hospital Pharmacy	5	Public	Kiambu	Manual	No	No
	Wajir County Referral Hospital Pharmacy	5	Public	Wajir	Manual/ Electronic	Partially	No
	Mater Misericoridia Hospital	5	Private faith-based	Nairobi	Electronic	Yes	No
	Moi Teaching and Referral Hospital Pharmacy	6	Public	Eldoret	Electronic	No	No
Community pharmacies~	Scorpion Chemist	Dispensing	Private	Busia	Manual	N/A	No
	Malibu Pharmacy	Dispensing	Private	Nairobi	Electronic	N/A	No
	Transchem Pharmacy	Dispensing	Private	Nairobi	Manual	N/A	No
	Thwake Pharmacy	Dispensing	Private	Machakos	Electronic	N/A	No
	Cherangani Chemist	Dispensing	Private	Kitale	Manual	N/A	No
	Al Furqan Pharmacy	Dispensing	Private	Wajir	Manual	N/A	No
	Malibu Pharmacy - Vedic	Dispensing	Private	Nairobi	Electronic	N/A	No
	Othaya Chemist	Dispensing	Private	Nyeri	Electronic	N/A	No
	Health Aid Chemist	Dispensing	Private	Nairobi	Electronic	N/A	No
	Meredian Four Pharmacy	Dispensing	Private	Kisii	Electronic	N/A	No

◊ Hospital anonymous as per their request; AMC=antimicrobial consumption

† Refers to the ability of the pharmacy to link dispensing records with the patient's hospital records to obtain patient diagnostic and characteristic information

#A Level 4 hospital is a 50-100 inpatient bed hospital with an operating theatre, mortuary and radiology facilities, while a level 5 hospital is a 100-150 inpatient bed hospital with an operating theatre, mortuary, radiology, intensive care unit, and a level 6 hospital is a hospital with ≥ 150 inpatient beds, operating theatre, mortuary, radiology, intensive care unit.

~Hospital pharmacies refer to pharmacies located within a hospital providing medicinal products to in and out-patients of the hospital. Community or retail pharmacies refer to commercial pharmaceutical stores that provide medicinal products (prescription only and over-the-counter medicines) to a specific community group or region.

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 the WHO's protocol for conducting AMC analysis using the DDD-ATC-AWaRe methodology (Figure 18).[33-35] Each of these WHO methodologies and the additional conducted are described in brief below. In addition, and where possible, associations were drawn between AMC and AMR (see Part A, Section II:3c).

i. Defined Daily Dose (DDD)

DDDs and related metrics are utilised to analyse the AMC. The DDD metric allows for easy comparison by standardising the different doses in milligrams of antibiotics used in managing infections. Also, it is recommended to use drug utilisation figures such as DDD with a relevant denominator for the health context, such as numbers of DDDs/1 000 inhabitants/day (DAD), DDD/ inhabitant/year, or DDDs/100 bed days. Studying DDDs or associated metrics over time helps to understand the consumption pattern or determine whether national or facility-level interventions have led to positive or negative change (s) in the consumption patterns over the study period or a pre-defined base period.

Using the WHO 2020 DDD guide, the total consumed milligrams per antimicrobial were divided against the standard DDD value issued by the WHO to obtain total DDDs.[36] The total DDDs were then adjusted for the country's population in the year of data collection, 2016, 2017 and 2018,[37] and presented as DID. Pharmacy-level AMC data were to be adjusted as DDD per the number of inpatients and presented as DDD/100 patient bed days. However, DDD per 100 patient bed days was not computed at the point of analysis, as the patient bed days and patient days' information was not easily accessible in most facilities. Secondly, the lack of DDD per bed days hindered comparing hospital and community pharmacy consumption. Therefore, the AMC pharmacy-level data are presented as absolute DDD to aid comparison between hospital and community pharmacies. Detailed DDD calculations can be found in AMC Appendix 7. All calculations were done in Microsoft Excel ™ software.

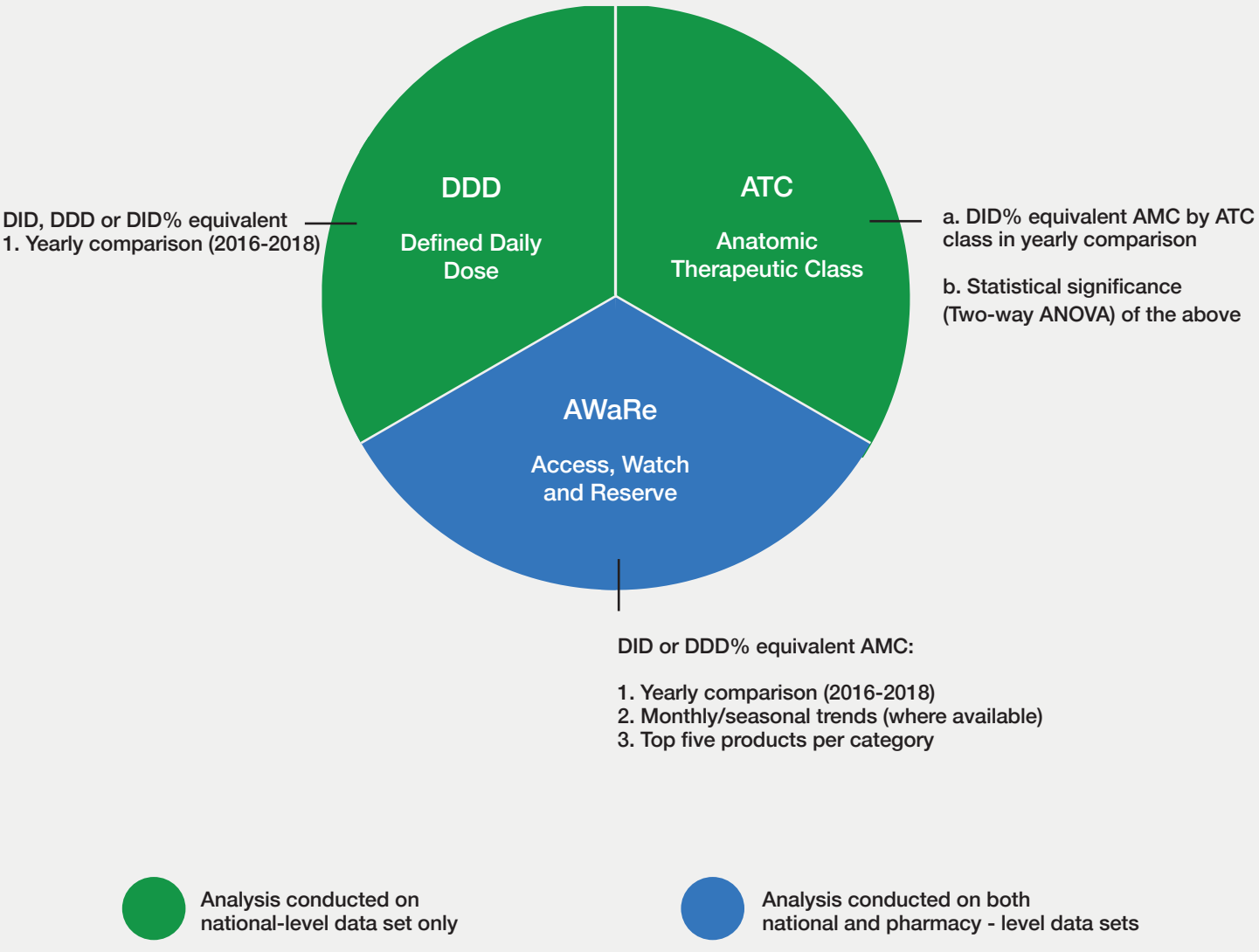
ii. Anatomic Therapeutic Chemical (ATC) Classification

The antimicrobials documented were coded by their standard antimicrobial names in the Excel analysis database per the 2020 WHO ATC codes (AMC Appendix 7) and then analysed to characterise the macro (above-molecule) AMC trends. In addition, the two-way analysis of variance (ANOVA) was used to determine year-on-year differences within each ATC class.

iii. WHO Access, Watch and Reserve (AWaRe)

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

We stratified the total AMC by DDDs per antibiotic molecule as either 'Access', 'Watch' or 'Reserve' categories per the 2019 WHO AWaRe list in Microsoft Excel ™. The total DDDs per each WHO AWaRe category was then analysed to determine the proportion of AMC per category and over time (yearly and monthly (where possible). The WHO recommends that at least 60% of a country's total AMC should come from the 'Access' antibiotics. Finally, we identified the top five antibiotics consumed in each WHO AWaRe category.



Defined Daily Dose (DDD) indicators utilised for volume metric standardisation were sourced from the WHOCC 2020. The ATC classification used to categorise the antibiotics according to the organ or system on which they act, and their therapeutic, pharmacological and chemical properties were sourced from the WHOCCC ATC database, and the 'Access', 'Watch' and 'Reserve' categorisation was sourced from the 2019 WHO AWaRe classification[35]

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

iv. Review of Essential Medicines List (EML)

According to the WHO, essential medicines are those that satisfy the priority health care needs of a population. They are selected with due regard to disease prevalence and public health relevance, evidence of efficacy and safety and comparative cost-effectiveness. They should always be available in functioning health systems, in appropriate dosage forms, of assured quality and at affordable prices for individuals and health systems. A document analysis was conducted in which the antimicrobials listed in the WHO EML were compared with the antimicrobials listed in the Kenya EML (KEML) and against the documented antimicrobials identified in the national- and pharmacy-level data collected. The comparison was conducted using the WHO AWaRe categories.

Results

National AMC datasets analysed by DDD per year

The average country AMC between 2016 and 2018 was 8.8 DDD per 1 000 inhabitants per day (DID). There was a 33% reduction in total consumption of antimicrobials from the year 2016 to 2017 and a 10% increase in consumption from 2017 to 2018. Overall, the results revealed an absolute reduction in total AMC between 2016-2018 (Figure 18).

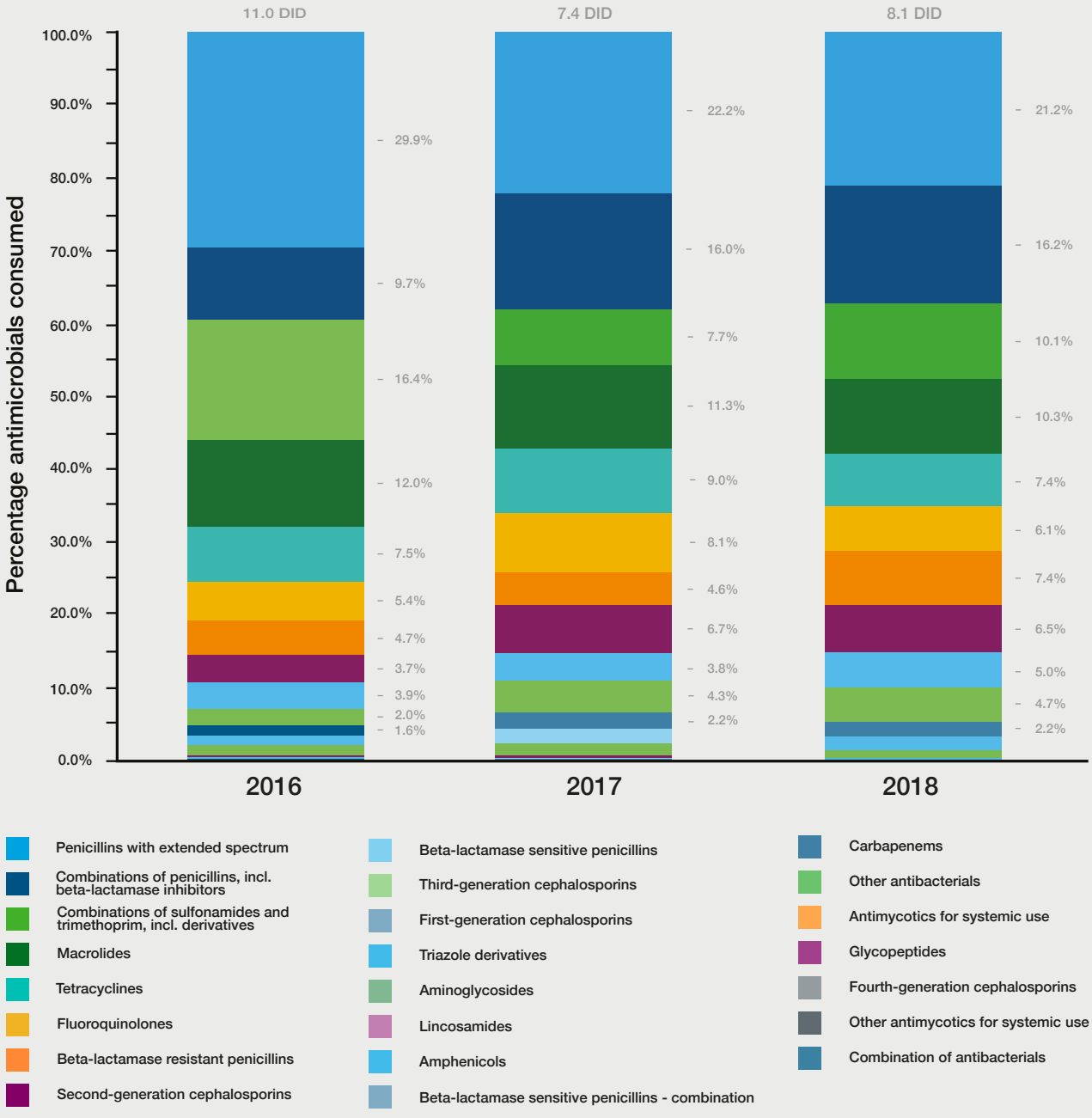
Abbreviations: DDD=defined daily dose

Figure 18: variation in the national-level DID per 1 000 inhabitants per day in Kenya, 2016 to 2018

National AMC analysed by ATC classification

Extended-spectrum penicillins (J01CA) were the most frequently consumed ATC class in Kenya across the review period at 29.9% in 2016, 22.2% in 2017 and 21.2% in 2018. Amoxicillin was the most frequently consumed extended-spectrum penicillin (J01CA) (Figure 20). Combinations of penicillins and beta-lactamase inhibitors (J01CR) and combinations of sulfonamides and trimethoprim, including derivatives (J01EE), were the second and third most consumed ATC classes. Fixed dose combinations (FDC) of amoxicillin/clavulanic acid and sulfamethoxazole/trimethoprim led consumption within these ATC classes, respectively. Sulfamethoxazole/trimethoprim exclusively accounted for 100% of the consumption within the combinations of sulfonamides and trimethoprim class. The top five most consumed antimicrobials were amoxicillin, sulfamethoxazole/trimethoprim, ampicillin/cloxacillin, erythromycin and doxycycline. Together they accounted for >58% of the total consumption share. A detailed breakdown of the national AMC by antimicrobial molecule and by ATC class are presented in AMC Appendix 8 and AMC Appendix 9, respectively.

Between 2016 and 2018, there was a decrease in the consumption of antimicrobials. However, the percentage consumption share of some ATC classes increased notably during the same period, such as penicillins with beta-lactamase inhibitors (from 9.7% to 16.2%) and beta-lactamase resistant penicillins (from 4.7% to 7.4%).



Penicillins with extended-spectrum were the most consumed antimicrobials in all the reviewed years (2016 to 2018). Significant changes (between 2016 and 2018) in consumption were noted for the following ATC classes: other antibacterial, a 65% increase; penicillins with extended-spectrum, 47% decrease; combinations of sulfonamides and trimethoprim, 54% decrease; amphenicol, 61% decrease; antimycotics for systemic use, 76% decrease; and fourth-generation cephalosporins, 49% decrease. See AMC Appendix 9 for a more detailed breakdown of the AMC by ATC classes

Figure 19: National-level AMC in Kenya, 2016-2018

The average national consumption of antibiotics across the three years analysed was 70.4% 'Access', 29.6% 'Watch' and <0.1% 'Reserve'. The percentage consumption share of 'Access' antibiotics reduced from 74.9% in 2016 to 68.7% in 2018, and an increased consumption share of 'Watch' antibiotics in 2017 and 2018 compared to 2016 (Figure 21). On average and within each year analysed, consumption of 'Access' category antibiotics in Kenya exceeded the 60% minimum consumption threshold set by the WHO. This national AMC by the WHO AWaRe categories omits 7.7% (0.9 DID) of total AMC antimicrobials that are not categorised within the WHO AWaRe list of 2019.

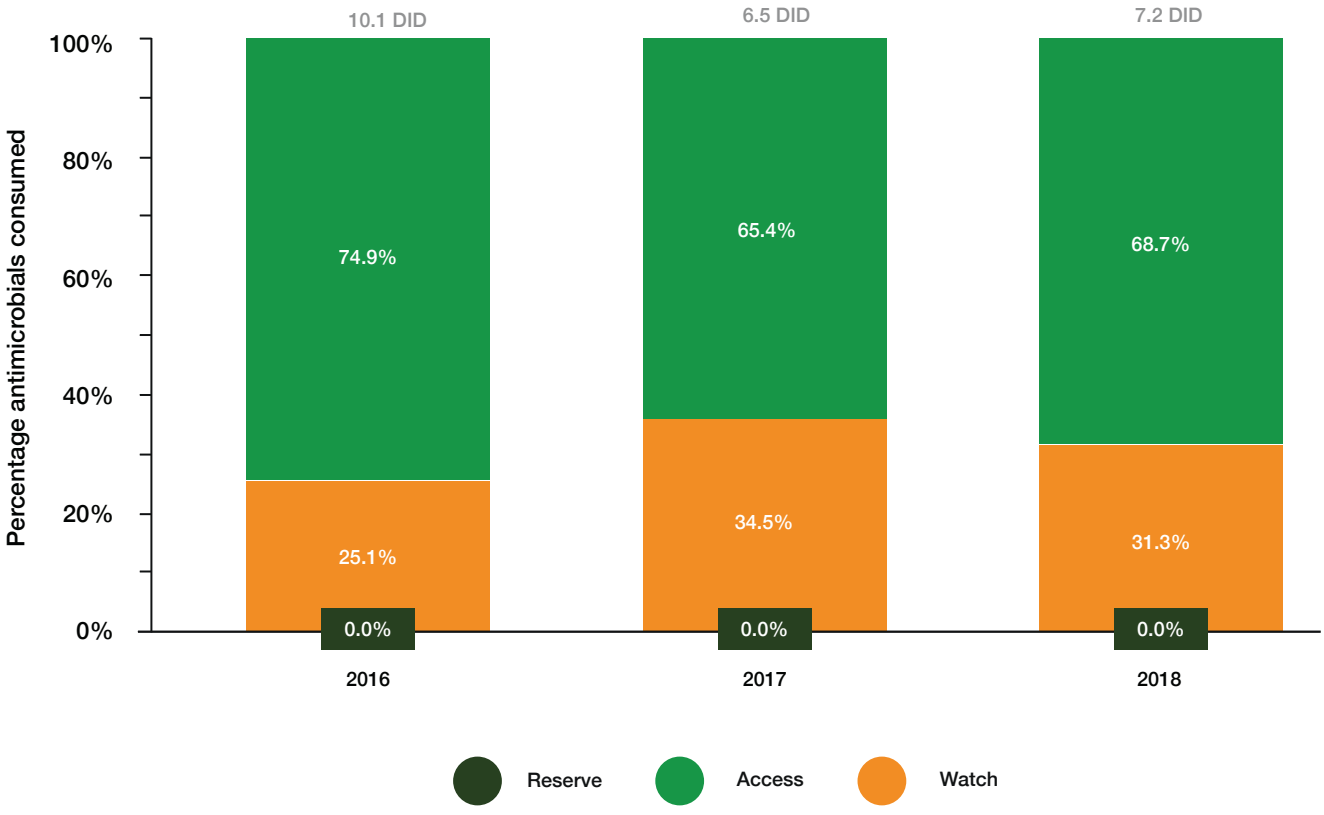
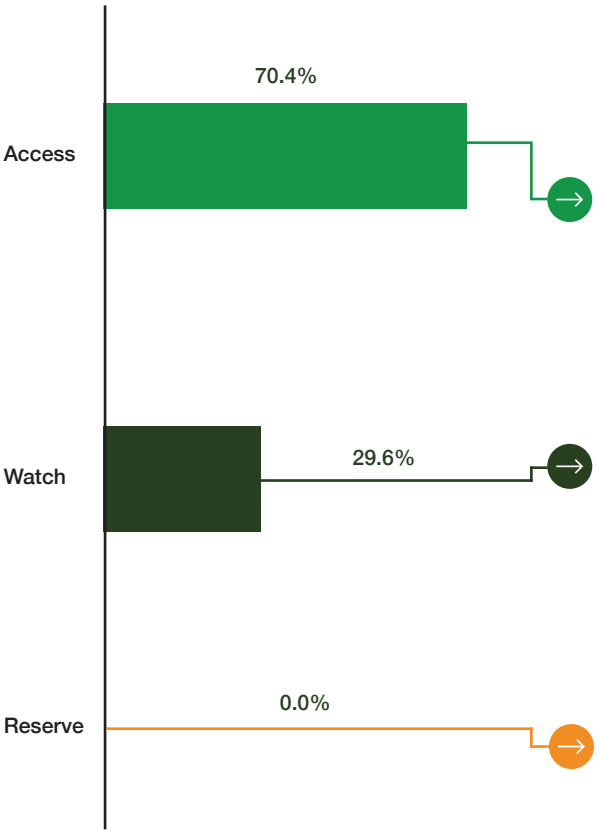


Figure 20: AMC per the WHO AWaRe categories in Kenya, 2016 to 2018

Further analysis was done to identify the most frequently consumed antibiotics nationally within each WHO AWaRe category (Figure 22). In the 'Access' category, the top five most frequently consumed antibiotics accounted for 83.4% of the category's consumption. While in the 'Watch' category, the top five consumed antibiotics accounted for 77.6% of all the consumption within this group. In the 'Reserve' category, national consumption was only recorded for two antibiotics and included linezolid (97.1%) and tigecycline (2.9%).



