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

Senegal (2016-2018)

SENEGAL

Fleming Fund Regional Grant (Round 1)

Mapping Antimicrobial Resistance and Antimicrobial Use Partnership

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

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

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Abbreviations

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

Executive Summary

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

The Fleming Fund, a 265-million-pound United Kingdom aid, supports a range of initiatives to increase the quantity and quality of AMR data in LMICs. Regional Grant (Round 1) activities in Africa are led by The African Society for Laboratory Medicine (ASLM) and implemented by the 'Mapping Antimicrobial resistance and Antimicrobial use Partnership' (MAAP) consortium.

This report summarises the activities undertaken by MAAP during the implementation of the Regional Grant, and aims to determine national AMR, AMC and AMU surveillance capacity, resistance rates and trends, and assess the antimicrobial flow in Senegal during 2016-2018.

Senegal had approximately 200 laboratories in the national laboratory network during the study period, of which 31 were reported to have capacity for bacteriology testing. Based on self-reported information from 20 laboratories, functioning and quality compliance were assessed to understand the laboratory preparedness for AMR surveillance.

AMR rates presented are based on the analysis of antimicrobial susceptibility results 0f 8 763 positive cultures obtained from 16 laboratories. Moderately high AMR rates were noted for 3rd generation cephalosporin-resistant Enterobacterales (40-42%), and methicillin-resistant Staphylococcus aureus (MRSA) (28-42%). Rates for carbapenem-resistant Enterobacterales (<5%) and carbapenem-resistant Pseudomonas aeruginosa (<10%) were lower. Antimicrobial resistant infections were found to be more common in males and in age groups such as infants and the elderly. Patients diagnosed with injuries were less prone to resistant infections. All results should be interpreted with caution as the participating laboratories were at different levels of service and had variable testing capacity.

AMC is measured as the quantity of antimicrobials sold or dispensed, whereas AMU reviews whether antimicrobials are used appropriately based on additional data such as clinical indicators. Only AMC data were retrievable at selected sentinel pharmacies. AMU data weres not obtained due to a lack of a unique patient identifier and tracking systems across hospital departments. The average national total AMC levels in Senegal between 2017-2019 were 43.8 defined daily doses (DDD) per 1 000 inhabitants per day, ranging from 17.3 in 2017, 60.6 in 2018 and 53.3 in 2019. Antimicrobial utilisation by the World Health OrganisationOrganisation (WHO) Anatomical Therapeutic Chemical (ATC) classification was highest for penicillins with extended spectrum (range 35.0% to 57.3%), followed by tetracyclines (range 12.0% to 47.2%) and by fluoroquinolones (range 2.2% to 15.6%). The top five most consumed antimicrobials were Amoxicillin, Doxycycline, Ciprofloxacin, Sulfamethoxazole/trimethoprim and Amoxicillin/Clavulanic acid. Together, they accounted for 92% of the total consumption share thus suggesting a lack of variation. This consumption trend could potentially increase AMR.

The total AMC came from 87.4% 'Access', 12.6% of 'Watch' and <0.1% of 'Reserve' antibiotics. Between 2016-2018, the use of 'Access' category antibiotics exceeded the WHO minimum recommended consumption threshold of 60%. Eight combinations of two or more broad-spectrum fixed dose combinations (FDC) of antimicrobials were identified that were not recommended for clinical utility but were nevertheless consumed in Senegal. Of those, Ciprofloxacin/Tinidazole was most consumed (mean DID of <0.1).

The drug resistance index (DRI) is a simple metric based on aggregate rates of resistance and measured on a scale of 0-100, where 0 indicates fully susceptible while 100 indicates fully resistant. The DRI estimate in Senegal was found to be high at 80.0% (95% CI, 73.7–86.1%) thus implying low antibiotic effectiveness which is a threat to effective infectious disease management and calls for urgent policy intervention.

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

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

Overview

The Fleming Fund Grants Programme

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

The Fleming Fund Regional Grants Round 1 Programme

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

Problem Statement

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

While the 'hidden treasure' is simply inaccessible for use in large-scale analytics, collecting and, where necessary, digitising data from these institutions has the potential to establish baselines of AMR across a wide range of pathogen/drug combinations and 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 further provide a valuable understanding of the current treatment efficacy, which can inform evidence-based policy and stewardship actions.