Molecule Name	% Total	Mean DDD/1000 inhabitants/ day
Amoxicillin	38.9%	2.2
Sulfamethoazole/ Trimethoprim	19.0%	1.1
Doxycycline	10.1%	0.6
Amoxicillin/Clavulanic Acid	7.8%	0.4
Flucloxacillin	7.7%	0.4

Molecule Name	% Total	Mean DDD/1000 inhabitants/ day
Erythromycin	24.2%	0.6
Cefuroxime	20.3%	0.5
Azithromycin	13.5%	0.3
Levofloxacin	9.9%	0.2
Ciprofloxacin	9.7%	0.2

Molecule Name	% Total	Mean DDD/1000 inhabitants/ day
Linezolid	97.1%	0.0
Tigecycline	2.9%	0.0

Abbreviations: DDD=defined daily dose

Figure 21: The top five most consumed 'Access', 'Watch' and 'Reserve' antibiotics consumed at the national level in Kenya, 2016 - 2018

Within the WHO AWaRe database, there exists a list of 'antibiotics not recommended'. This group of antibiotics consists of fixed-dose combination (FDC) of multiple broad-spectrum antibiotics that are neither evidence-based nor recommended in high-quality international guidelines. As a result, the WHO does not recommend their use in clinical practice. These antibiotics are represented as 'uncategorised' by the MAAP and were consumed in the country. Nine of these 'not-recommended' antibiotics were consumed, representing 8.1% consumption of the total national AMC (Table 12). Among them, the FDC of ampicillin/ cloxacillin was the most frequently consumed, accounting for 99.5% of the total 'not recommended' antibiotics consumption (Table 12), with a mean DID of 0.7. This FDC antibiotic was also found to be the third most frequently consumed antimicrobial in the overall national dataset analysed (AMC Appendix 8).

Table 12: AMC rank of the WHO AWaRe 'not recommended' antimicrobials in Kenya, 2016-2018*

Overall AMC rank*	Not recommended combination
3	Ampicillin/Cloxacillin
35	Cefuroxime/Clavulanic Acid
37	Cefixime/Clavulanic Acid
49	Ceftriaxone/Sulbactam
50	Cefpodoxime proxetil/Clavulanic Acid
53	Amoxicillin/Sulbactam
57	Ofloxacin/Ornidazole
60	Levofloxacin/Ornidazole
61	Cefoperazone/Sulbactam

*AMC rank reports the position of antibiotics consumed (in terms of the total defined daily dose per 1 000 inhabitants per day (DID) and percentage share) from the reviewed list of antimicrobials in Kenya (see AMC Appendix 8 for the consumption rate of each listed antibiotic).

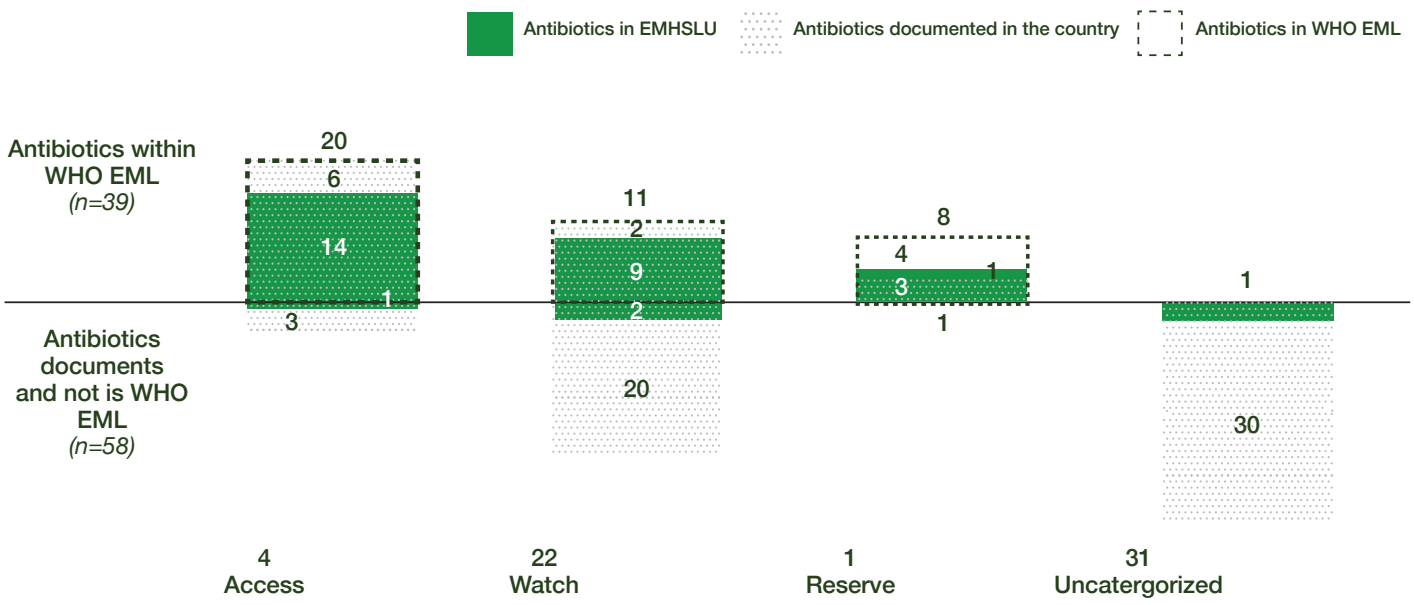
Aggregated pharmacy-level data from the (n=25) participating pharmacies were examined by the pharmacy type (hospital-based or community-based) and their proportional consumption of WHO AWaRe categories. Community pharmacies consumed 14% more 'Watch' category antibiotics than hospital pharmacies. However, the hospital and community pharmacies met the WHO threshold of 60% consumption of antibiotics from the 'Access' category. The hospital pharmacies far exceeded the threshold (81.4%) compared to community pharmacies which consumed 67.8%. Further analysis identified the reasons for the 13.6% higher consumption of 'Access' antibiotics within the hospital pharmacies. The (n=6) public hospital pharmacies recorded high sulfamethoxazole/trimethoprim consumption, accounting for 70% to 96% of the 'Access' group consumption. The high consumption of sulfamethoxazole/trimethoprim skewed the data towards the 'Access' category and rendered observations of consumption of other antibiotics difficult to interpret. Therefore, to ensure a clearer representation of consumption of other 'Access' antibiotics, consumption data of sulfamethoxazole/trimethoprim was excluded. Following this exclusion, a reduction of 14% in the average AMC consumption share of 'Access' group antibiotics within the public hospital pharmacies was observed (Table 13). There was no significant change for the community pharmacies in the consumption of sulfamethoxazole/trimethoprim. Despite this shift, hospital and community pharmacies maintained an average consumption of greater than 60% for the 'Access' group antibiotics (hospital pharmacies 67.4%, community pharmacies 66.0% 'Access' antibiotic consumption). However, within the hospital pharmacies, one level 5 private hospital and three public hospitals failed to meet the WHO 'Access' antibiotics consumption threshold. Also, within the community pharmacies, four failed to meet the WHO 'Access' antibiotics consumption target. Scrutiny of the hospital pharmacies data showed that level 4 facilities recorded zero consumption of 'Reserve' antibiotics, while all the 'Reserve' group antibiotic consumption from level 5 facilities were recorded from the private (n=1) and faith-based (n=1) hospitals.

Table 13: The percentage share of total antibiotics consumption per the WHO AWaRe categories at the hospital and community pharmacies in Kenya, 2016-2018

Pharmacy Type	AWaRe Categorisation		
	Access	Watch	Reserve
	Percentage share (Absolute DDD)		
Community pharmacies (10/15)	67.8% (5 096 million)	32.2% (2 423 million)	0.0% (395.5)
Hospital pharmacies	81.4% (27. 7 million)	18.5% (6.3 million)	0.1% (19 072.8)
Level 4 facilities (2/15)	96.7% (3.8 million)	3.3% (131 791.1)	0.0% (0)
Level 5 facilities (10/15)	80.4% (19.6 million)	19.5% (4.8 million)	0.1% (17 317.7)
Level 6 facilities (3/15)	75.0% (4.2 million)	24.9% (1.4 million)	0.0% (1 755.1)
Private (1)/ faith-based (1) hospitals (2/15)	69.3% (8.8 million)	30.6% (3.9 million)	0.1% (17 317.7)
Public hospitals (13/15)	88.7% (18.9 million)	11.3% (2.4 million)	0.0% (1 755.1)
Grand Total	67.8% (5 124 million)	32.2% (2 429 million)	0.0% (19 468.3)
Excluding outlier sulfamethoxazole/trimethoprim			
Community pharmacies (10/15)	66.1% (4 713 million)	34.0% (2 423 million)	0.00% (395.5)
Hospital pharmacies	67.4% (13.1 million)	32.5% (6.3 million)	0.1% (19 072.8)
Level 4 facilities (2/15)	74.7% (3 88 7 80.4)	25.3% (131 791.1)	0.0% (0)
Level 5 facilities (10/15)	68.1% (10.2 million)	31.8% (4.8 million)	0.1% (17 317.7)
Level 6 facilities (3/15)	63.7% (2.5 million)	36.2% (1.4 million)	0.1% (1 755.1)
Private (1)/ faith-based (1) hospitals (2/15)	69.1% (8.7 million)	30.8% (3.9 million)	0.1% (17 317.7)
Public hospitals (13/15)	64.2% (4.3 million)	35.8% (2.4 million)	0.0% (1 755.1)
Grand Total	66.1% (4 726 million)	34.0% (2 429 million)	0.0% (19 468.3)

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

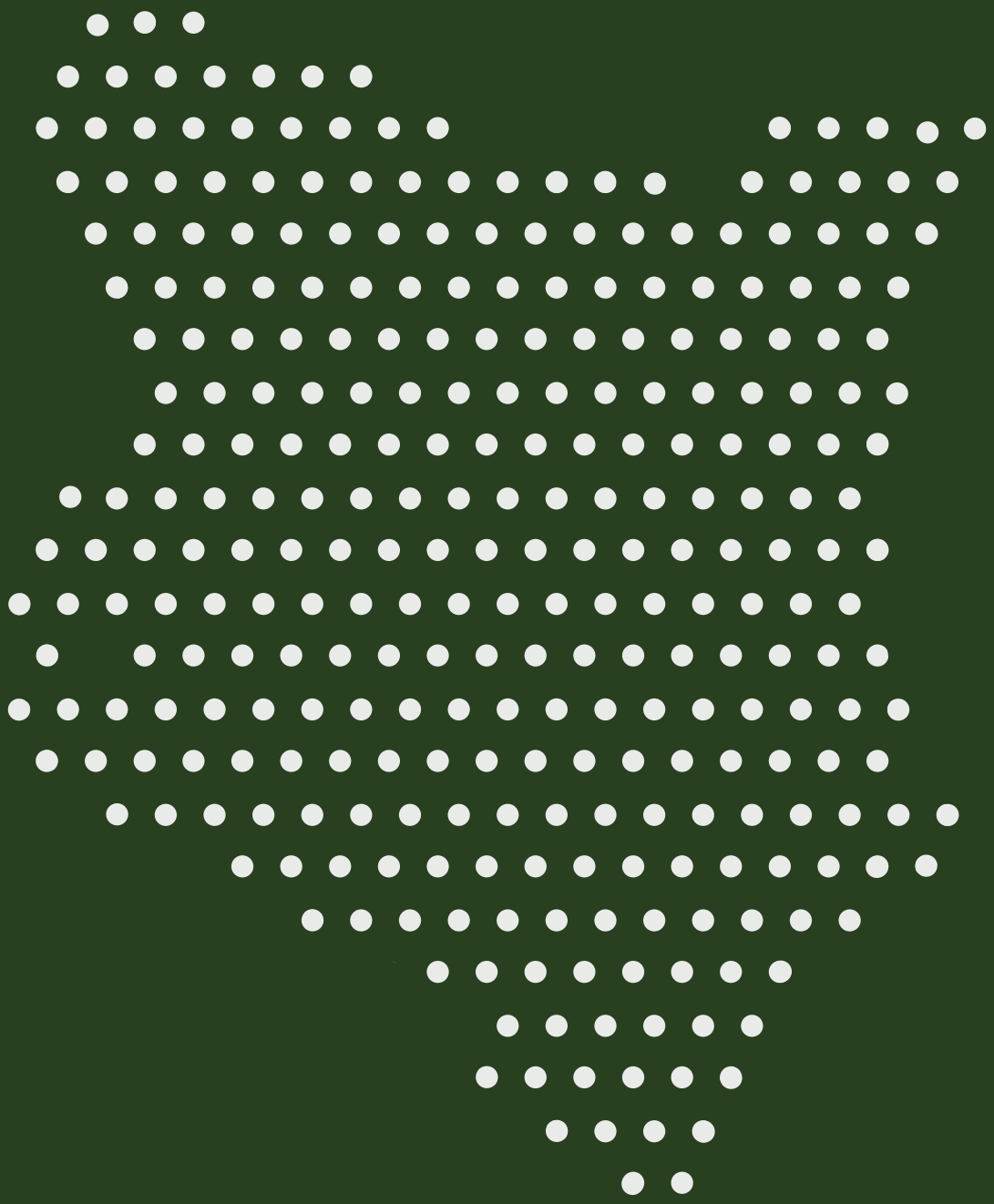
The WHO EML includes 39 antibiotics across the AWaRe categories. Ninety-seven antimicrobials were documented during national-and pharmacy-level data collection (Figure 22). Six antibiotics in the 'Access' category and two in the 'Watch' category were listed in the WHO EML and documented during data collection, but they are not part of the KEML. In the 'Reserve' category, four antibiotics are part of the WHO EML but are not listed in the KEML nor documented during data collection. For each AWaRe category, including the uncategorised, 30 antimicrobials were documented during data collection but were neither part of the WHO EML nor KEML (AMC Appendix 10).



Abbreviations: WHO=World Health Organisation; EML=Essential Medicines List, KEML=Kenya Essential Medicines List

Figure 22. Documented antibiotics in national- and pharmacy-level data in Kenya, 2016-2018 compared to WHO- and Kenya Essential Medicine List definitions

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 were 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[38,39] (AMR Appendix 8) and communicated the effectiveness of antibiotic therapy to decision-makers. The DRI values range from 0 (100% susceptibility) to 100 (100% resistance). Available AST results for at least 30 tested isolates and 15 of the 25 combinations were prerequisites for estimating the DRI. The variance of the proportions of non-susceptible isolates was combined with a uniform standard deviation based on the estimated DDD to generate CIs for the DRI as the variance of the product of variables.[40,41]

Apart from the DRI, the correlation between AMC and AMR was conducted. Data on antimicrobial consumption were obtained from facilities 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). A Pearson's correlation analysis was performed to determine the correlation 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 the previously described methodology, the resistance of all pathogens tested against the most and least consumed antimicrobial classes is reported by the laboratories and based on data availability in each study year.

Results

Drug Resistance Index

The DRI estimate was found to be moderately high at 56.2% (95% CI, 42.1–70.3%), implying low antibiotic effectiveness, which is a threat to effective infectious disease management and calls for urgent policy interventions (Figure 23).

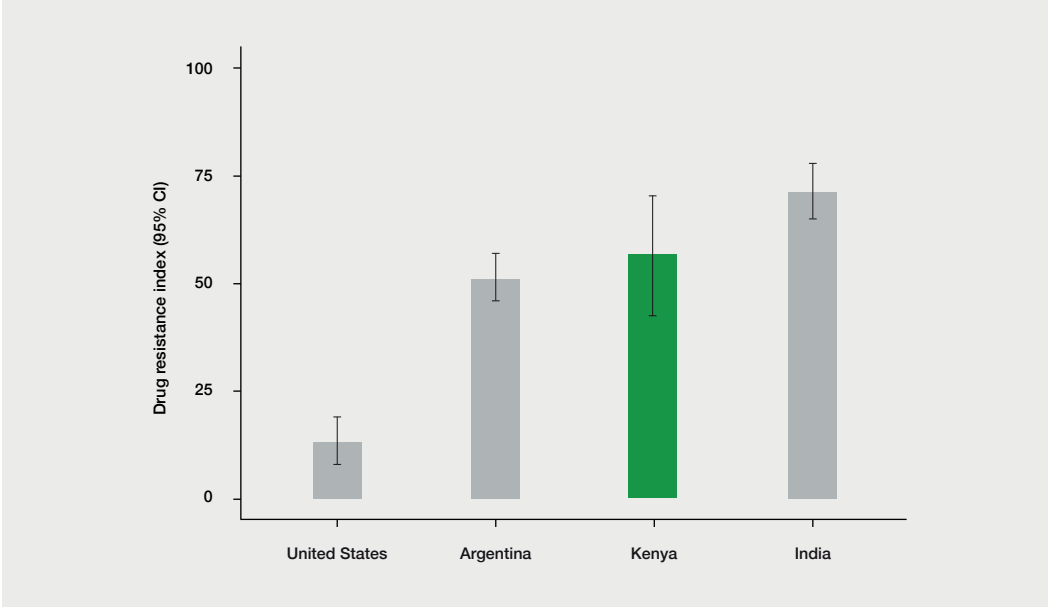


Figure 23: Drug Resistance Index of Gabon, 2016-2018, compared to the drug resistance index estimates for the United States, Argentina and India

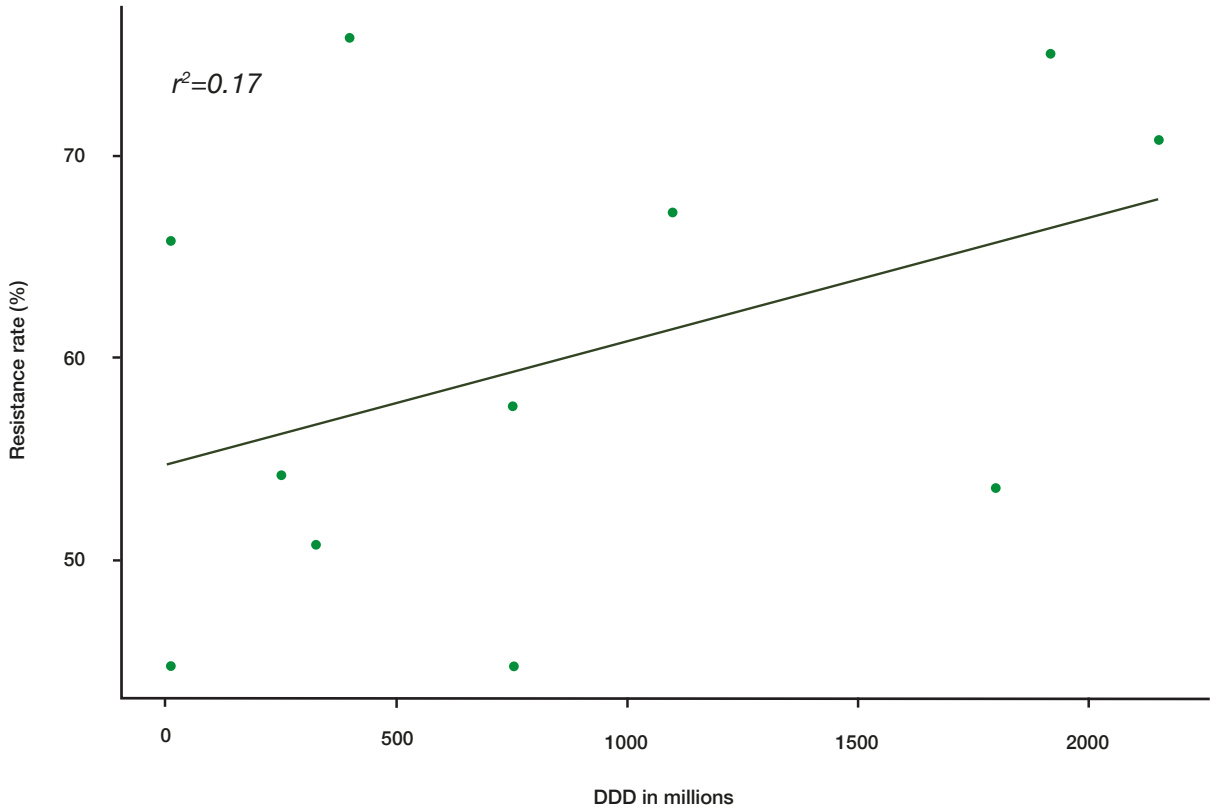
AMC and AMR correlation

The top three highly consumed antibiotic classes at the facility level were cephalosporins (3rd generation), penicillins and beta-lactam combinations. The AMR rates were highest for third-generation cephalosporins (70.9%), penicillins (75.2%) and folate pathway inhibitors (75.9%) (Table 14). Pearson's correlation analysis revealed a moderate positive correlation (r^{22}=0.17) between AMR and AMC, implying that the latter is a potential driver of AMR in Kenya (Figure 24).

Table 14: AMC and AMR rates across antibiotic classes

Antibiotic class	Year	Total DDD in thousands	Resistance rate (%)
Cephalosporins (3rd generation)	2016-18	2 150.76	70.9%
Penicillins	2016-18	1 914.67	75.2%
Beta-lactam combinations	2016-18	1 793.26	53.5%
Aminopenicillins	2016-18	1 095.64	67.1%
Aminoglycosides	2016-18	753.88	44.6%
Tetracyclines	2016-18	753.55	57.5%
Folate pathway inhibitors	2016-18	397.72	75.9%
Methicillin	2016-18	324.60	50.6%
Cephalosporins (2nd generation)	2016-18	252.39	54.2%
Macrolides	2016-18	14.15	65.8%
Fluoroquinolones	2016-18	11.75	44.6%
Nitrofurans	2016-18	1.72	41.8%
Cephalosporins (1st generation)	2016-18	1.09	52.4%
Lincosamides	2016-18	0.78	44.6%
Carbapenems	2016-18	0.07	33.4%

Abbreviations: DDD=defined daily dose



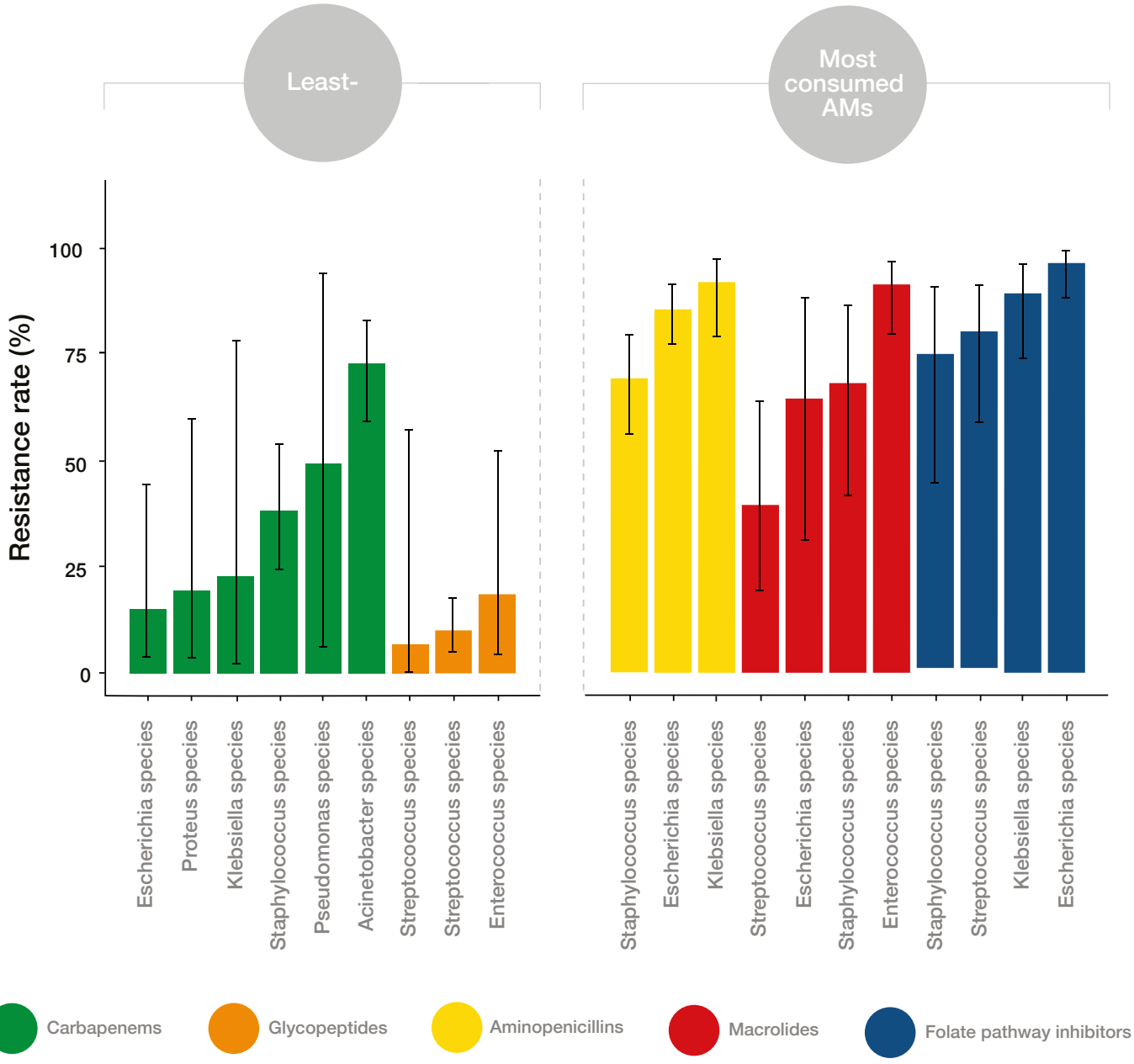
Abbreviations: DDD=defined daily dose

Figure 24: Correlation between AMR and AMC in Kenya, 2016-2018

Resistance profiles of the most and least consumed antimicrobial classes

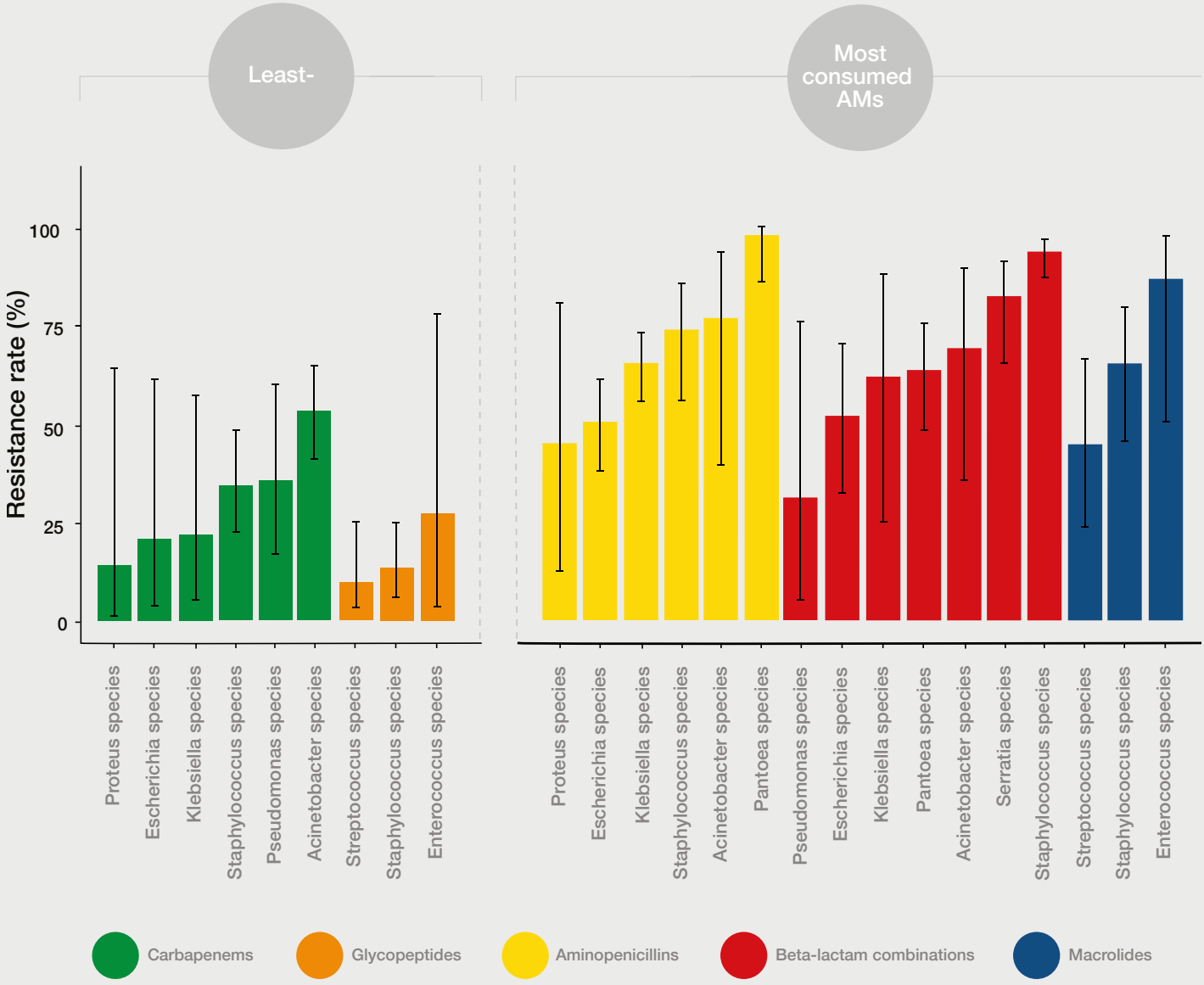
The most consumed antimicrobial classes across the study years were aminopenicillins, macrolides, folate pathway inhibitors, and beta-lactam combinations. In 2016, resistance rates were more than >75% for folate inhibitor-resistant Escherichia species, Klebsiella species, and Streptococcus species, macrolide-resistant Escherichia species, Klebsiella species, and aminopenicillin-resistant Klebsiella species and Escherichia species. In 2017, there were high rates (>75%) for beta-lactam-resistant Staphylococcus species and Serratia species, macrolide-resistant Enterococcus species and aminopenicillin-resistant Pantoea species. In 2018, the highest rates (>75%) of macrolide-resistant Vibrio species, Enterococcus species and Escherichia species and aminopenicillin-resistant Vibrio species were observed (Figures 25, 26 and 27).

The least consumed antimicrobial classes across the study years were carbapenems and glycopeptides. Even though the consumption of these antimicrobial classes was low, there were high resistance rates across many pathogen-antimicrobial class combinations. For example, in 2016 and 2017, resistance rates were more than >50% for carbapenem-resistant Acinetobacter species. In 2018, resistance rates to carbapenem were more than >75% in Vibrio species and Acinetobacter species (Figures 25, 26 and 27).



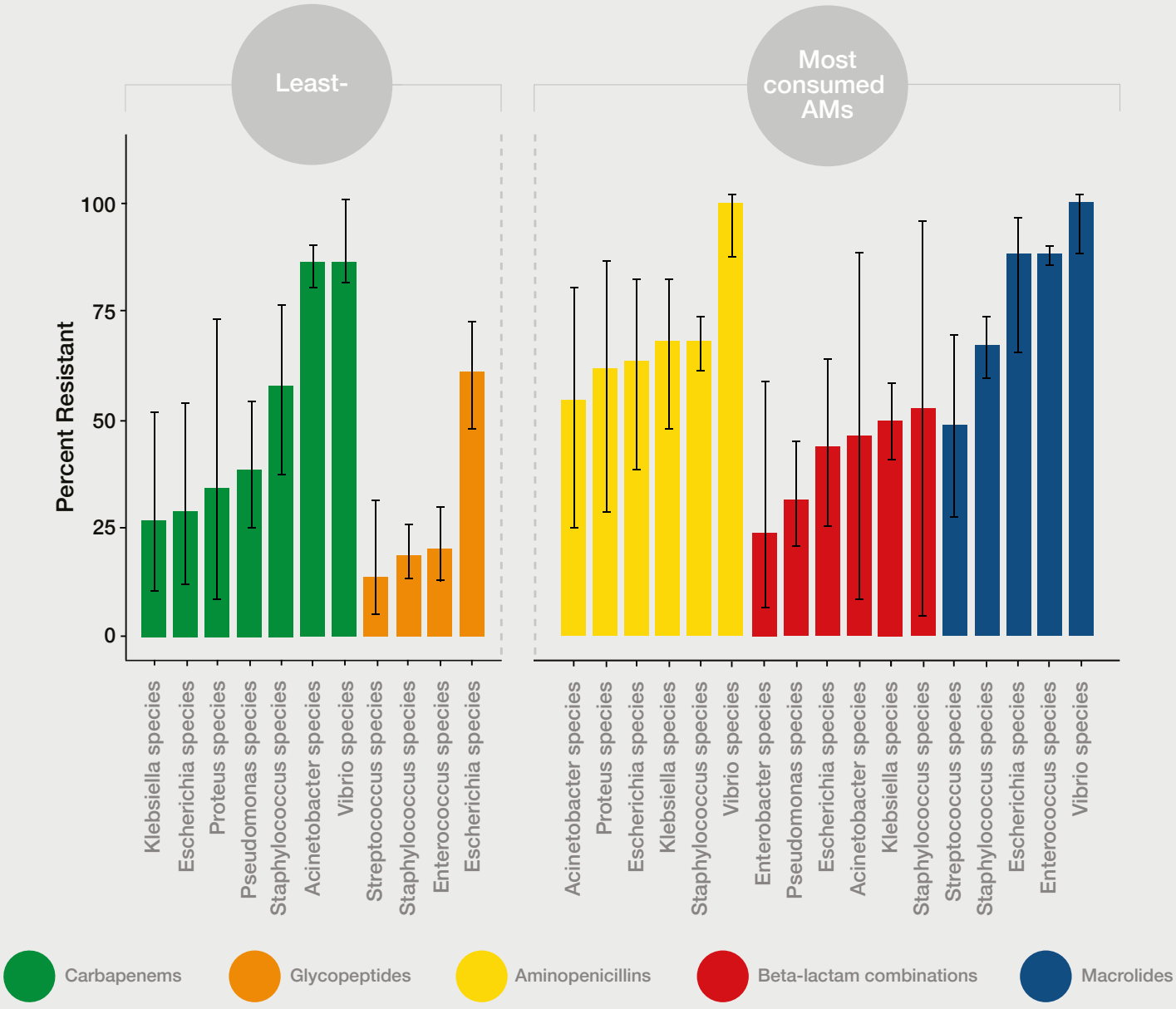
Abbreviations: AMs= antimicrobials

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



Abbreviations: Least cons. AMs=least consumed antimicrobials; Most cons. AMs=most consumed antimicrobials

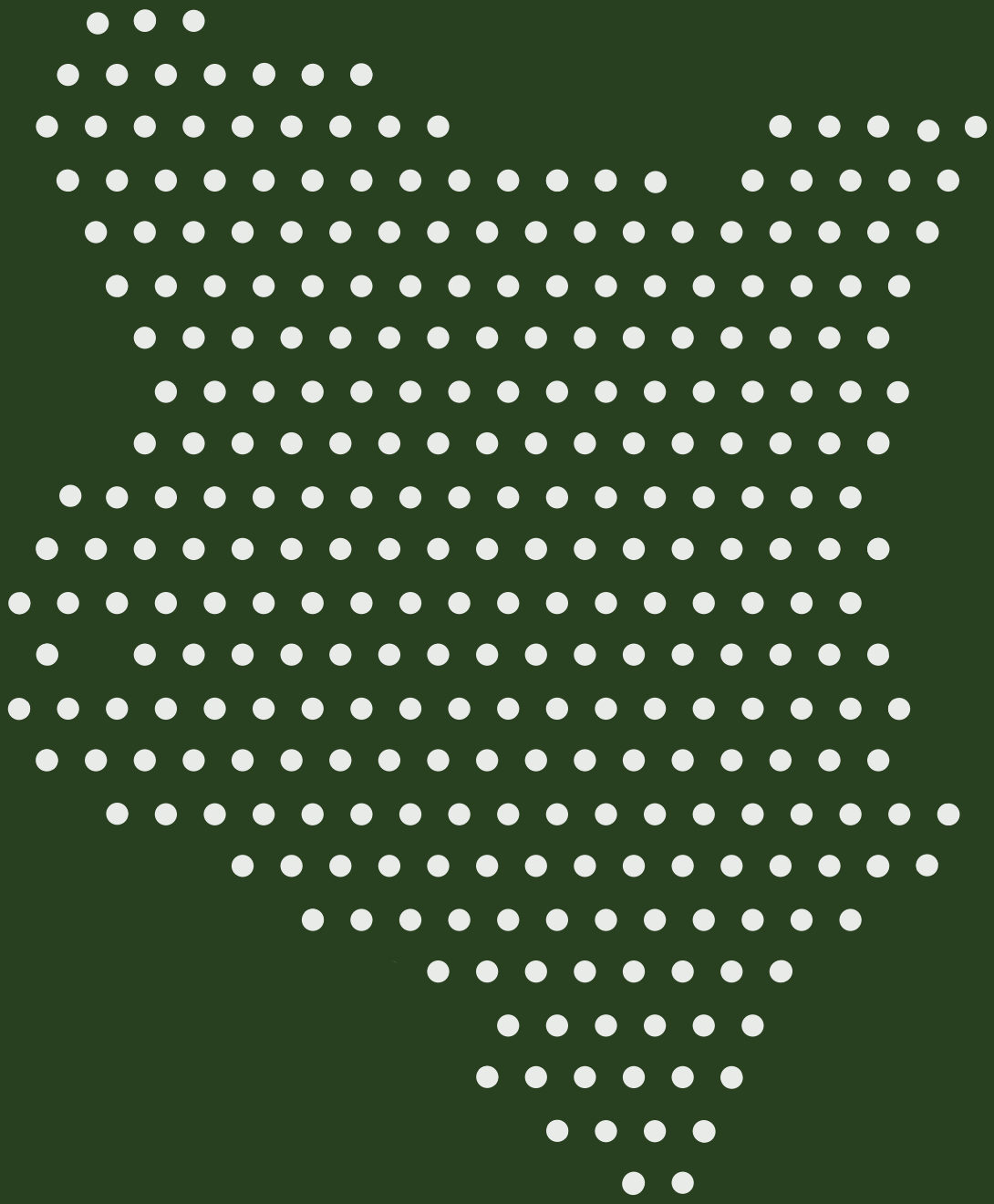
Figure 26: AMR rates for the least (left) and the most (right) consumed antimicrobial classes in Kenya in 2017



Abbreviations: AMs= antimicrobials

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

Part D: Recommendations



AMR is a major threat to medical advancements and has drawn global attention over the past few years, even more so with the recent COVID-19 pandemic. Unfortunately, the AMR burden is not well quantified in most countries due to inadequate surveillance data. A recent review reported the 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.[42]

Mitigating AMR calls for a multipronged approach that involves building resilient health and oratory systems and improving AMR stewardship (diagnostic, antimicrobial use, and infection prevention). Therefore, based on our study findings, we propose recommendations to strengthen AMR surveillance in Kenya.