MAAP

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

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

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

The results of this analysis contribute to the determination of baselines and trends for AMR and AMC, AMR drivers, as well as critical gaps in surveillance. The study recommendations aim to increase country-level-capacity for future collection, analysis and reporting of AMR and AMC or AMU data. Fourteen African countries across West Africa (Burkina Faso, Ghana, Nigeria, Senegal and Sierra Leone), East Africa (Kenya, Tanzania and Uganda), Central Africa (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 Senegal 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 Senegal, including the public and private human healthcare sector
- To collect, digitise and analyse retrospective data from selected facilities using standardised electronic tools; to describe the completeness and validity of AMR data in selected facilities

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

Outcome measures

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

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

Key engagements and activities

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

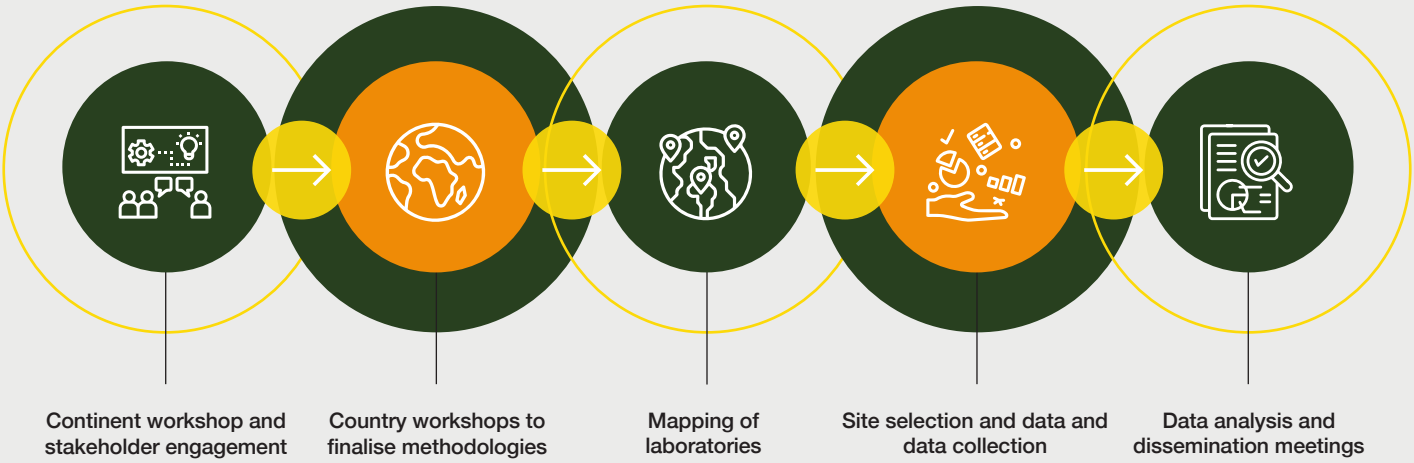


Figure 1: Key engagements and activities

Ethical issues and data sharing agreements

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

Country Profile

Health and Demographic Profile

As of 2020, Senegal was estimated to have a population of 16.7 million inhabitants with a life expectancy of 68 years. The country has a considerable infectious disease burden with a TB incidence of 117 per 100 000 and an HIV prevalence of 0.3%. The country has a physician density rate of 0.09 per 1 000 inhabitants and nurse density rate of 0.54 per 1 000 inhabitants. With a universal health coverage index of 49, Senegal appears to have an average coverage of essential services (Table 1).

Table 1: Health and demographic profile of Senegal

	Senegal		Comparator values (most recent year)*		
	Year	Value	India	Argentina	United States
Population	2020	16 743 ,930	1, 380 004 390	45 376 763	329 484 123
Life expectancy during the study period, total (years)	2019	68	70	77	79
Universal health coverage service index (0-100)	2019	49	61	67	83
GDP per capita (current US$)		1 471.83	1 ,927.7	8 579.0	63 593.4
Immunisation, DPT (% of children ages 12-23 months)	2019	93	91.0	86.0	94.0
Incidence of tuberculosis (per 100 000 people)		117	188.0	31.0	2.4
Prevalence of HIV, total (% of population ages 15-49)#	2020	0.3	0.2*	0.4 2020	0.4 2019
Primary education (%)#	2019	61.2	94.6	98.6	100
Physicians density (physicians per 1 000)#	2019	0.09	0.93	4.0	2.6
Nurses density (nurses and midwives per 1 000)#	2019	0.54	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

Policy frameworks

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

Senegal has a National Multisectoral Antimicrobial Resistance Surveillance and Control Action Plan (2018-2022). The overall objective of the national action plan for AMR is to provide an effective response, through an integrated approach (One Health), to the growing threat of AMR in Senegal.[10] Senegal is not enrolled in GLASS. However, since 2018, Senegal served as a pilot site for the implementation of the GLASS-One Health Tricycle Project, which is a WHO Integrated Global Survey on Extended Spectrum Beta-Lactamase (ESBL) Escherichia coli, along with eight other member states.[11] Senegal 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 historical data on AMR generated routinely by the national laboratory network of Senegal, including the public and private healthcare sectors.