Significance of AMR and DRI data and recommendations

Analysis of available AMR data from Kenya revealed high levels of third-generation cephalosporin-resistant Enterobacterales (67-73%), carbapenem-resistant P. aeruginosa (36-51%) and MRSA (40-52%).

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

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 driver of carbapenem resistance in P. aeruginosa. Other risk factors include extended ICU stay, invasive devices, prolonged bladder catheterisation, underlying comorbidities (such as diabetes and cystic fibrosis), burns and immunocompromised status. Since resistant pseudomonas infections are often fatal, it is essential to promptly initiate appropriate treatment and adopt simple source control measures, such as standard precautions (e.g., hand hygiene), catheter care, early device removal, and compliance with the infection prevention bundles. AMS and infection control programmes must be established as it provides concerted efforts for AMR control.

S. aureus (methicillin-resistant or sensitive) is a common cause of many skin and soft tissue infections (SSTI) 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, trauma, use of invasive devices (catheters, shunts, implants, 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 treatment modalities, preventing and controlling the spread of MRSA infections are also important. The use of catheters and invasive devices must be minimised, and stewardship principles should be practised, including taking culture specimens before initiating antibiotics therapy 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.

The estimated DRI for Kenya is also moderately high and indicates decreasing effectiveness of antimicrobials. This DRI calls for targeted interventions, such as improved ASP, infection prevention and regulations on the use of high-end antibiotics. Also, we observed that the male and the elderly were more prone to resistant infections, though further studies will be needed to establish the connection.

Service delivery

The laboratory network in Kenya consisted of 1 037 laboratories, of which only 64 were bacteriology laboratories, and 56 confirmed their AST capabilities. While most of the surveyed laboratories reported implementing QMS, not all were certified or accredited. The laboratories did not equitably cover the country's population of over 53.7 million. The testing load (quantum of cultures) at most participating laboratories was less and suggested a lack of routine microbiology testing. There is also the likelihood of overestimated AMR rates as most tests would have been conducted on special patient categories, such as those unresponsive to first-line therapy or those in the ICU).

To strengthen the delivery of services by the laboratories, we recommend that all laboratories get mapped across a range of indicators, including population coverage, infectious disease burden, testing capabilities, and quality compliance. This mapping would inform decision-makers of unmet needs and inform laboratory network expansion approaches. A more extensive network also provides a richer sampling frame for better representation and generalisation of results.

Health workforce

As reported by the surveyed laboratories, 88% had an experienced laboratory scientist or technologist, 61% had up-to-date records on training and competence, and only 50% had at least one qualified microbiologist. For high-quality microbiology testing and reporting, it is essential to train staff on laboratory standards, common pathogen identification and data management skills[27]. Staff capacity building may be achieved by leveraging in-house expertise or outsourcing to external organisations or tertiary facilities.

Information systems

The Regional Grant was a step towards collecting and digitising data. Most surveyed laboratories relied on paper-based records, and very few linked patients' clinical records. In the current study involving 16 laboratories over three years, susceptibility results were collected for just 16 027 positive cultures.

It is essential to curate the right data and generate robust evidence to strengthen AMR surveillance. We recommend standardised formats for data collection at all levels (laboratories, clinics and pharmacies) and automated data analyses. For the current study, we used WHONET for data digitisation. Empirical guidelines for infectious disease management should be based on the specific epidemiology of the patient's setting, and AMR data should be shared with national and supra-national platforms. We also recommend establishing a system of assigning permanent identification numbers for tracking patients over time. Permanent patient identification numbers would help collect and link patients 'clinical profile, antimicrobial history, and pathogen(s)'s molecular profile (where available), thus offering more context to the AMR epidemiology than stand-alone AST 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 inappropriate testing that made the data unfit for analysis. The results of inappropriate tests can be misleading and impact patient care.

It is imperative to generate reliable laboratory results using appropriate testing methods and authorised surrogates while ensuring uninterrupted reagents availability, including reagents for AST. Improving supply chains for essential reagents should be a country's priority, and interruptions in routine testing must be minimal. Standardising testing methods across laboratories allows for pooled purchases coordinated by the MoH. All laboratories and testing centres must conform to the AST quality standards and aim for accreditation and quality certification status.

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

Significance of AMC and AMU data and recommendations

This section discusses the significance of our AMC and AMU findings and suggests recommendations for Kenya to improve future surveillance and AMS activities.

Feasibility of obtaining AMC and AMU data in Kenya and recommendations

The MAAP successfully collected and analysed national and pharmacy-level AMC data; this indicates the possibility of conducting routine AMC surveillance in the country, and Kenya can respond to the WHO's call to participate in the GLASS, which now has an AMC reporting component. In Kenya, the recently published National Antimicrobial Stewardship Guidelines for healthcare settings in Kenya (Ministry of Health, 2020) provides the framework to enable AMC surveillance. However, updated future releases of this document could build on the specific principles required for AMC data collection and reporting, for which recommendations are provided further down. To make future AMC surveillance more time and cost-efficient, hospitals could consider converting to electronic systems and ensure such systems can transfer data across systems and or produce user-friendly reports on AMC.

The MAAP could not obtain AMU data in Kenya, which would have helped to characterise antimicrobial prescriptions at the facility level in line with the WHO's drug use research methodology.[43] This inability to collect AMU data from participating AST-laboratory-co-located pharmacies was because the AMC data sources (i.e., stock cards at the pharmacy) did not allow back-tracing to individual patients antimicrobials were dispensed to, as prescription chits were not archived. Hence, retrieving the relevant clinical and laboratory files for any patients who received antimicrobials was impossible. Nevertheless, a few studies which reported AMU data in Kenya have been documented,[30,31] and AMU data were collected through prospective study design (point-prevalence survey).[34]

The MAAP was, however, unable to extrapolate the findings from these AMU studies to help elaborate our AMC findings as these studies sampled few facilities and conclusions drawn from them would likely be inapplicable on a national scale. Nonetheless, the success of these AMU studies perhaps implies that retrieval of AMU data where sub-optimal data systems exist can only be achieved through prospective study, for which data collection systems are intentionally set up to follow the patient in real-time through the cascade of care. Retrospective studies similar to this MAAP study may not be ideal.

Therefore, the MAAP, per the WHO guide on facility AMU assessment, recommends that future AMU surveillance attempts in the country be prospective data collection approaches.[34] However, such an approach is time-consuming, unlike retrospective data collection, and often requires specialised data collection teams, making it expensive and challenging to undertake in resource-limited settings. Retrospective AMU data collection remains an option if targeted facilities have electronic patient records and cross-department unique patient identifiers.

Overview of AMC consumption trends and recommendations

To the best of our knowledge, the total AMC levels documented in this report provide the first AMC quantification in Kenya. Our data can serve as a useful benchmark to assess the impact of future country ASPs. Compared to studies from other countries in the region, the observed AMC levels in Kenya exceeded levels described in the literature for Burundi but were lower than the levels described in other African countries such as Burkina Faso, Cote d'Ivoire,[23] Sierra Leone[28] and Tanzania[44]. Methodological differences may have contributed to the differences. Our data for Kenya included public and private wholesaler data, whereas Burundi used only data from the public sector, representing hospital use. Kenya's AMC levels are lower than Tanzania's, probably because the population DDD was calculated using import data that lacks local production data and is uncorrected for exports. The disparities in AMC within the compared countries might be due to differences in the burden of infectious diseases and limited availability of laboratory and point-of-care diagnostics at the health facility level. These factors may lead to presumptive treatment and unnecessary prescription of antimicrobials. The widespread availability of antimicrobials over the counter and unexplained use of some antimicrobials in the animal health sector may be additional contributing factors.[23] Despite the lower rates of AMC in Kenya, AMU point-prevalence surveys are recommended to determine the country's AMC levels and eventually guide any future national action plans to optimise antimicrobials consumption.

Evaluation of antibiotics consumption according to the WHO AWaRe categories revealed that the consumption of narrow-spectrum antibiotics in the 'Access' category exceeded the minimum WHO[13,23] recommended consumption threshold and fair consumption of broader spectrum 'Watch' class antibiotics. This consumption trend is commendable as it implies that any emerging AMR trends due to misuse or overuse will likely be restricted to narrow-spectrum antibiotics, sparing the less used broader-spectrum antibiotics in the 'Watch' category. However, a closer examination of the spectrum of antibiotics used within each WHO AWaRe category revealed that an overwhelming majority of antibiotics consumed within the 'Access' and 'Watch' categories were the top five medicines in each category. Such a consumption pattern is sub-optimal and serves as a selective pressure for evolutionary resistance of the narrow-band antibiotics.[45] This narrow consumption of antibiotics within the 'Access' and 'Watch' classes can also make the country susceptible to stockouts if manufacturing and supply chain issues are encountered for these few antibiotics. Therefore it is recommended that the country's ASPs ensure a wider spread in consumption of the antibiotics within each WHO AWaRe category (such as revision of national treatment guidelines) to avoid such eventualities, which should go hand-in-hand with ensuring appropriate use and resistant patterns in Kenya.

Interestingly, in the review of the pharmacy-level usage of 'Access' category antibiotics, hospital pharmacies showed a very high consumption of 'Access' antibiotics compared to the community pharmacies due to the high consumption of sulfamethoxazole/trimethoprim, a WHO 'Access' group antibiotic, in public hospital pharmacies. Sulfamethoxazole or trimethoprim is used for prophylaxis against opportunistic infections among HIV/AIDS-positive populations and is a routine intervention in HIV treatment programmes under the M0H guidelines, and its procurement is largely through donations. This prophylactic use of sulfamethoxazole/trimethoprim contributed to the high use observed of this fixed-dose combination antibiotic in the country, well above the minimum recommended consumption threshold, i.e., that 60% of all drugs consumed should come from the 'Access' type drugs. The consumption of 'Access' group antibiotics remained above the WHO recommended minimum of 60% even after excluding sulfamethoxazole/trimethoprim. This consumption trend of 'Access'-type medicines in Kenya is commendable and indicates that narrow-spectrum antibiotics are typically the first line of antibiotics used in Kenya, further lowering the potential for widespread AMR in case of drug overuse/misuse. This finding also suggests that the KEML antibiotics, which comprise mostly 'Access' antibiotics, are widely available in the country.[46]

It is important to mention that Kenya has included a list of AWaRe antibiotics in the KEML publication 2019.[46,47] The KEML lists some antibiotics into different AWaRe categories. For example, sulfamethoxazole/trimethoprim falls within the 'Watch' group in the Kenyan AWaRe classification instead of in the 'Access' group as per the WHO AWaRe classification. The KEML was reviewed by an expert technical group and was not formulated based on a review of national AMR and AMC trends. Further, the KEML list was not used for the analysis because it does not classify all the MAAP-reviewed antibiotics into the 'Access', 'Watch' and 'Reserve' categories. The findings from the MAAP provide a useful starting point for the country AMRCC to review the current KEML list of antimicrobials based on the country's AMR and AMC patterns, the WHO AWaRe categories and WHO EML antibiotics.

Only a few 'Reserve' antibiotics were consumed, and these were listed as essential medicines within the KEML. There is room to increase the range of 'Reserve' antibiotics in the KEML. The current 'Reserve' antibiotic representation in the Kenya datasets implies their limited accessibility rather than regulation of their consumption or a lack of need for their use. Moreover, the above finding shows better accessibility to the 'Reserve' antibiotics in Kenya than the WHO AMC data analysis in the African region that recorded zero consumption in the four countries studied.[23] The AMRCC are therefore encouraged to investigate and identify why antibiotics listed as essential medicines within the Kenyan AWaRe 'Reserve' category are not available in most facilities in the country and work to ensure 'Access', when necessary, to save lives. Interestingly, there was a notable increase in consumption of other antibacterial (J01XX), which also includes the 'Reserve' category antibiotic Linezolid. Although its consumption was low overall, the AMRCC should note this trend and ensure interventions are set to monitor the appropriate use of this and other last-resort antibiotics.

The most frequently consumed 'Access' group antibiotic was Amoxicillin, which is from the penicillins with extended spectrum (J01CA) ATC class and was the top consumed antimicrobial in Kenya overall. This finding aligns with the pilot WHO AMC data analysis conducted in four other countries in sub-Saharan Africa that identified penicillin ATC medicine classes as the most consumed category.[23] The AMRCC could review the use of amoxicillin in the country and aim to reduce unnecessary use.

The WHO also guides on antibiotics that are 'not recommended' in clinical practice due to their broader activity spectrum and the lack of clinical evidence supporting their use.[35] In Kenya, the use of nine such fixed-dose combinations (FDCs) 'not recommended' by WHO was detected in the national level data. Of these antibiotic combinations, ampicillin/cloxacillin was the most consumed. However, 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 antibiotic treatment are uncommon.[48] As there is no recommendation for using these FDC antibiotics within the Kenya clinical treatment guidelines (2019)[47], the AMRCC should identify the reasons for prescribing or dispensing these FDC and the exact locations commonly prescribing or dispensing these FDC antibiotics listed in AMC Appendix 8. Additionally, this information guide targeted sensitisation of prescribers by the country's MoH and associated drug regulatory bodies (e.g., PPB) to correct this prescribing practice.

In conclusion, data generated from AMC and AMU surveillance trends can provide unique insights for national stewardship programmes and policy formulation to stem the emergence of AMR. Kenya should be commended for far exceeding the minimum threshold of consumption of at least 60% of antibiotics from the WHO 'Access' (narrow spectrum, first-choice antibiotics) category. Yet, only five antibiotics account for 58% of the consumption, suggesting the opportunity for more use of other antibiotics. Table 15 describes the next steps for AMC and AMU surveillance in Kenya.

Table 15: Next steps for AMC and AMU surveillance

A.

Leadership and Governance

The country should develop an AMC surveillance policy and address who, how and when the national AMC datasets should be reported. The AMRCC could lead this activity.

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

The regulatory authority, Pharmacy and Poison Board, could reconsider the registration status of unapproved FDCs

The national stewardship programmes could work to review the KEML and national treatment guidelines to anchor the availability and appropriate use of the essential 'Reserve' antibiotics.

B.

Service Delivery

Future attempts to collect AMU data in the country should seek to identify facilities with unique patient identifiers and fully electronic medical records capabilities. Alternatively, the country could aim to prospectively collect this data as guided by WHO methodology for point prevalence surveys[34] as the number of facilities with electronic record systems are limited.

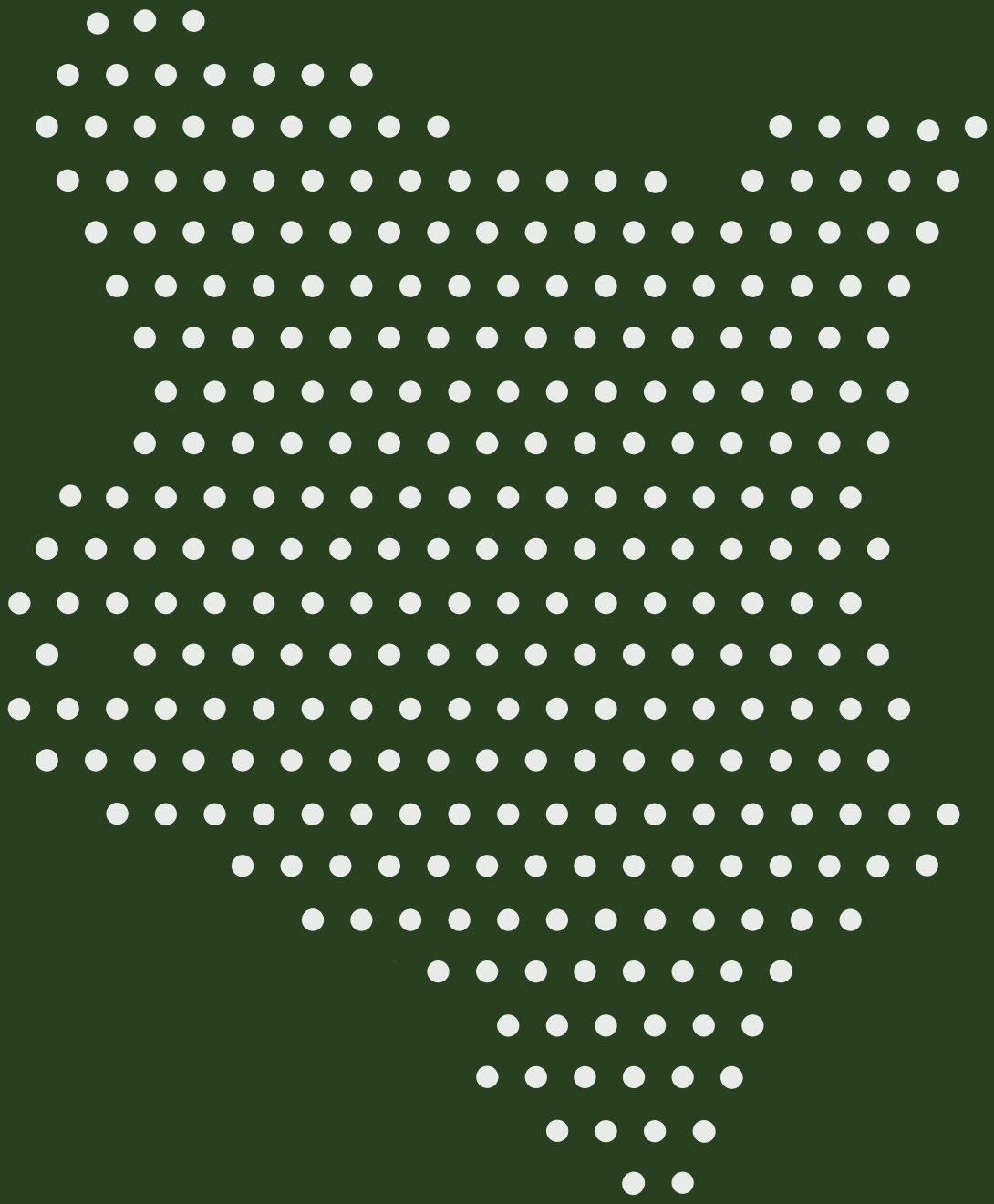
National stewardship programmes led by the AMRCC could conduct educational campaigns for healthcare practitioners to ensure that they are aware of the full spectrum of antimicrobials available in the country EML, as well as ensure that unapproved (fixed dose antibiotic combinations) prescriptions are not used

C.

Medical products and technologies

The national ASP should collaborate with pharmacists and medicine importers to increase the availability of 'Reserve' category antibiotics in selected facilities, per the country's EML.

Part E: Limitations



Since the participating laboratories were at different service levels and had varying testing capacities, all results in this report should be interpreted cautiously. The limitations of the current study are summarised below.

1. Obtaining patients' hospital identifiers from laboratory records was difficult, directly impeding the retrieval of demographic and clinical information from medical archives. Where patient identifiers could be matched in hospital records with paper medical records, data were manually retrieved. Manual retrieval 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 16 participating laboratories may not fully represent the true resistance rates in the country as they only encompassed a small proportion of the country's population (over 53.7 million). Furthermore, routine testing is most likely uncommon in most hospitals and laboratories, as AST is mostly conducted in instances of failed therapy; thus, the resistance rates in this study may have been overestimated.

4. Clinical data and antimicrobial usage information were insufficient to analyse AMR drivers comprehensively.

5. Approximately 30% of the national antimicrobial market was not covered, including the private-not-for-profit sector and part of the private sector. Because of this data coverage gap, our results may not comprehensively account for all the antimicrobials in the country and therefore present an underestimation of actual consumption.

6. In this study, twenty-five pharmacies were purposively selected for data collection. However, this sample size was a relatively small proportion of total pharmacies in Kenya and did not represent all counties. Therefore, a more systematic sampling strategy that factors in the populations serviced and geographical locations will be required to make conclusions from pharmacy-level data more representative.

7. The MAAP could not obtain AMU data from the participating AST-laboratories-co-located pharmacies and clinics and, therefore, could not determine how and why antimicrobials were prescribed and dispensed (i.e., appropriateness of prescriptions and drugs consumed), was not achieved. Nevertheless, AMU is important to guide the country ASP.

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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 and measurements based on third-party assessment and following international standards.

Antimicrobial consumption (AMC):

According to the WHO, AMC is defined as quantities of antimicrobials used in a specific setting (total, community and hospital etc.) during a specific period (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 and 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 year:
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 CLSI, EUCAST, 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 to weigh 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 information, 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, the GLASS provides a standardised approach to the collection, analysis and sharing of AMR data by countries and seeks to support capacity development and to 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 or 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 and 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 evaluates participant performance against pre-established criteria by means of inter-laboratory comparisons.

Quality Certification:

Certification verifies that laboratory personnel have adequate credentials to practice the specific discipline 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.

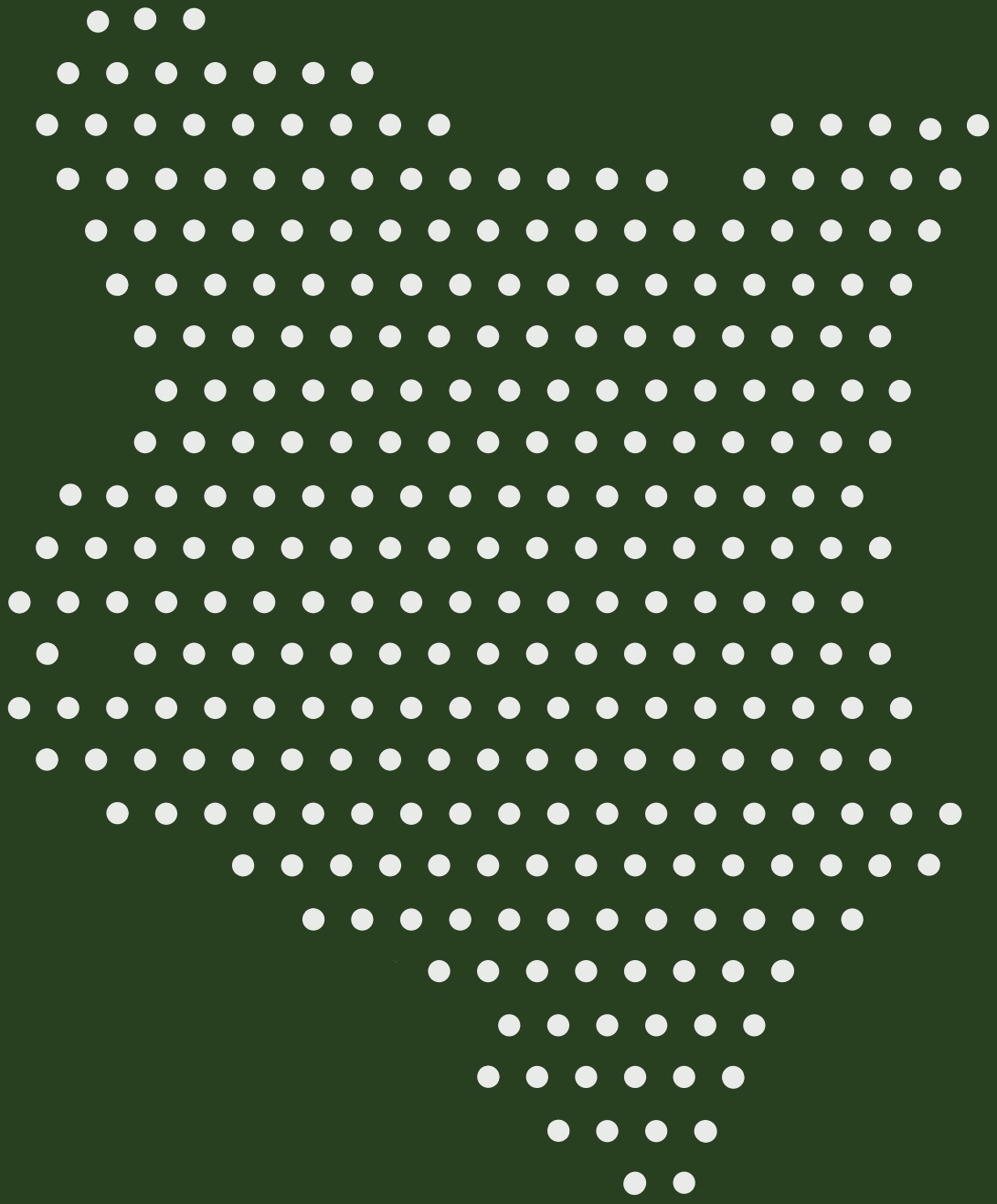
Total cultures:

The number of patient rows retrieved from the database of the laboratories.

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 Tables



Appendix 1: Terms of Reference and Data Sharing Agreements

MINISTRY OF HEALTH
OFFICE OF THE DIRECTOR GENERAL

Telephone Nairobi 0202717077
Email: dghealth2019@health.go.ke
Fax: 254 -20 - 2735236
When replying please quote

AFYA HOUSE
CATHEDRAL ROAD
P O Box 30016 - 00100
NAIROBI

MOH/DHSQAR/AMR/Vol. 1

24th February, 2020

All County Executive Committee Members for Health

Thro'
The Chief Executive Officer
Council of Governors
Delta Corner, Westlands
NAIROBI.

RE: REQUEST FOR PARTICIPATION IN THE RETROSPECTIVE MAPPING OF ANTIMICROBIAL RESISTANCE AND ANTIMICROBIAL USE IN LABORATORIES AND PHARMACIES

The Ministry of Health with support from the UK Fleming Fund Mapping Antimicrobial Resistance Partnership (MAAP) project regional grant is taking steps to generate data that will provide baseline information and inform ongoing decision making on antimicrobial resistance (AMR) surveillance and antimicrobial use (AMU) in Kenya. This will involve collecting retrospective data for the years 2016-2018 on AMR related diagnosis from both public and private sector laboratories and quantifying the antimicrobial consumption in both the public and private pharmacy sector. Overall, this data will be used to provide a national level view with the aim of gaining an understanding on the trends and patterns surrounding antimicrobial resistance and antimicrobial consumption and the gaps that exist to support the Ministry of Health in designing appropriate surveillance systems.

Given the importance of the emergence of antimicrobial resistance globally, the Ministry of Health is requesting your assistance and support in participating in an eligibility assessment and data collection that will be conducted by a designated team. The purpose of this assessment is to determine eligibility of the hospital pharmacies and laboratories for the data collection on antimicrobial resistance and antimicrobial use/consumption exercise. The eligibility assessments and data requests are planned to begin from the month of February 2020. The data collection will also cover the Kenya Medical Supplies Agency and the Mission for Essential Drugs and Supplies as national level data sources.

For any questions or further information, please contact (*Dr. Evelyn Wesangula 0721244868, wesangulaeva@gmail.com*) or (*Susan Githii 0722685718, Susan.githii@yahoo.com*).

We take this opportunity to thank you for your continued support and we look forward to a fruitful collaboration.

Dr. Patrick Amoth

Ag. Director General for Health

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 and 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 utilise? (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 utilise 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 and 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 and 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 and18?	Yes		No	
5.2	Did the laboratory comply with specimen rejection criteria for rejecting inadequate specimens, at any time between 2016 and 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:

	Question	Response				Scoring
Part 1: Site Information (Maximum score=0)						
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 utilise? (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 utilise 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 programme	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	Quinupristin dalfopristin	Any isolate that tested non-susceptible to quinupristin dalfopristin	Any isolate that tested susceptible or non-susceptible to quinupristin 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 = 56 n (%)	Reference N = 12 n (%)	Regional/ Intermediate N = 24 n (%)	District/ Community N = 11 n (%)	Unspecified N = 9 n (%)
Government	44 (78.57)	10 (83.3)	23 (95.8)	10 (90.9)	1 (11.1)
Private	4 (7.14)	1 (8.3)	1 (4.2)	0	2 (22.2)
NGO	2 (3.57)	0	0	0	2 (22.2)
Others	6 (10.71)	1 (8.3)	0	1 (9.1)	4 (44.4)

Supplementary Table 2: Assessment of preparedness for AMR surveillance

Parameters	Surveyed laboratories N=56 n (%)
Commodity and equipment status	
Regular power supply and functional back up	54 (96.4)
Continuous water supply	54 (96.4)
Certified and functional biosafety cabinets	52 (92.9)
Automated methods for pathogen identification	14 (25.0)
Automated methods for antimicrobial susceptibility testing	12 (21.4)
Methods for testing antimicrobial resistance mechanisms	12 (21.4)
QMS implementation	
Reported QMS Implementation	50 (89.3)
• Reported QMS tool (n=50)	
• LQMS	2 (4.0)
• SLIPTA	21 (42.0)
• SLMTA	6 (12.0)
• Mentoring	-
• Combination‡	14 (28.0)
• Others	5 (10.0)
Quality Certification	33 (58.9)
• Reported certification type (n=33)	
• SLIPTA	16 (48.5)
• College of American Pathologists	-
• Others	16 (48.5)
Accreditation	18 (32.1)
Participation in proficiency testing	29 (51.8)
Utilisation of reference strains	32 (57.1)
Reported consistent maintenance of QC records	37 (66.1)
Designated focal quality person	52 (92.9)
Reported compliance to standard operating procedures	53 (94.6)
Reported compliance to antimicrobial susceptibility testing standards	36 (64.3)
Personnel and training status	
Presence of at least one qualified microbiologist	28 (50.0)
Presence of an experienced laboratory scientist/technologist	49 (87.5)
Up-to-date and complete records on staff training and competence	37 (66.1)
Specimen Management status	
Reported compliance to standard operating procedures on specimen collection and testing	54 (96.4)
Reported compliance to standard operating procedures on specimen rejection	54 (96.4)
Availability on average number of specimens processed for culture and sensitivity in year 2018	54 (96.4)
Laboratory Information System and Linkage to Clinical Data	
Assigned specimen (laboratory) identification number	53 (94.6)
Availability of system/database to store patient data	51 (91.1)
• System/database format (n=51)	
• Paper-based	26 (51.0)
• Electronic	10 (19.6)
• Mixed	15 (29.4)
Captured patients' demographics and clinical information on test request forms	51 (91.1)
• Retrievable test request forms (n=51)	23 (45.1)

**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		**14 164**	**17 337**	**3 2827**	**3 855**	**3 405**	**16 318**	**3 307**	**2 907**	**9 813**
Pathogen type	bacteria				3,525 (91.4)	3,101 (91.1)	15,668 (96.0)	3,304 (99.9)	2,899 (99.7)	9,768 (99.5)
	fungi				330 (8.6)	304 (8.9)	650 (4.0)	3 (0.1)	8 (0.3)	45 (0.5)
Age, years	Less than 1	885 (6.2)	864 (5.0)	2,083 (6.3)	486 (12.6)	392 (11.5)	1,577 (9.7)	467 (14.1)	384 (13.2)	931 (9.5)
	1 to 17	2,882 (20.3)	2,920 (16.8)	4,482 (13.7)	588 (15.3)	544 (16.0)	1,863 (11.4)	532 (16.1)	475 (16.3)	1,168 (11.9)
	18 to 49	6,330 (44.7)	5,969 (34.4)	10,845 (33.0)	1,697 (44.0)	1,308 (38.4)	5,245 (32.1)	1,368 (41.4)	1,050 (36.1)	3,077 (31.4)
	50 to 65	1,352 (9.5)	1,499 (8.6)	2,639 (8.0)	332 (8.6)	341 (10.0)	1,332 (8.2)	280 (8.5)	303 (10.4)	858 (8.7)
	Above 65	902 (6.4)	1,213 (7.0)	1,945 (5.9)	288 (7.5)	329 (9.7)	1,053 (6.5)	244 (7.4)	279 (9.6)	655 (6.7)
	Unknown Age	1,813 (12.8)	4,872 (28.1)	10,833 (33.0)	464 (12.0)	491 (14.4)	5,248 (32.2)	416 (12.6)	416 (14.3)	3,124 (31.8)
Gender	Male	6,534 (46.1)	6,888 (39.7)	12,359 (37.6)	1,550 (40.2)	1,383 (40.6)	5,848 (35.8)	1,394 (42.2)	1,227 (42.2)	3,628 (37.0)
	Female	7,630 (53.9)	10,449 (60.3)	20,468 (62.4)	2,305 (59.8)	2,022 (59.4)	10,470 (64.2)	1,913 (57.8)	1,680 (57.8)	6,185 (63.0)
Laboratory	Kisii	293 (2.1)	-	218 (0.7)	186 (4.8)	-	91 (0.6)	169 (5.1)	-	78 (0.8)
	Mater	8,132 (57.4)	8,607 (49.6)	8,467 (25.8)	1,535 (39.8)	1,526 (44.8)	1,389 (8.5)	1,227 (37.1)	1,239 (42.6)	489 (5.0)
	Kitale	247 (1.7)	76 (0.4)	337 (1.0)	107 (2.8)	16 (0.5)	147 (0.9)	98 (3.0)	16 (0.6)	139 (1.4)
	Kenyatta	-	-	11,525 (35.1)	-	-	11,525 (70.6)	-	-	6,278 (64.0)
	Bungoma	471 (3.3)	572 (3.3)	653 (2.0)	25 (0.6)	26 (0.8)	142 (0.9)	18 (0.5)	21 (0.7)	107 (1.1)
	Busia	11 (0.1)	12 (0.1)	81 (0.2)	3 (0.1)	6 (0.2)	51 (0.3)	2 (0.1)	1 (0.0)	44 (0.4)
	Nyeri	14 (0.1)	171 (1.0)	121 (0.4)	3 (0.1)	44 (1.3)	22 (0.1)	3 (0.1)	34 (1.2)	(0.1)
	Moi County	362 (2.6)	238 (1.4)	315 (1.0)	128 (3.3)	59 (1.7)	119 (0.7)	122 (3.7)	59 (2.0)	114 (1.2)
	Wajir	228 (1.6)	199 (1.1)	321 (1.0)	76 (2.0)	50 (1.5)	123 (0.8)	62 (1.9)	47 (1.6)	119 (1.2)
	Moi Teaching	3,425 (24.2)	3,876 (22.4)	4,678 (14.3)	1,454 (37.7)	1,290 (37.9)	1,726 (10.6)	1,327 (40.1)	1,175 (40.4)	1,603 (16.3)
	MP Shah	18 (0.1)	2,854 (16.5)	3,038 (9.3)	-	127 (3.7)	172 (1.1)	-	124 (4.3)	145 (1.5)
	Thika	376 (2.7)	334 (1.9)	418 (1.3)	75 (1.9)	73 (2.1)	101 (0.6)	56 (1.7)	47 (1.6)	96 (1.0)
	Coptic	-	96 (0.6)	1,469 (4.5)	-	59 (1.7)	301 (1.8)	-	38 (1.3)	242 (2.5)
	Machakos	-	-	465 (1.4)	-	-	49 (0.3)	-	-	43 (0.4)
	Meru	231 (1.6)	49 (0.3)	372 (1.1)	96 (2.5)	28 (0.8)	182 (1.1)	90 (2.7)	25 (0.9)	147 (1.5)
	Kilifi	356 (2.5)	253 (1.5)	349 (1.1)	167 (4.3)	101 (3.0)	178 (1.1)	133 (4.0)	81 (2.8)	157 (1.6)