Methodology

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

During the initial stages of in-country work, the laboratory network was mapped with support from the country's MoH. An inventory of laboratories in the tiered network was created and laboratories capable of conducting antimicrobial susceptibility testing (AST) were identified. A survey was administered to the identified laboratories, with the aim of obtaining site-specific details and assessing the laboratories on five aspects: status of commodities and equipment, quality management systems (QMS), personnel and training, specimen management, and laboratory information systems (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 Senegal, 200 laboratories were mapped to the national laboratory network. An eligibility questionnaire was sent to 31 laboratories identified as having capacity for bacteriology testing. Of the 22 laboratories that responded to the questionnaire, a majority were affiliated with the government (Table 2, Supplementary Table 1). The laboratory readiness scores of the surveyed laboratories varied widely (range 39.5–84.2%). From the 22 responding laboratories, 16 laboratories were selected for data collection (Figure 2). The laboratories named in Table 2 below are listed in order of decreasing laboratory readiness scores.

Table 2: Laboratory readiness scores

Surveyed laboratories*	Laboratory readiness score (%)	Level of service	Affiliation
Selected			
Laboratoire de Biologie Médicale de l'Hôpital Général Idrissa Pouye (Idrissa Pouye)	84.2	Reference	Government
Centre d'analyses de biologie médicale du centre hospitalier Abass NDAO de Dakar (Abass)	84.2	Reference	Government
Laboratoire Biomédical Centre Hospitalier Régional de Thiès (Thiès)	76.3	Regional/Intermediate	Government
Laboratoire regional heinrich lubke de Diourbel (Heinrich Lubke)	76.3	Regional/Intermediate	Government
Laboratoire Hôpital Enfants de Diamniadio (Diamniadio)	76.3	Reference	Government
Laboratoire de Bactériologie de l'hôpital régional de Saint-Louis (CHR Sr. Louis)	73.7	Regional/Intermediate	Government
Laboratoire Centre hospitalier National d'Enfants Albert Royer (Albert Royer)	73.7	Reference	Government
Hôpital Régional de Matam (Matam)	71.1	Regional/Intermediate	Government
Hôpital Saint Jean De Dieu De Thies (Saint Jean)	71.1	Regional/Intermediate	Private
Laboratoire d'analyses biomédicales EPS1 Youssou Mbargane Diop de Rufisque (Mbargane)	68.4	Other	Government
Centre Hospitalier régional de Ourossogui (CHR Ourossogui)	57.9	Regional/Intermediate	Government
Laboratoire Hopital Regional Fatick (Fatick)	57.9	Regional/Intermediate	Government
EPS Mbour (Mbour)	57.9	Regional/Intermediate	Government
Laboratoire Régional Sor Saint-Louis (Sor Saint-Louis)	55.3	Regional/Intermediate	Government
EPS 3 Matlaboul Fawzaini (Matlaboul)	55.3	Reference	Government
Laboratoire de Bactériologie -Virologie de l'EPS Institut d'Hygiène Sociale (IHS)	52.6	Other	Government
Not Selected			
Laboratoire de l'hopital Magatte Lo de Linguere	65.8	Regional/Intermediate	Government
Laboratoire regional de kaolack	55.3	Regional/Intermediate	
Laboratoire CHR Ziguinchor	47.4	Reference	Government
laboratoire hôpital Régional de Kolda	47.4	Regional/Intermediate	Government
CHR de Ndioum	47.4	Regional/Intermediate	Government
	39.5	Regional/Intermediate	Government