Supplementary Table 4: Specimen characteristics

Specimen Type	All years* N= 16,027 n (%)	2016 N = 3,307 n (%)	2017 N = 2,907 n (%)	2018 N = 9,813 n (%)
Abscess (abdominal)	2 (0)	2 (0.1)	-	-
Abscess (brain/cerebral)	2 (0)	-	1 (0)	1 (0)
Abscess/Discharge/Pus/Swab/Wound	4,600 (28.7)	955 (28.9)	921 (31.7)	2,724 (27.8)
Aspirate/discharge	99 (0.6)	11 (0.3)	22 (0.8)	66 (0.7)
Blood	3,604 (22.5)	767 (23.2)	810 (27.9)	2,027 (20.7)
Catheter (central line)	14 (0.1)	-	1 (0)	13 (0.1)
Catheter (unspecified)	51 (0.3)	22 (0.7)	10 (0.3)	19 (0.2)
Catheter (urinary)	2 (0)	-	2 (0.1)	-
Catheter tip	27 (0.2)	1 (0)	-	26 (0.3)
CSF	97 (0.6)	12 (0.4)	15 (0.5)	70 (0.7)
Fluid (abdominal/peritoneal)	67 (0.4)	4 (0.1)	6 (0.2)	57 (0.6)
Fluid (bile)	6 (0)	-	-	6 (0.1)
Fluid (cyst)	1 (0)	-	-	1 (0)
Fluid (dialysis)	1 (0)	-	1 (0)	-
Fluid (joint/synovial)	15 (0.1)	3 (0.1)	2 (0.1)	10 (0.1)
Fluid (pericardial)	2 (0)	-	-	2 (0)
Fluid (pleural)	52 (0.3)	4 (0.1)	7 (0.2)	41 (0.4)
Fluid (shunt)	1 (0)	-	-	1 (0)
Fluid (unspecified)	57 (0.4)	11 (0.3)	21 (0.7)	25 (0.3)
Other	16 (0.1)	1 (0)	11 (0.4)	4 (0)
Respiratory-Lower	1,543 (9.6)	132 (4)	172 (5.9)	1,239 (12.6)
Respiratory-Upper	251 (1.6)	47 (1.4)	60 (2.1)	144 (1.5)
Scraping (cornea)	2 (0)	2 (0.1)	-	-
Semen	4 (0)	-	1 (0)	3 (0)
Shunt	3 (0)	-	-	3 (0)
Stool	436 (2.7)	207 (6.3)	46 (1.6)	183 (1.9)
Swab (bedsore)	1 (0)	-	-	1 (0)
Swab (bone)	1 (0)	-	-	1 (0)
Swab (cervical)	6 (0)	1 (0)	1 (0)	4 (0)
Swab (high vaginal)	84 (0.5)	-	-	84 (0.9)
Swab (rectal)	49 (0.3)	-	2 (0.1)	47 (0.5)
Swab (urethral)	73 (0.5)	21 (0.6)	14 (0.5)	38 (0.4)
Swab (vaginal)	493 (3.1)	209 (6.3)	126 (4.3)	158 (1.6)
Swab/discharge	53 (0.3)	-	-	53 (0.5)
Swab/discharge (ear)	1 (0)	-	1 (0)	-
Swab/discharge (eye)	2 (0)	-	-	2 (0)
Swab/discharge (genital)	1 (0)	-	-	1 (0)
Swab/discharge (nose)	1 (0)	-	-	1 (0)
Swab/discharge (skin)	1 (0)	1 (0)	-	-
Swab/discharge (urethral)	9 (0.1)	-	-	9 (0.1)
Tissue/biopsy	107 (0.7)	16 (0.5)	19 (0.7)	72 (0.7)
Ulcer	3 (0)	1 (0)	-	2 (0)
Unknown	1 (0)	-	-	1 (0)
Urine	4,186 (26.1)	877 (26.5)	635 (21.8)	2,674 (27.2)

**Indicates positive cultures with AST results*

Supplementary Table 5: Pathogen identification

Pathogen	All years* N=16,027 n(%)	2016 N=3,307 n(%)	2017 N=2,907 n(%)	2018 N=9,813 n(%)
Positive cultures with specific pathogen name	12 569 (78.4)	2 127 (64.3)	1 970 (67.8)	8 472 (86.3)
Achromobacter xylosoxidans ss. denitrificans	1 (0)	-	-	1 (0)
Acinetobacter baumannii	310 (1.9)	6 (0.2)	9 (0.3)	295 (3)
Acinetobacter calcoaceticus	2 (0)	-	-	2 (0)
Acinetobacter calcoaceticus-baumannii complex	38 (0.2)	-	-	38 (0.4)
Acinetobacter haemolyticus	2 (0)	-	-	2 (0)
Acinetobacter lwoffii	1 (0)	-	-	1 (0)
Aeromonas caviae	1 (0)	-	-	1 (0)
Aeromonas hydrophila	7 (0)	1 (0)	-	6 (0.1)
Aeromonas sobria	2 (0)	-	-	2 (0)
Alcaligenes faecalis	2 (0)	-	-	2 (0)
Brevundimonas diminuta	1 (0)	-	-	1 (0)
Burkholderia cepacia	13 (0.1)	-	-	13 (0.1)
Candida albicans	24 (0.1)	1 (0)	3 (0.1)	20 (0.2)
Candida ciferrii	5 (0)	-	-	5 (0.1)
Candida glabrata	2 (0)	-	-	2 (0)
Candida krusei	1 (0)	-	-	1 (0)
Candida lipolytica	2 (0)	-	-	2 (0)
Candida lusitaniae	1 (0)	-	-	1 (0)
Candida norvegensis	1 (0)	-	-	1 (0)
Candida parapsilosis	2 (0)	-	-	2 (0)
Candida rugosa	1 (0)	-	-	1 (0)
Candida tropicalis	8 (0)	-	-	8 (0.1)
Cedecea davisae	1 (0)	-	-	1 (0)
Cedecea lapagei	2 (0)	-	-	2 (0)
Chryseobacterium indologenes	4 (0)	-	-	4 (0)
Chryseomonas luteola	52 (0.3)	1 (0)	1 (0)	50 (0.5)
Citrobacter amalonaticus	1 (0)	-	-	1 (0)
Citrobacter braakii	1 (0)	-	-	1 (0)
Citrobacter farmeri	1 (0)	-	-	1 (0)
Citrobacter freundii	57 (0.4)	5 (0.2)	8 (0.3)	44 (0.4)
Citrobacter koseri	10 (0.1)	-	-	10 (0.1)
Citrobacter youngae	1 (0)	-	-	1 (0)
Clostridium baratii	1 (0)	1 (0)	-	-

Cronobacter sakazakii	1 (0)	-	-	1 (0)
Cryptococcus neoformans	1 (0)	-	1 (0)	-
Enterobacter amnigenus	1 (0)	-	-	1 (0)
Enterobacter asburiae	1 (0)	-	-	1 (0)
Enterobacter cloacae	124 (0.8)	-	7 (0.2)	117 (1.2)
Enterobacter dissolvens	57 (0.4)	-	-	57 (0.6)
Enterobacter gergoviae	6 (0)	-	-	6 (0.1)
Enterococcus avium	2 (0)	-	-	2 (0)
Enterococcus casseliflavus	5 (0)	-	-	5 (0.1)
Enterococcus casseliflavus/flavescens	1 (0)	-	1 (0)	-
Enterococcus durans	3 (0)	-	-	3 (0)
Enterococcus faecalis	493 (3.1)	131 (4)	62 (2.1)	300 (3.1)
Enterococcus faecium	182 (1.1)	-	1 (0)	181 (1.8)
Enterococcus gallinarum	127 (0.8)	-	2 (0.1)	125 (1.3)
Enterococcus hirae	1 (0)	-	-	1 (0)
Escherichia coli	3,765 (23.5)	929 (28.1)	784 (27)	2,052 (20.9)
Escherichia hermannii	2 (0)	1 (0)	-	1 (0)
Flavimonas oryzihabitans	1 (0)	-	-	1 (0)
Klebsiella aerogenes	62 (0.4)	4 (0.1)	-	58 (0.6)
Klebsiella oxytoca	174 (1.1)	55 (1.7)	22 (0.8)	97 (1)
Klebsiella pneumoniae	1,805 (11.3)	171 (5.2)	237 (8.2)	1,397 (14.2)
Kluyvera cryocrescens	1 (0)	-	-	1 (0)
Kluyvera intermedia	1 (0)	-	-	1 (0)
Kocuria kristinae	1 (0)	-	-	1 (0)
Lactobacillus fermentum	1 (0)	-	-	1 (0)
Leclercia adecarboxylata	3 (0)	-	-	3 (0)
Leuconostoc mesenteriodes	1 (0)	-	1 (0)	-
Moraxella catarrhalis	3 (0)	-	2 (0.1)	1 (0)
Morganella morganii	39 (0.2)	1 (0)	4 (0.1)	34 (0.3)
Neisseria gonorrhoeae	26 (0.2)	11 (0.3)	4 (0.1)	11 (0.1)
Neisseria meningitidis	3 (0)	-	3 (0.1)	-
Pantoea (enterobacter) agglomerans	99 (0.6)	-	-	99 (1)
Pasteurella aerogenes	2 (0)	-	-	2 (0)
Pasteurella multocida	2 (0)	-	-	2 (0)
Pasteurella pneumotropica	6 (0)	-	1 (0)	5 (0.1)
Proteus hauseri	11 (0.1)	-	-	11 (0.1)
Proteus mirabilis	301 (1.9)	16 (0.5)	39 (1.3)	246 (2.5)

Proteus penneri	14 (0.1)	-	-	14 (0.1)
Proteus vulgaris	73 (0.5)	15 (0.5)	16 (0.6)	42 (0.4)
Providencia alcalifaciens	1 (0)	-	-	1 (0)
Providencia rettgeri	3 (0)	-	-	3 (0)
Providencia stuartii	4 (0)	-	-	4 (0)
Pseudomonas aeruginosa	701 (4.4)	48 (1.5)	110 (3.8)	543 (5.5)
Pseudomonas alcaligenes	1 (0)	-	-	1 (0)
Pseudomonas fluorescens	1 (0)	-	-	1 (0)
Pseudomonas mendocina	2 (0)	-	-	2 (0)
Pseudomonas putida	11 (0.1)	-	2 (0.1)	9 (0.1)
Pseudomonas stutzeri	2 (0)	-	-	2 (0)
Raoultella ornithinolytica	41 (0.3)	-	-	41 (0.4)
Raoultella planticola	7 (0)	-	-	7 (0.1)
Salmonella enterica	5 (0)	-	-	5 (0.1)
Salmonella enteritidis	20 (0.1)	-	-	20 (0.2)
Salmonella paratyphi	7 (0)	-	6 (0.2)	1 (0)
Salmonella typhi	72 (0.4)	16 (0.5)	32 (1.1)	24 (0.2)
Salmonella typhimurium	6 (0)	1 (0)	2 (0.1)	3 (0)
Serratia ficaria	3 (0)	-	-	3 (0)
Serratia fonticola	41 (0.3)	-	-	41 (0.4)
Serratia liquefaciens	25 (0.2)	-	-	25 (0.3)
Serratia marcescens	107 (0.7)	3 (0.1)	4 (0.1)	100 (1)
Serratia odorifera	14 (0.1)	-	-	14 (0.1)
Serratia plymuthica	9 (0.1)	-	-	9 (0.1)
Shewanella putrefaciens	2 (0)	-	-	2 (0)
Shigella boydii	2 (0)	-	-	2 (0)
Shigella dysenteriae	4 (0)	2 (0.1)	2 (0.1)	-
Shigella flexneri	6 (0)	3 (0.1)	1 (0)	2 (0)
Shigella sonnei	10 (0.1)	3 (0.1)	1 (0)	6 (0.1)
Shimwellia (Escherichia) blattae	2 (0)	1 (0)	-	1 (0)
Sphingomonas paucimobilis	48 (0.3)	1 (0)	1 (0)	46 (0.5)
Staphylococcus aureus	1,993 (12.4)	528 (16)	460 (15.8)	1,005 (10.2)
Staphylococcus auricularis	1 (0)	-	-	1 (0)
Staphylococcus capitis	17 (0.1)	-	6 (0.2)	11 (0.1)
Staphylococcus carnosus	1 (0)	-	-	1 (0)
Staphylococcus chromogenes	1 (0)	-	-	1 (0)
Staphylococcus cohnii	6 (0)	-	-	6 (0.1)

Staphylococcus epidermidis	482 (3)	12 (0.4)	7 (0.2)	463 (4.7)
Staphylococcus haemolyticus	273 (1.7)	8 (0.2)	29 (1)	236 (2.4)
Staphylococcus hominis	82 (0.5)	-	8 (0.3)	74 (0.8)
Staphylococcus hyicus	2 (0)	-	-	2 (0)
Staphylococcus intermedius	19 (0.1)	-	-	19 (0.2)
Staphylococcus lugdunensis	6 (0)	-	1 (0)	5 (0.1)
Staphylococcus pseudintermedius	17 (0.1)	-	-	17 (0.2)
Staphylococcus saprophyticus	52 (0.3)	4 (0.1)	6 (0.2)	42 (0.4)
Staphylococcus schleiferi	2 (0)	-	-	2 (0)
Staphylococcus sciuri	34 (0.2)	-	3 (0.1)	31 (0.3)
Staphylococcus simulans	1 (0)	-	-	1 (0)
Staphylococcus warneri	4 (0)	-	-	4 (0)
Staphylococcus xylosus	24 (0.1)	-	-	24 (0.2)
Stenotrophomonas (xanthomonas) maltophilia	4 (0)	2 (0.1)	-	2 (0)
Streptococcus agalactiae	96 (0.6)	36 (1.1)	27 (0.9)	33 (0.3)
Streptococcus bovis	1 (0)	-	-	1 (0)
Streptococcus canis	4 (0)	2 (0.1)	2 (0.1)	-
Streptococcus ferus	1 (0)	-	-	1 (0)
Streptococcus pleomorphus	1 (0)	1 (0)	-	-
Streptococcus pneumoniae	74 (0.5)	19 (0.6)	10 (0.3)	45 (0.5)
Streptococcus pyogenes	108 (0.7)	51 (1.5)	30 (1)	27 (0.3)
Streptococcus viridans	45 (0.3)	10 (0.3)	11 (0.4)	24 (0.2)
Vibrio cholerae	90 (0.6)	26 (0.8)	1 (0)	63 (0.6)
Vibrio fluvialis	1 (0)	-	-	1 (0)
Vibrio parahaemolyticus	2 (0)	-	-	2 (0)
Yersinia aldovae	1 (0)	-	-	1 (0)
Yersinia enterocolitica	7 (0)	1 (0)	-	6 (0.1)
Yersinia kristensenii	1 (0)	-	-	1 (0)
Positive cultures with non-specific pathogen name	3,458 (21.6)	1,180 (35.7)	937 (32.2)	1,341 (13.7)
Acetobacterium Sp.	2 (0)	1 (0)	-	1 (0)
Acinetobacter Sp.	435 (2.7)	127 (3.8)	134 (4.6)	174 (1.8)
Aeromonas Sp.	1 (0)	-	-	1 (0)
Alcaligenes Sp.	20 (0.1)	3 (0.1)	7 (0.2)	10 (0.1)
Anaerobes	1 (0)	-	-	1 (0)
Bacillus Sp.	3 (0)	-	-	3 (0)
Bordetella Sp.	1 (0)	-	-	1 (0)
Brucella Sp.	1 (0)	-	-	1 (0)

Candida Sp.	6 (0)	1 (0)	4 (0.1)	1 (0)
Citrobacter Sp.	30 (0.2)	9 (0.3)	14 (0.5)	7 (0.1)
Corynebacterium Sp.	3 (0)	-	1 (0)	2 (0)
Edwardsiella Sp.	1 (0)	1 (0)	-	-
Enterobacter Sp.	46 (0.3)	13 (0.4)	22 (0.8)	11 (0.1)
Enterococcus Sp.	38 (0.2)	10 (0.3)	5 (0.2)	23 (0.2)
Erwinia Sp.	3 (0)	-	-	3 (0)
Escherichia Sp.	11 (0.1)	5 (0.2)	6 (0.2)	-
Klebsiella Sp.	787 (4.9)	288 (8.7)	237 (8.2)	262 (2.7)
Kluyvera Sp.	1 (0)	-	-	1 (0)
Lactobacillus Sp.	4 (0)	2 (0.1)	1 (0)	1 (0)
Micrococcus Sp.	66 (0.4)	19 (0.6)	17 (0.6)	30 (0.3)
Moraxella Sp.	2 (0)	2 (0.1)	-	-
Morganella Sp.	1 (0)	-	-	1 (0)
Myroides Sp.	1 (0)	-	-	1 (0)
Pantoea Sp.	3 (0)	-	-	3 (0)
Proteus Sp.	133 (0.8)	47 (1.4)	35 (1.2)	51 (0.5)
Providencia Sp.	20 (0.1)	12 (0.4)	5 (0.2)	3 (0)
Pseudallescheria Sp.	2 (0)	1 (0)	-	1 (0)
Pseudomonas Sp.	137 (0.9)	38 (1.1)	42 (1.4)	57 (0.6)
Salmonella Sp.	34 (0.2)	13 (0.4)	8 (0.3)	13 (0.1)
Serratia Sp.	2 (0)	-	1 (0)	1 (0)
Shigella Sp.	30 (0.2)	14 (0.4)	7 (0.2)	9 (0.1)
Staphylococcus Sp.	1,322 (8.2)	471 (14.2)	340 (11.7)	511 (5.2)
Streptococcus Sp.	142 (0.9)	32 (1)	36 (1.2)	74 (0.8)
Unspecified (Gram negative bacilli)	87 (0.5)	26 (0.8)	6 (0.2)	55 (0.6)
Unspecified (Gram negative bacteria)	7 (0)	3 (0.1)	4 (0.1)	-
Unspecified (Gram negative cocci)	15 (0.1)	8 (0.2)	-	7 (0.1)
Unspecified (Gram negative coccobacilli)	3 (0)	2 (0.1)	-	1 (0)
Unspecified (Gram positive bacilli)	16 (0.1)	7 (0.2)	1 (0)	8 (0.1)
Unspecified (Gram positive bacteria)	2 (0)	2 (0.1)	-	-
Unspecified (Gram positive cocci)	37 (0.2)	21 (0.6)	4 (0.1)	12 (0.1)
Unspecified (Gram positive coccobacilli)	2 (0)	2 (0.1)	-	-

*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
Kisii	3	-	3	3
Mater	4	4	4	4
Kitale	4	3	4	3.7
Kenyatta	4	4	4	4
Bungoma	3	3	3	3
Busia	4	4	2	3.3
Nyeri	-	3	4	3.5
Moi County	3	3	3	3
Wajir	4	3	2	3
Moi Teaching	2	2	2	2
MP Shah	-	4	4	4
Thika	2	4	4	3.3
Coptic	-	4	4	4
Machakos	3	4	2	3
Meru	3	4	4	3.7
Kilifi	3	2	2	2.3

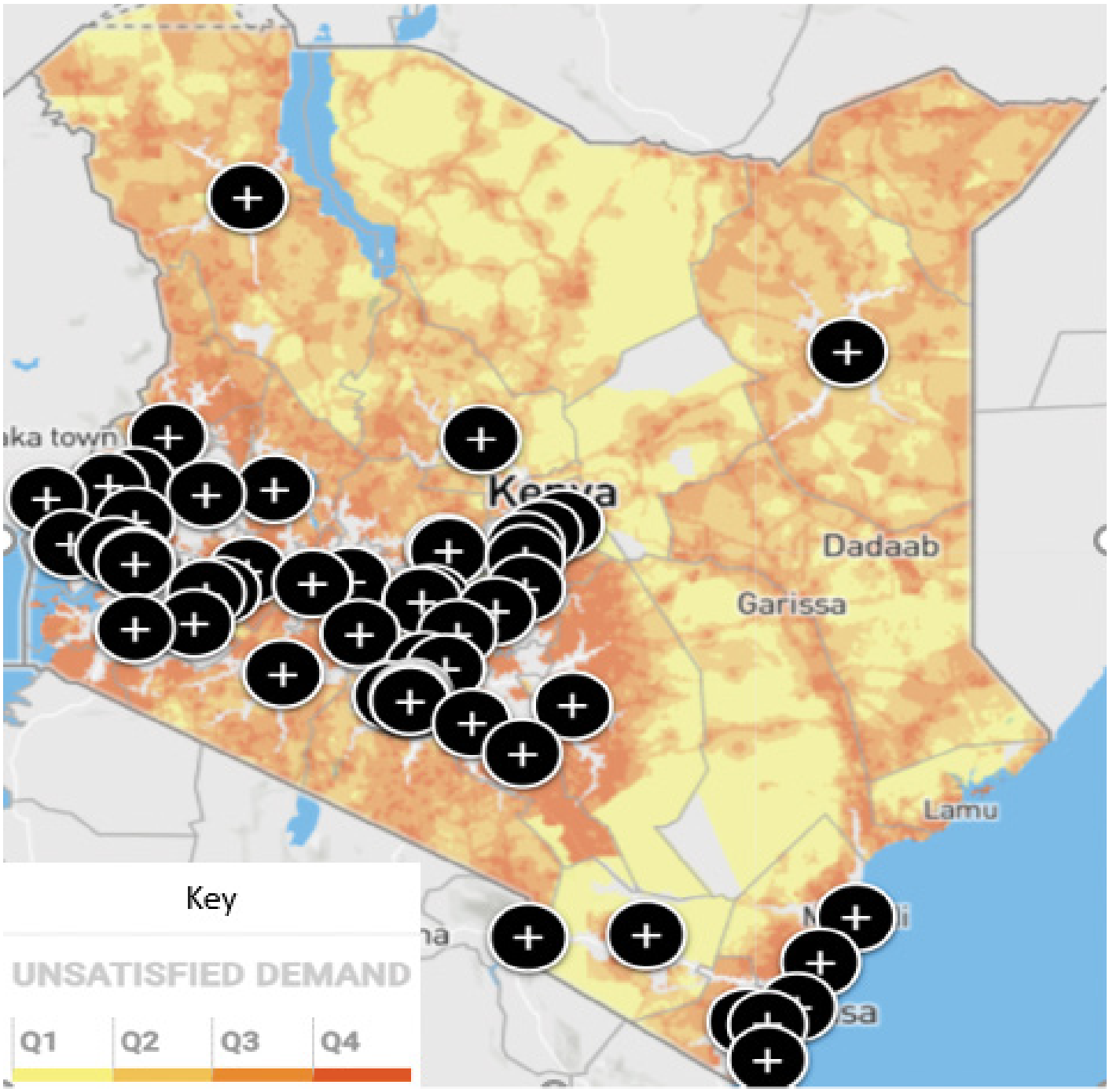
Supplementary Table 7: Univariate logistic regression analysis