** Laboratory names are abbreviated.*

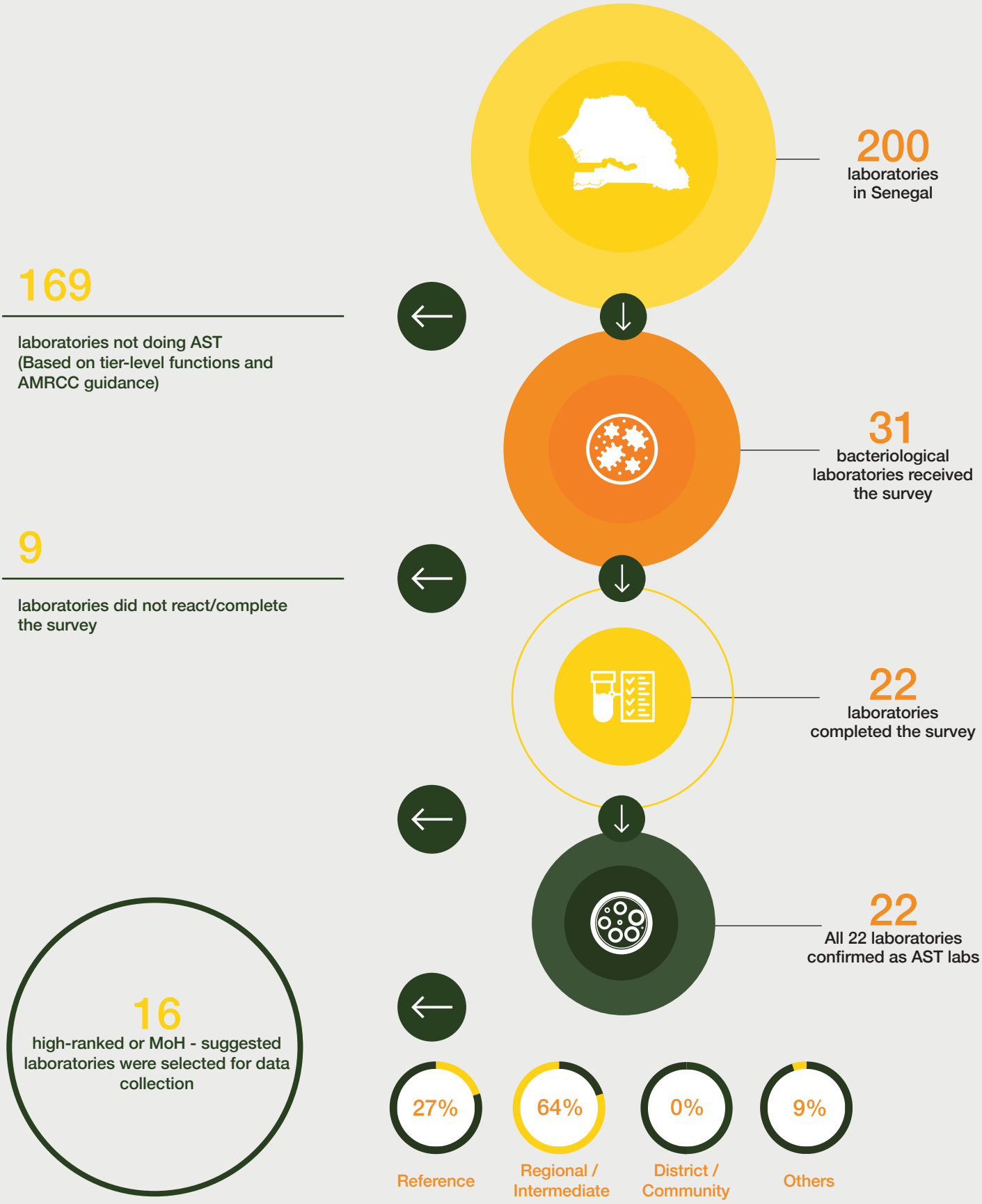


Figure 2: Selection of laboratories in Senegal

Surveillance preparedness of surveyed laboratories

Based on self-reported information from 22 laboratories, laboratory function and quality compliance were assessed to understand preparedness for AMR surveillance. Sixteen laboratories had implemented QMS and had at least one qualified microbiologist on board. None of the laboratories were accredited, while three used automated methods for pathogen identification (Figure 3, Supplementary Table 2). Since these findings may affect the quality of laboratory data, caution is warranted in interpreting the AMR rates presented in this report.