Variable	Options	N	NS (%)	Crude OR (95% CI)	P-value
Gender	Female	5,164	42.1	Ref	0.0014
	Male	3,593	47.7	**1.27 (1.10 – 1.50)**	
Age, years	<1	783	46.1	1.21 (0.50 – 2.64)	0.0001
	1-17	1,647	43.2	1.04 (0.92 – 1.18)	
	18-49	4,324	42.3	Ref	
	50-65	1,165	46.1	1.20 (0.88 – 1.66)	
	>65	804	48.8	**1.32 (1.07 – 1.42)**	
Diagnosis	Infection/Inflammation	657	63.2	Ref	0.5789
	Neoplasm	220	60.9	0.91 (0.66 – 1.24)	
	Injuries	199	67.8	1.23 (0.88 – 1.72)	
	Renal	140	68.6	1.27 (0.86 – 1.88)	
	Cerebrovascular	136	60.3	0.88 (0.61 – 1.29)	
	Cardiovascular	90	61.1	0.92 (0.58 – 1.44)	
	Surgical/Orthopedics	87	64.4	1.05 (0.66 – 1.68)	

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 1: Population coverage of laboratories

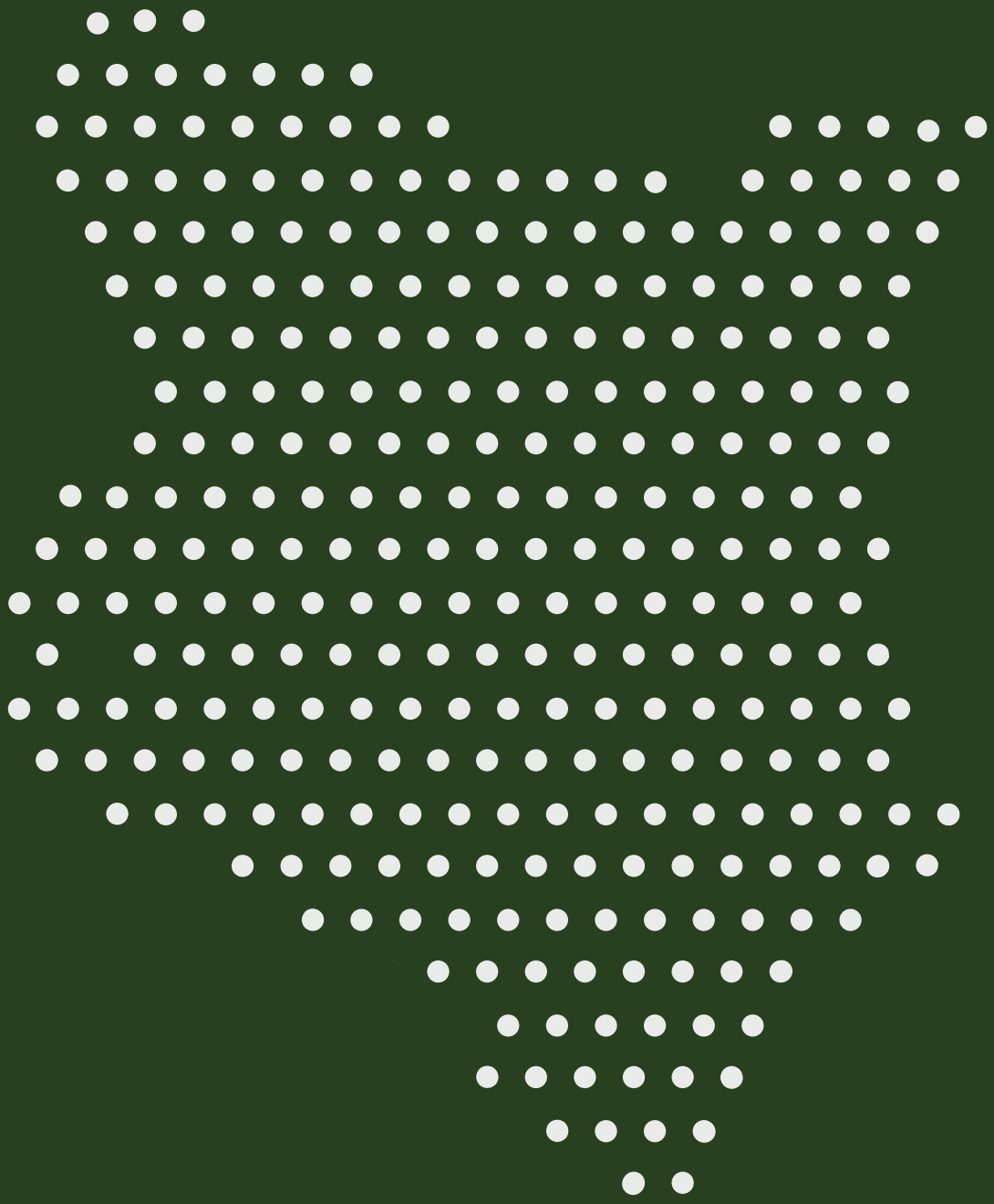
Supplementary Figure 2a: Inappropriate testing A

Organism Name	Antimicrobial Agent	Agent Code	Interpreted Results	Antimicrobial Susceptibility Method	Year
Escherichia coli	Vancomycin	VAN_ND30	R	Disk	2018
Escherichia coli	Vancomycin	VAN_ND30	R	Disk	2018
Escherichia coli	Vancomycin	VAN_ND30	R	Disk	2018
Escherichia coli	Vancomycin	VAN_ND30	R	Disk	2018
Klebsiella sp.	Penicillin G	PEN_ND10	I	Disk	2018
Escherichia coli	Penicillin G	PEN_ND10	R	Disk	2018
Escherichia coli	Penicillin G	PEN_ND10	R	Disk	2018
Escherichia coli	Penicillin G	PEN_ND10	R	Disk	2018
Escherichia coli	Penicillin G	PEN_ND10	R	Disk	2018
Escherichia coli	Penicillin G	PEN_ND10	R	Disk	2018
Escherichia coli	Oxacillin	OXA_ND1	R	Disk	2017
Klebsiella sp.	Oxacillin	OXA_ND1	I	Disk	2017
Klebsiella sp.	Oxacillin	OXA_ND1	R	Disk	2017
Klebsiella sp.	Oxacillin	OXA_ND1	I	Disk	2017
Staphylococcua aureus	Vancomycin	VAN_ND30	I	Disk	2018
Staphylococcua aureus	Vancomycin	VAN_ND30	I	Disk	2018
Staphylococcua aureus	Vancomycin	VAN_ND30	I	Disk	2018
Staphylococcua aureus	Vancomycin	VAN_ND30	I	Disk	2018
Staphylococcua aureus	Vancomycin	VAN_ND30	I	Disk	2018
Staphylococcua aureus	Vancomycin	VAN_ND30	R	Disk	2018

Supplementary Figure 2b: Inappropriate testing B

Organism Name	Antimicrobial Agent	Agent Code	Interpreted Results	Antimicrobial Susceptibility Method	Year
Gram positive cocci	Vancomycin	VAN_ND30	R	Disk	2018
Gram positive cocci	Vancomycin	VAN_ND30	R	Disk	2018
Gram positive cocci	Vancomycin	VAN_ND30	R	Disk	2017
Gram positive rods	Vancomycin	VAN_ND30	S	Disk	2018
Gram positive cocci	Vancomycin	VAN_ND30	S	Disk	2017
Gram positive cocci	Vancomycin	VAN_ND30	S	Disk	2016
Gram positive cocci	Vancomycin	VAN_ND30	S	Disk	2016
Gram positive rods	Vancomycin	VAN_ND30	S	Disk	2016
Gram positive cocci	Vancomycin	VAN_ND30	S	Disk	2016
Gram positive bacteria	Vancomycin	VAN_ND30	S	Disk	2016
Candida sp.	Tetracycline	TCY_ND30	R	Disk	2018
Candida sp.	Ampicillin	AMP_ND10	R	Disk	2017
Candida sp.	Erythromycin	ERY_ND15	R	Disk	2017
Candida sp.	Gentamicin	GEN_ND10	R	Disk	2017
Candida sp.	Kanamycin	KAN_ND30	R	Disk	2017
Candida sp.	Lincomycin	LIN_ND19	R	Disk	2017
Candida sp.	Methicillin	MET_ND5	R	Disk	2017
Candida sp.	Minocycline	MNO_ND30	R	Disk	2017

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 programmes; 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 programmes, 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 programmes, 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 programmes, 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 utilised 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 the 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
Meticillin	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

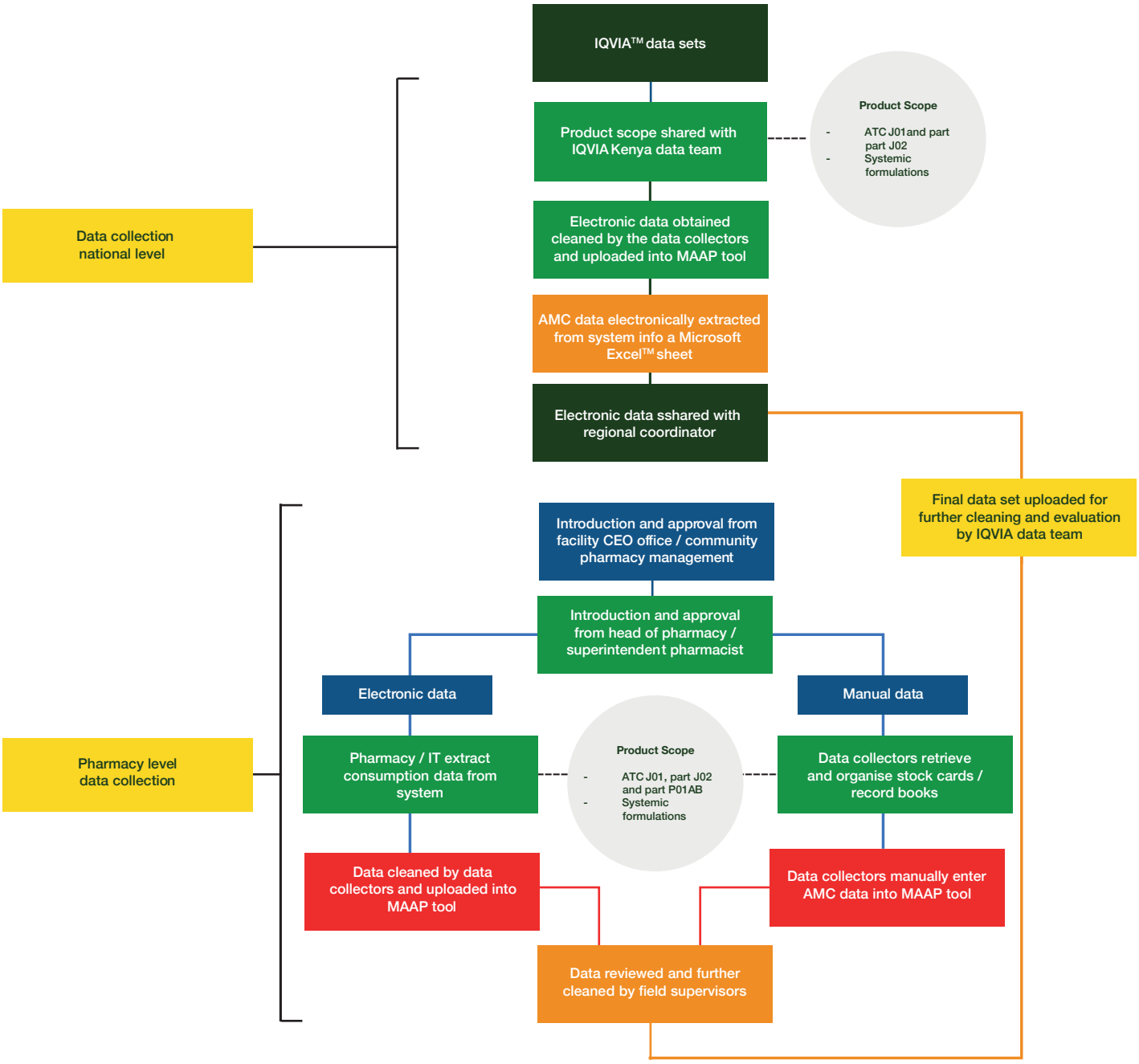
Ciprofloxacin/Metronidazole	J01RA10	U
Ciprofloxacin/Tinidazole	J01RA11	U
Ciprofloxacin/Ornidazole	J01RA12	U
Norfloxacin/Tinidazole	J01RA13	U
Vancomycin	J01XA01	W
Teicoplanin	J01XA02	W
Telavancin	J01XA03	R
Dalbavancin	J01XA04	R
Oritavancin	J01XA05	R
Colistin	J01XB01	R
Polymyxin B	J01XB02	R
Fusidic Acid	J01XC01	W
Metronidazole	J01XD01	A
Tinidazole	J01XD02	U
Ornidazole	J01XD03	U
Nitrofurantoin	J01XE01	U
Nifurtoinol	J01XE02	U
Furazidin	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

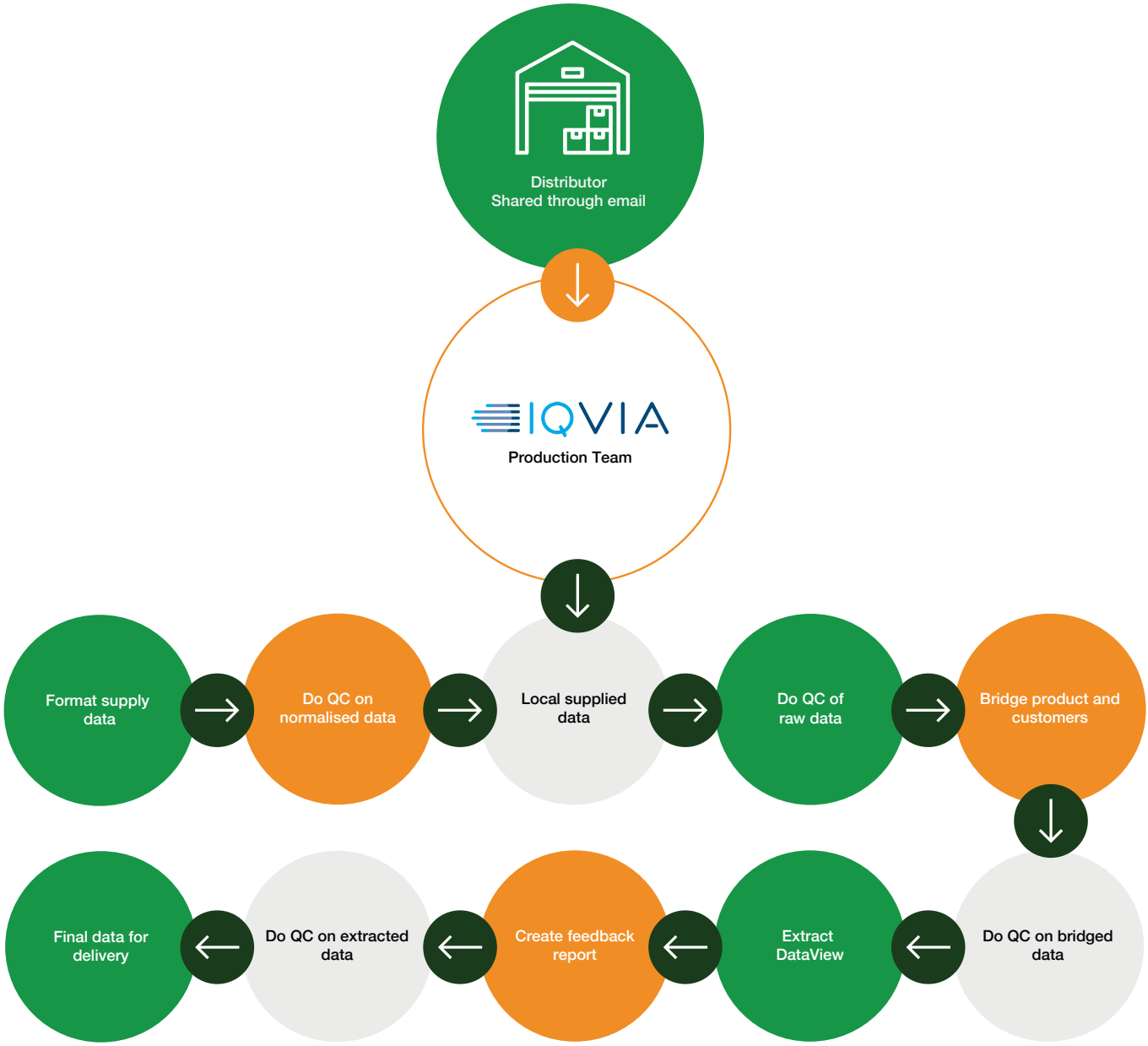
Appendix 4: Key AMC specific variables

	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



Appendix 6: Data checks and validation process for national AMC data



Appendix 7: Description of AMC analysis methodology

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

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

***calculated for the WHO approved for antibiotics: https://www.whocc.no/atc_ddd_index/**

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 the AMC is converted to standard DDDs, the data are further analysed into the below standard units:

1. DDDs/1 000 inhabitants/day (DID): used to calculate total AMC for the Kenyan 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:

DDD/1000 Inhabitants/day =

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

*Kenya population estimated for 2016-2018 obtained from: https://www.worldometers.info/world-population/kenya-population/C

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

DDD equivalent (%) =

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

*WHO approved DDDs for antibiotics: https://www.whocc.no/atc_ddd_index/

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 is 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 minimising 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%). The 'Access' group comprises 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 programmes 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 8: National AMC by Antimicrobial Molecules