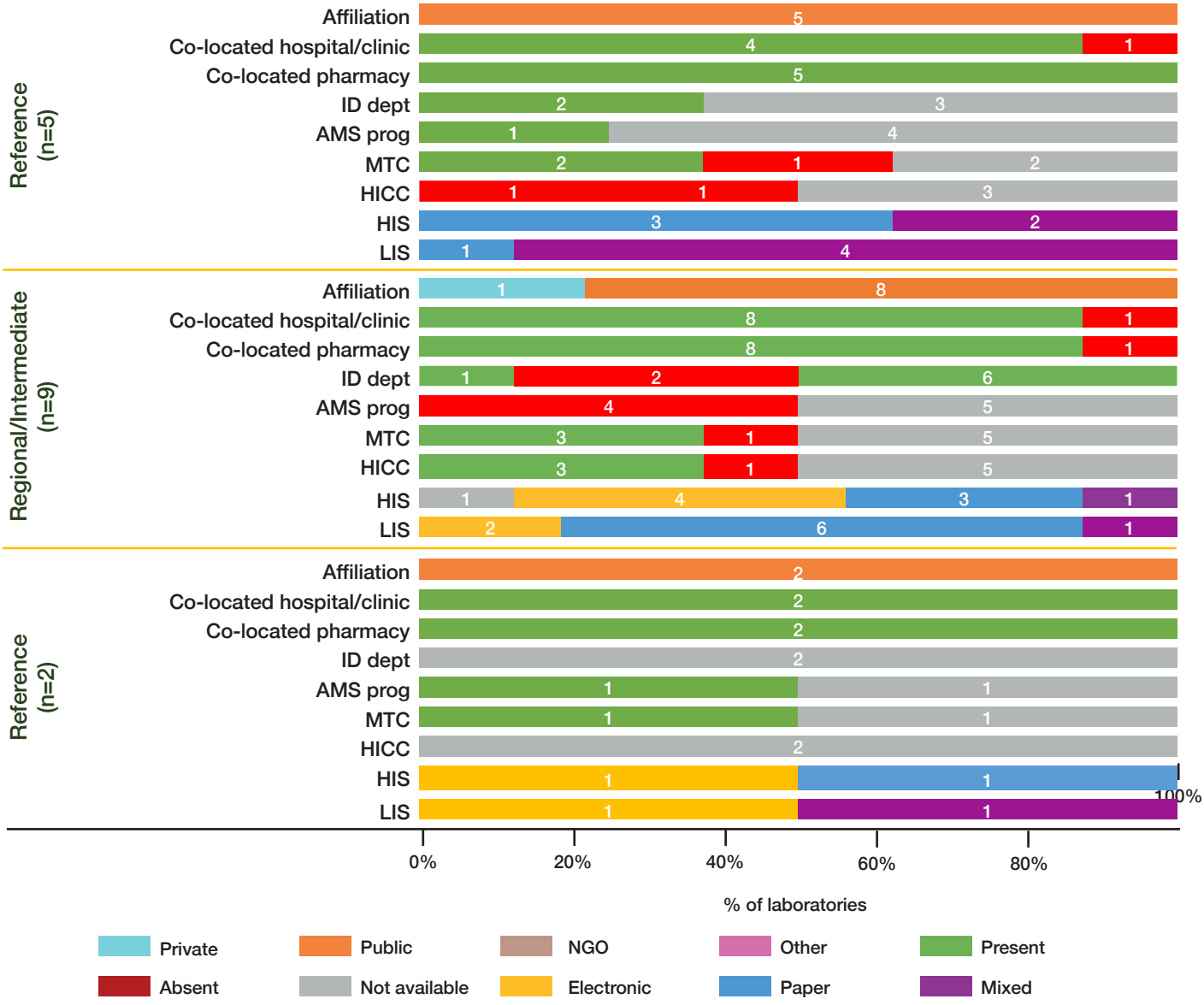
	Parameters			N (%)
Commodity and equipment status	Regular power supply and functional back up			18 (81.8)
	Continuous water supply)			19 (86.4)
	Certified and functional biosafety cabinets			10 (45.5)
	Automated methods for pathogen identification			3 (13.6)
	Automated methods for AST			3 (13.6)
	Methods for testing AMR mechanisms			12 (54.5)
QMS implementation	Reported QMS Implementation			16 (72.7)
		Types of QMS	LQMS	0
			SLIPTA	13 (81.2)
			SLMTA	0
			Mentoring	0
			Combination‡	1 (6.3)
			Others	1 (6.3)
	Quality Certification			2 (9.1)
		Types of Quality certification	SLIPTA	-
			Col. of Am. Path	-
			Others	-
	Accreditation			0
	Participation in proficiency testing			13 (59.1)
	Utilization of reference strains			11 (50.0)
	Reported consistent maintenance of QC records			11 (50.0)
	Designated focal quality person			16 (72.7)
	Reported compliance to standard operating procedures			20 (90.9)
	Reported compliance to AST standards			15 (68.2)
Personnel and training status	Presence of at least one qualified microbiologist			16 (72.7)
	Presence of an experienced laboratory scientist/technologist			18 (81.8)
	Up-to-date and complete records on staff training and competence			13 (59.1)
Specimen Management status	Reported compliance to SOPs on specimen collection and testing			19 (86.4)
	Reported compliance to SOPs on specimen rejection			21 (95.5)
	Average number of specimens processed for AST in 2018			18 (81.8)
LIS and Linkage to Clinical Data	Assigned specimen (laboratory) identification number			22 (100.0)
	Availability of system/database to store patient data			22 (100.0)
		Database format	Paper-based	11 (50.0)
			Electronic	3 (13.6)
			Mixed	8 (36.4)
	Captured patients' records on test request forms			21 (95.5)
			Retrievable	11 (52.4)

‡ 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).

Figure 3: Laboratory preparedness for AMR surveillance

Profile of Selected Laboratories

Out of the 16 selected laboratories, 12 were co-located with clinical facilities. Nine clinical facilities lacked infectious disease departments and antimicrobial stewardship programmes (ASP). Medical therapeutic and hospital infection control committees were functional in 11 facilities. Most laboratories and hospitals had mixed (paper and electronic) information systems (Figure 4).



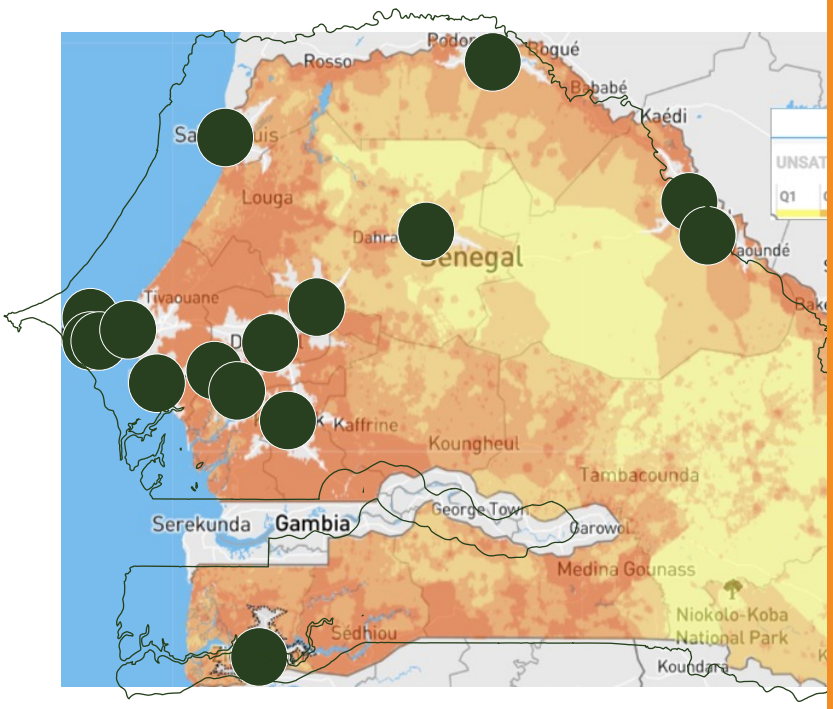
Abbreviations: AMS=antimicrobial stewardship; HICC=hospital infection control committee; HIS=hospital information system; ID Dept=infectious diseases department; LIS=laboratory information system; MTC=medical therapeutics committee

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 as well as geospatial optimisation techniques to show unmet needs. We evaluated the proportion of the population covered by mapped laboratories within a two-hours' drive (Supplementary Figure 1).

As of 2020, Senegal had an estimated population of 16.74 million.



Population coverage of laboratory services is defined as the catchment population living within one-hour travel (car, foot) from the testing laboratory. It is rep-resented in grey on the map. The analysis uses the assumption that the laboratory has sufficient testing capacity to serve the entire population within the catchment area. The population outside the catchment area of the facilities is representative of the overall unmet need. For ease of use, the unit of unmet need is rep-resented on the map as a 'pixel', i.e., the lowest base unit of a raster image. To visualise the geographical areas with the most critical unmet needs, each base component is ranked from the lowest to the highest, according to the number of the population living in the 'pixel'. The ranking is then divided into quartiles made of equal population fractions (from Q1: lowest density to Q4: highest density) corresponding to different colours (from yellow to dark red, see the legend). Therefore, 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 AST laboratories in Senegal

In Senegal, the catchment population living within o one hour travel time from the 16 participating AMR surveillance sites covers 47% of the population. Hence, 53% of the population is not covered at all by the existing facilities. To increase the population coverage, new capacity should be introduced (either by upgrading an existing lab to start providing services or by constructing a new lab) in regions in dark red (Q4), prioritising regions with the highest absolute unmet need.

Section II: Collection, analysis and interpretation of AMR data

Objective

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

Methodology

Data collection

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

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

As a first step, the MoH and IQVIA were jointly involved in recruiting local field data collectors. A capacity-building workshop was conducted as part of MAAP to train the field staff on data collection, including the use of WHONET13 and the specially developed MAAP tool for secure transfer of collected data.