ATC Class Rank	AWaRe category	Molecule	2016	2017	2018	Mean DDD/1000 inhabitant-days
			DDD/1000 inhabitant/days (%*)			
J01 Class		Total	10.81 (100)	7.24 (100)	8.01 (100)	8.69
1	Access	Amoxicillin	3.191502 (29.5)	1.615894 (22.3)	1.72042 (21.5)	2.18
2	Access	Sulfamethoxazole/ Trimethoprim	1.795982 (16.6)	0.565271 (7.8)	0.825539 (10.3)	1.06
3	Uncategorised	Ampicillin/Cloxacillin	0.645898 (6)	0.71077 (9.8)	0.771877 (9.6)	0.71
4	Watch	Erythromycin	0.828769 (7.7)	0.424923 (5.9)	0.446819 (5.6)	0.57
5	Access	Doxycycline	0.709423 (6.6)	0.546037 (7.5)	0.434568 (5.4)	0.56
6	Watch	Cefuroxime	0.405538 (3.8)	0.489979 (6.8)	0.531926 (6.6)	0.48
7	Access	Amoxicillin/ Clavulanic Acid	0.36686 (3.4)	0.431796 (6)	0.509384 (6.4)	0.44
8	Access	Flucloxacillin	0.472028 (4.4)	0.273366 (3.8)	0.537278 (6.7)	0.43
9	Watch	Azithromycin	0.38725 (3.6)	0.295207 (4.1)	0.264091 (3.3)	0.32
10	Watch	Levofloxacin	0.21963 (2)	0.250245 (3.5)	0.226201 (2.8)	0.23
11	Watch	Ciprofloxacin	0.269905 (2.5)	0.227673 (3.1)	0.187604 (2.3)	0.23
12	Access	Benzylpenicillin	0.305773 (2.8)	0.199707 (2.8)	0.174145 (2.2)	0.23
13	Access	Cefalexin	0.149775 (1.4)	0.148548 (2.1)	0.162096 (2)	0.15
14	Watch	Ceftriaxone	0.134555 (1.2)	0.153255 (2.1)	0.156173 (2)	0.15
15	Access	Phenoxymethylpenicillin	0.120166 (1.1)	0.077989 (1.1)	0.232483 (2.9)	0.14
16	Access	Tetracycline	0.114403 (1.1)	0.118817 (1.6)	0.164407 (2.1)	0.13
17	Watch	Cefixime	0.059004 (0.5)	0.138679 (1.9)	0.196212 (2.5)	0.13
18	Access	Gentamicin	0.154352 (1.4)	0.126538 (1.7)	0.077567 (1)	0.12
19	Watch	Clarithromycin	0.099603 (0.9)	0.112864 (1.6)	0.126519 (1.6)	0.11
20	Watch	Norfloxacin	0.08838 (0.8)	0.106172 (1.5)	0.072483 (0.9)	0.09
21	Access	Cloxacillin	0.047551 (0.4)	0.070077 (1)	0.062515 (0.8)	0.06

22	Access	Ampicillin	0.087166 (0.8)	0.027719 (0.4)	0.005077 (0.1)	0.04
23	Uncategorised	Amoxicillin/Flucloxacillin	0.044421 (0.4)	0.039472 (0.5)	0.032518 (0.4)	0.04
24	Watch	Cefpodoxime proxetil	0.021881 (0.2)	0.020197 (0.3)	0.023157 (0.3)	0.02
25	Access	Cefadroxil	0.022077 (0.2)	0.015094 (0.2)	0.013674 (0.2)	0.02
26	Access	Clindamycin	0.011011 (0.1)	0.011257 (0.2)	0.011781 (0.1)	0.01
27	Access	Chloramphenicol	0.015898 (0.1)	0.007417 (0.1)	0.006275 (0.1)	0.01
28	Watch	Moxifloxacin	0.007102 (0.1)	0.006741 (0.1)	0.00691 (0.1)	0.007
29	Uncategorised	Benzathine benzylpenicillin/ Procaine benzylpenicillin/Sodium benzylpenicillin	0.007149 (0.1)	0.00658 (0.1)	0.004833 (0.1)	0.006
30	Watch	Ofloxacin	0.005876 (0.1)	0.003856 (0.1)	0.003113 (0)	0.004
31	Reserve	Linezolid	0.001766 (0)	0.002494 (0)	0.00291 (0)	0.002
32	Watch	Meropenem	0.00193 (0)	0.002492 (0)	0.002065 (0)	0.002
33	Watch	Lincomycin	0.003585 (0)	0.000438 (0)	0.001592 (0)	0.002
34	Access	Amikacin	0.001742 (0)	0.001822 (0)	0.001722 (0)	0.002
35	Uncategorised	Cefuroxime/Clavulanic Acid	0.003865 (0)	0.001302 (0)	0 (0)	0.002
36	Watch	Kanamycin	0.001471 (0)	0.002085 (0)	0.001142 (0)	0.002
37	Uncategorised	Cefixime/Clavulanic Acid	0.000261 (0)	0.001997 (0)	0.001479 (0)	0.001
38	Watch	Midecamycin	0.002106 (0)	0.000863 (0)	0.000564 (0)	0.001
39	Watch	Ceftazidime	0.001131 (0)	0.000695 (0)	0.001243 (0)	0.001
40	Reserve	Minocycline	0.000838 (0)	0 (0)	0.002212 (0)	0.001
41	Watch	Piperacillin/Tazobactam	0.00053 (0)	0.000617 (0)	0.001047 (0)	0.0007
42	Watch	Imipenem/Cilastatin	0.000505 (0)	0.000519 (0)	0.000384 (0)	0.0005
43	Access	Cefazolin	0.000776 (0)	0.000322 (0)	0.000288 (0)	0.0005
44	Watch	Vancomycin	0.00049 (0)	0.000364 (0)	0.000393 (0)	0.0004
45	Watch	Cefepime	0.000346 (0)	0.00027 (0)	0.000177 (0)	0.0003

46	Watch	Roxithromycin	0.000634 (0)	0.000122 (0)	0 (0)	0.0003
47	Watch	Cefaclor	0.00039 (0)	0.000041 (0)	0.000288 (0)	0.0002
48	Watch	Cefdinir	0.000218 (0)	0.000432 (0)	0 (0)	0.0002
49	Uncategorised	Ceftriaxone/Sulbactam	0.000088 (0)	0.00021 (0)	0.000256 (0)	0.0002
50	Uncategorised	Cefpodoxime proxetil/Clavulanic Acid	0.000364 (0)	0.000076 (0)	0 (0)	0.0001
51	Watch	Ertapenem	0.000131 (0)	0.00015 (0)	0.000124 (0)	0.0001
52	Watch	Pefloxacin	0.00008 (0)	0.000183 (0)	0.000109 (0)	0.0001
53	Uncategorised	Amoxicillin/Sulbactam	0.000118 (0)	0.000188 (0)	0.000015 (0)	0.0001
54	Watch	Teicoplanin	0.0001 (0)	0.00009 (0)	0.000069 (0)	0.00009
55	Watch	Cefotaxime	0.000067 (0)	0.000056 (0)	0.000133 (0)	0.00009
56	Reserve	Tigecycline	0.000047 (0)	0.000083 (0)	0.000086 (0)	0.00007
57	Uncategorised	Ofloxacin/Ornidazole	0.000056 (0)	0.000055 (0)	0 (0)	0.00004
58	Watch	Sparfloxacin	0.000087 (0)	0 (0)	0 (0)	0.00003
59	Access	Ampicillin/Sulbactam	0.000026 (0)	0.000022 (0)	0.000021 (0)	0.00002
60	Uncategorised	Levofloxacin/Ornidazole	0 (0)	0 (0)	0.000028 (0)	0.000009
61	Uncategorised	Cefoperazone/Sulbactam	0.000019 (0)	0.000003 (0)	0 (0)	0.000007
62	Access	Spectinomycin	0.000001 (0)	0.000015 (0)	0 (0)	0.000005
J02 Class		**Total**	**0.14 (100)**	**0.15 (100)**	**0.13 (100)**	**0.14**
1	Uncategorised	Fluconazole	0.124814 (86.8)	0.129051 (87.3)	0.112008 (84.9)	0.12
2	Uncategorised	Itraconazole	0.017603 (12.2)	0.017845 (12.1)	0.019433 (14.7)	0.02
3	Uncategorised	Amphotericin-B	0.001086 (0.8)	0.00056 (0.4)	0.000258 (0.2)	0.0006
4	Uncategorised	Voriconazole	0.000234 (0.2)	0.000203 (0.1)	0.000188 (0.1)	0.0002
5	Uncategorised	Caspofungin	0.000088 (0.1)	0.000088 (0.1)	0.00007 (0.1)	0.00008
6	Uncategorised	Micafungin	0 (0)	0 (0)	0.000003 (0)	0.000001

Appendix 9: Breakdown of the national AMC by ATC classes

	% consumption		
ATC class	2016	2017	2018
Penicillins with extended spectrum	29.9%	22.2%	21.2%
Combinations of penicillins, incl. beta-lactamase inhibitors	9.7%	16.0%	16.2%
Macrolides	12.0%	11.3%	10.3%
Combinations of sulfonamides and trimethoprim, incl. derivatives	16.4%	7.7%	10.1%
Tetracyclines	7.5%	9.0%	7.4%
Beta-lactamase resistant penicillins	4.7%	4.6%	7.4%
Second-generation cephalosporins	3.7%	6.7%	6.5%
Fluoroquinolones	5.4%	8.1%	6.1%
Beta-lactamase sensitive penicillins	3.9%	3.8%	5.0%
Third-generation cephalosporins	2.0%	4.3%	4.7%
First-generation cephalosporins	1.6%	2.2%	2.2%
Triazole derivatives	1.3%	2.0%	1.6%
Aminoglycosides	1.4%	1.8%	1.0%
Lincosamides	0.1%	0.2%	0.2%
Amphenicols	0.1%	0.1%	0.1%
Beta-lactamase sensitive penicillins - combinations	0.1%	0.1%	0.1%
Other antibacterial*	0.0%	0.0%	0.0%
Carbapenems*	0.0%	0.0%	0.0%
Glycopeptides*	0.0%	0.0%	0.0%
Antimycotics for systemic use*	0.0%	0.0%	0.0%
Fourth-generation cephalosporins*	0.0%	0.0%	0.0%
Other antimycotics for systemic use*	0.0%	0.0%	0.0%
Combinations of antibacterial*	0.0%	0.0%	0.0%

**Consumption was recorded for the last four classes; however, rates were below 0.1% of the total AMC.*

Appendix 10: Breakdown of antibiotic documented and their inclusion in the WHO EML and Kenya EML

Standardised Molecule Name	WHO AWaRe Categorisation	WHO ATC Code	WHO EML	National EML	Documented Data
Amikacin	Access	J01GB06	Y	Y	Y
Amoxicillin	Access	J01CA04	Y	Y	Y
Amoxicillin/Clavulanic acid	Access	J01CR02	Y	Y	Y
Amoxicillin/Cloxacillin	-	J01CR50	N	N	Y
Amoxicillin/Flucloxacillin	-	J01CR50	N	N	Y
Amoxicillin/Sulbactam	Access	J01CR02	N	N	Y
Amphotericin-B	-	J02AA01	N	N	Y
Ampicillin	Access	J01CA01	Y	Y	Y
Ampicillin/Cloxacillin	-	J01CR50	N	N	Y
Ampicillin/Sulbactam	-	J01CR01	N	N	Y
Azithromycin	Watch	J01FA10	Y	Y	Y
Azithromycin/Fluconazole/ Secnidazole	-	J01RA07	N	N	Y
Benzathine Benzylpenicillin	Access	J01CE08	Y	Y	Y
Benzathine Benzylpenicillin/Procaine Benzylpenicillin/Sodium Benzylpencillin	-	J01CE30	N	N	Y
Benzylpenicillin	Access	J01CE01	Y	Y	Y
Caspofungin	-	J02AX04	N	N	Y
Cefaclor	Watch	J01DC04	N	N	Y
Cefadroxil	Access	J01DB05	N	N	Y
Cefalexin	Access	J01DB01	Y	N	Y
Cefazolin	Access	J01DB04	Y	Y	Y
Cefdinir	Watch	J01DD15	N	N	Y
Cefepime	Watch	J01DE01	N	N	Y
Cefiderocol	Reserve	J01DI04	Y	N	N
Cefixime	Watch	J01DD08	Y	Y	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
Cefprozil	Watch	J01DC10	N	N	Y
Ceftazidime	Watch	J01DD02	Y	Y	Y
Ceftazidime/Avibactam	Reserve	J01DD52	Y	N	N
Ceftriaxone	Watch	J01DD04	Y	Y	Y
Ceftriaxone/Sulbactam	-	J01DD63	N	N	Y
Cefuroxime	Watch	J01DC02	Y	N	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	N	Y
Colistin	Reserve	J01XB01	Y	Y	Y
Doxycycline	Access	J01AA02	Y	Y	Y
Ertapenem	Watch	J01DH03	N	Y	Y
Erythromycin	Watch	J01FA01	N	N	Y

Flucloxacillin	Access	J01CF05	N	Y	Y
Fluconazole	-	J02AC01	N	N	Y
Fosfomycin (IV)	Reserve	J01XX01	Y	Y	N
Fosfomycin (oral)	Watch	J01XX01	N	Y	Y
Gentamicin	Access	J01GB03	Y	Y	Y
Imipenem/Cilastatin	Watch	J01DH51	N	N	Y
Itraconazole	-	J02AC02	N	N	Y
Kanamycin	Watch	J01GB04	N	N	Y
Ketoconazole	--	J02AB02	N	N	Y
Levofloxacin	Watch	J01MA12	N	N	Y
Levofloxacin/Ornidazole	-	J01RA05	N	N	Y
Lincomycin	Watch	J01FF02	N	N	Y
Linezolid	Reserve	J01XX08	Y	Y	Y
Meropenem	Watch	J01DH02	Y	Y	Y
Meropenem/Vaborbactam	Reserve	J01DH52	Y	N	N
Metronidazole	Access	P01AB01, J01XD01	Y	Y	Y
Metronidazole/Diloxanide	-	P01AB51	N	N	Y
Metronidazole/Diloxanide/ Dicyclomine	-	P01AB51	N	N	Y
Micafungin	-	J02AX05	N	N	Y
Midecamycin	Watch	J01FA03	N	N	Y
Minocycline	Watch	J01AA08	N	N	Y
Miocamycin	-	J01FA11	N	N	Y
Moxifloxacin	Watch	J01MA14	N	N	Y
Nalidixic acid	-	J01MB02	N	N	Y
Nitrofurantoin	Access	J01XE01	Y	Y	Y
Norfloxacin	Watch	J01MA06	N	N	Y
Norfloxacin/Tinidazole	--	J01RA13	N	N	Y
Ofloxacin	Watch	J01MA01	N	N	Y
Ofloxacin/Ornidazole	-	J01RA09	N	N	Y
Ornidazole	-	P01AB03	N	N	Y
Pefloxacin	Watch	J01MA03	N	N	Y
Phenoxymethylpenicillin	Access	J01CE02	Y	Y	Y
Piperacillin/Tazobactam	Watch	J01CR05	Y	Y	Y
Plazomicin	Reserve	J01GB14	Y	N	N
Polymyxin-B	Reserve	J01XB02	Y	Y	Y
Procaine benzylpenicillin	Access	J01CE09	Y	N	Y
Roxithromycin	Watch	J01FA06	N	N	Y
Satranidazole	-	P01AB--	N	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
Teicoplanin	Watch	J01XA02	N	Y	Y
Tetracycline	Access	J01AA07	N	N	Y
Tigecycline	Reserve	J01AA12	N	Y	Y
Tinidazole	-	P01AB02	N	Y	Y
Tinidazole/Diloxanide/ Dimethicone	-	P01AB--	N	N	Y
Trimethoprim	Access	J01EA01	Y	N	Y
Vancomycin	Watch	J01XA01	Y	Y	Y

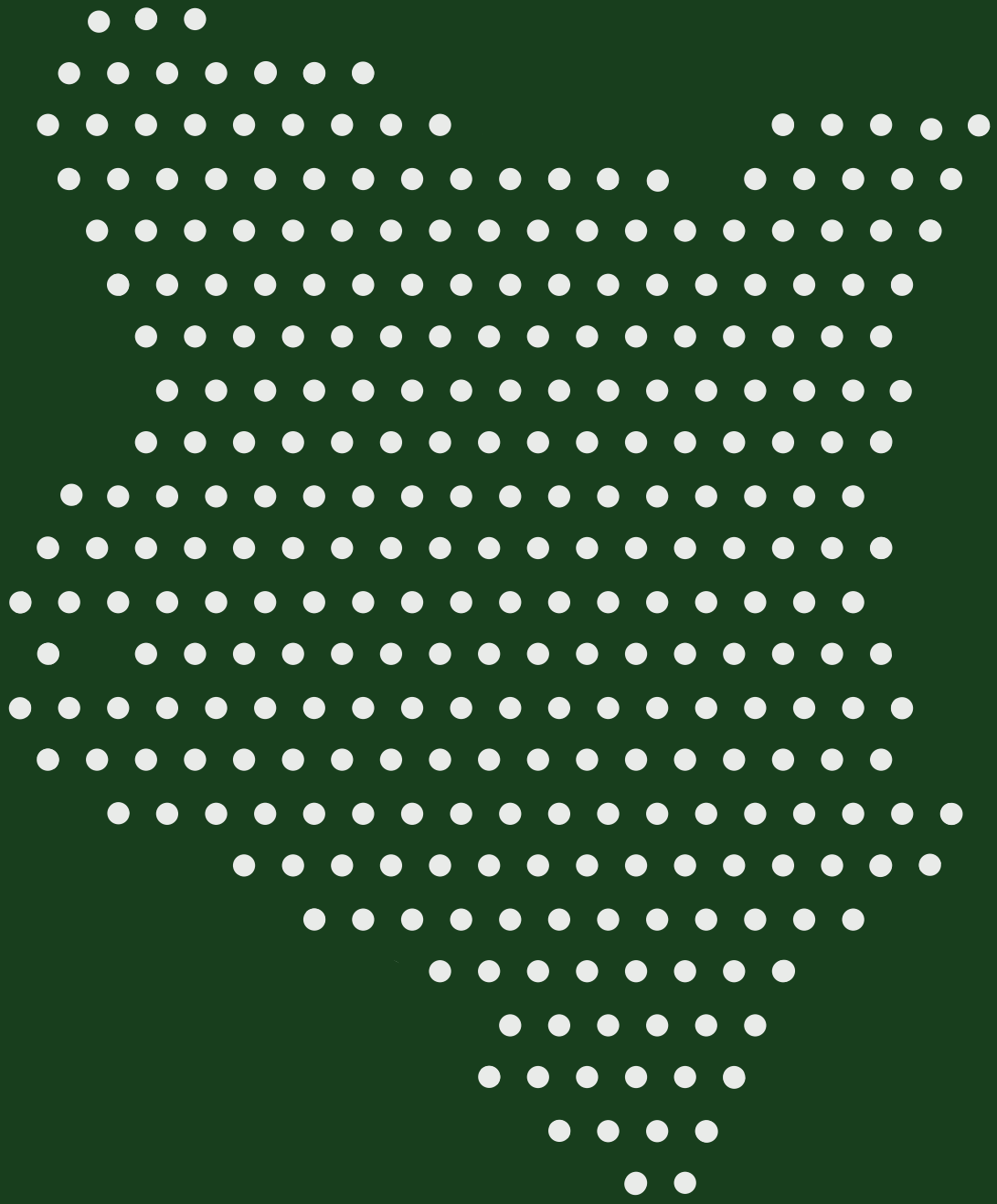
Appendix 10: AMC data collection and expired drug and losses tool

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
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African Union

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Centres for Disease Control and Prevention
Safeguarding Africa's Health

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ECSA Health Community

InSTEDD
Innovative Support To Emergencies Diseases and Disasters

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