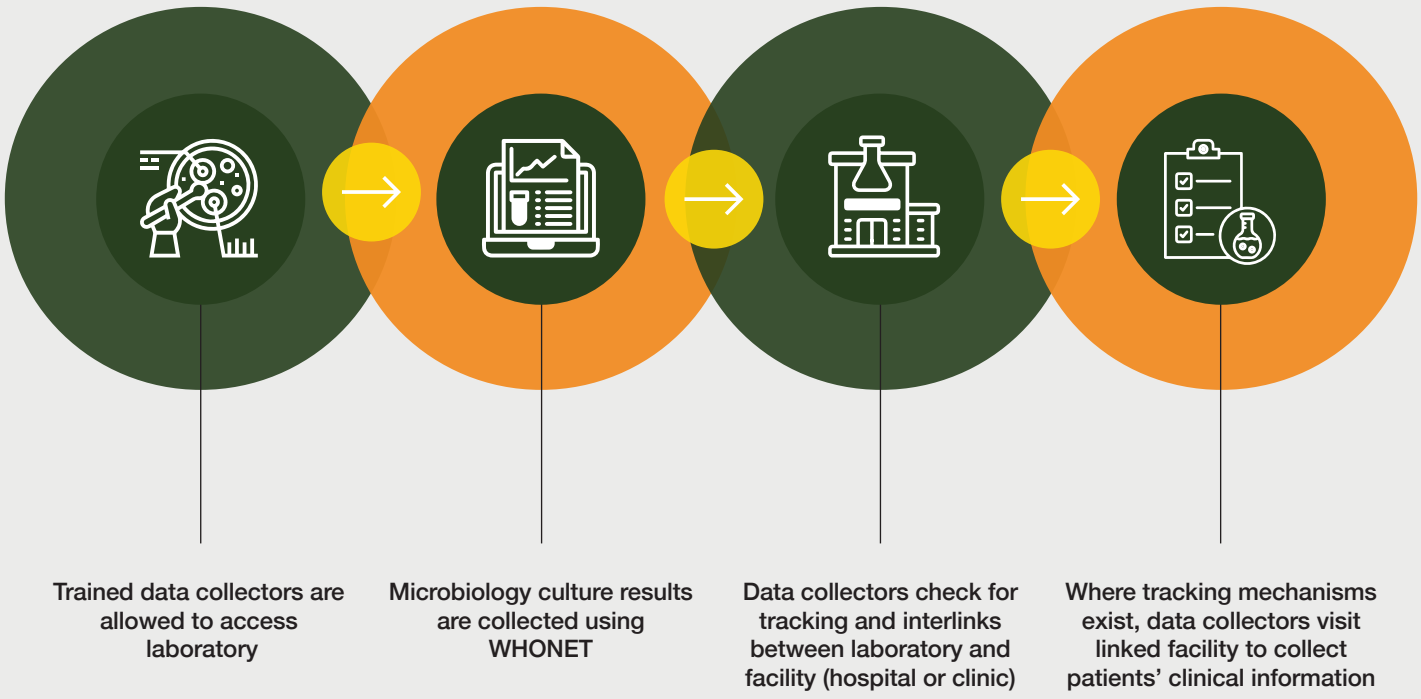


Figure 5: Steps of AMR data collection

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

Figure 6: Data collection at a Senegal facility

Data analysis

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

- **Quantum of cultures:** Total cultures were the number of patient rows in the database received from the laboratories. Valid cultures were a subset of total cultures which had complete information on the specimen type, collection date and pathogen name. Positive cultures were valid cultures for which pathogen growth was reported, irrespective of AST results. Total cultures were quantified for each laboratory and over the entire study period. Valid cultures and positive cultures were stratified for each laboratory as well as for each study year (Figure 7).
- **Level of pathogen identification:** Positive cultures with AST results were summarised based on the level of pathogen identification. Gram identification and genus-level identification were considered incomplete, where reporting at a species level indicated complete pathogen identification. Data were stratified for each laboratory and assessment was conducted over the entire study period (Figure 7).

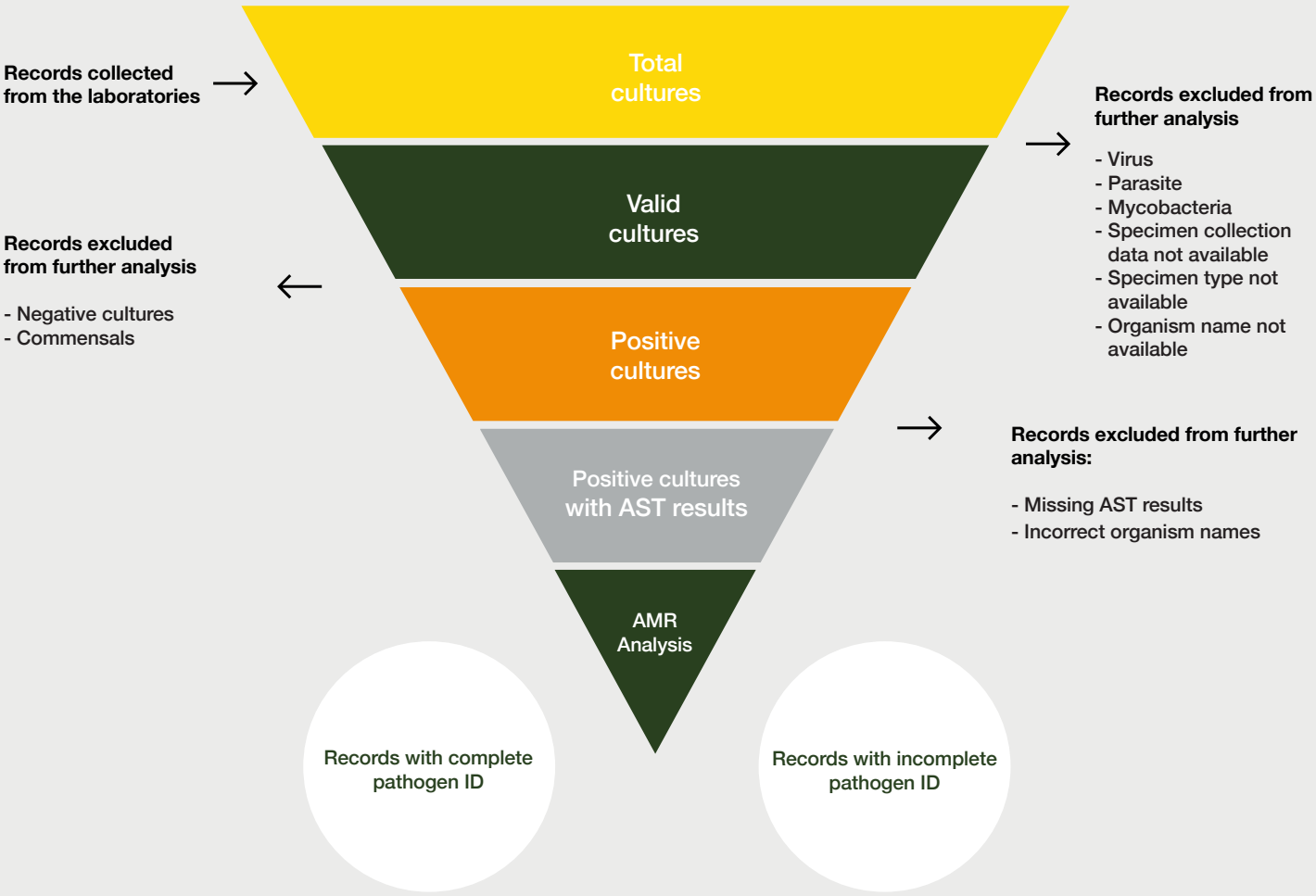


Figure 7: Conceptual framework for deriving quantum of cultures

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

Table 3: Data scoring scheme

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

- 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. The maximum attainable score is 4; each country's data quality score was rated (Table 4).

Table 4: Data quality rating

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

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

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

Results

Retrospective data from 2016–18 were collected from 16 laboratories and corresponding facilities in Senegal.

1. Quantum of cultures and level of pathogen identification

Data were retrieved for 78 304 total cultures, of which 51 771 were valid and 15 845 were positive. Of the positive cultures, AST results were available for 8 763 positive cultures, maximum (n=2 528) coming from Idrissa Pouye and the least (n=113) from Albert Royer (Figure 8 and 9). Not all pathogens were identified completely (i.e., at species level). Complete identifications were highest for CHR Ourossogui (95.1%) and lowest for Diamniadio laboratory (71.6%) (Table 5).

Table 5: 2016 -2018 culture and AST data retrieved from 16 selected laboratories in Senegal

Variable (Columns) / Laboratory (Rows)	Total Cultures (N= 78 304)	Valid Cultures N=51 771	Positive cultures N=15 845	Positive cultures with AST results N=8 763	Incomplete identity* N= 853	Complete identity* N= 7 910
Idrissa Pouye	6 964	4 258 (61.1)	2 903 (68.2)	2 528 (87.1)	161 (6.4)	2 367 (93.6)
Abass	9 897	5 570.0 (56.3)	2 019 (36.2)	464 (23.0)	33 (7.1)	431 (92.9)
Thies	3 860	3 580.0 (92.7)	1 358 (37.9)	355 (26.1)	47 (13.2)	308 (86.8)
Heinrich Lubke	3 450	2 417.0 (70.1)	512 (21.2)	418 (81.6)	33 (7.9)	385 (92.1)
Diamniadio	5 481	4 319.0 (78.8)	605 (14.0)	264 (43.6)	75 (28.4)	189 (71.6)
CHR Saint-Louis	10 598	7 251.0 (68.4)	1 133 (15.6)	960 (84.7)	94 (9.8)	866 (90.2)
Albert Royer	2 607	6 97.0 (26.7)	114 (16.4)	113 (99.1)	24 (21.2)	89 (78.8)
Matam	3 580	2 398.0 (67.0)	1 579 (65.8)	177 (11.2)	9 (5.1)	168 (94.9)
Saint Jean	9 287	6 248.0 (67.3)	1 201 (19.2)	558 (46.5)	31 (5.6)	527 (94.4)
Mbargane	3 197	2 205.0 (69.0)	609 (27.6)	608 (99.8)	113 (18.6)	495 (81.4)
CHR Ourossogui	3 998	2 649.0 (66.3)	954 (36.0)	508 (53.2)	25 (4.9)	483 (95.1)
Fatick	3 296	1 940.0 (58.9)	646 (33.3)	414 (64.1)	51 (12.3)	363 (87.7)
Mbour	4 298	2 024.0 (47.1)	653 (32.3)	414 (63.4)	81 (19.6)	333 (80.4)
Sor Saint-Louis	2 283	1 572.0 (68.9)	226 (14.4)	226 (100.0)	16 (7.1)	210 (92.9)
Matlaboul	4 306	3 701.0 (85.9)	789 (21.3)	223 (28.3)	20 (9.0)	203 (91.0)
IHS	1 202	9 42.0 (78.4)	544 (57.7)	533 (98.0)	40 (7.5)	493 (92.5)

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

AST=Antibiotic Susceptibility Testing

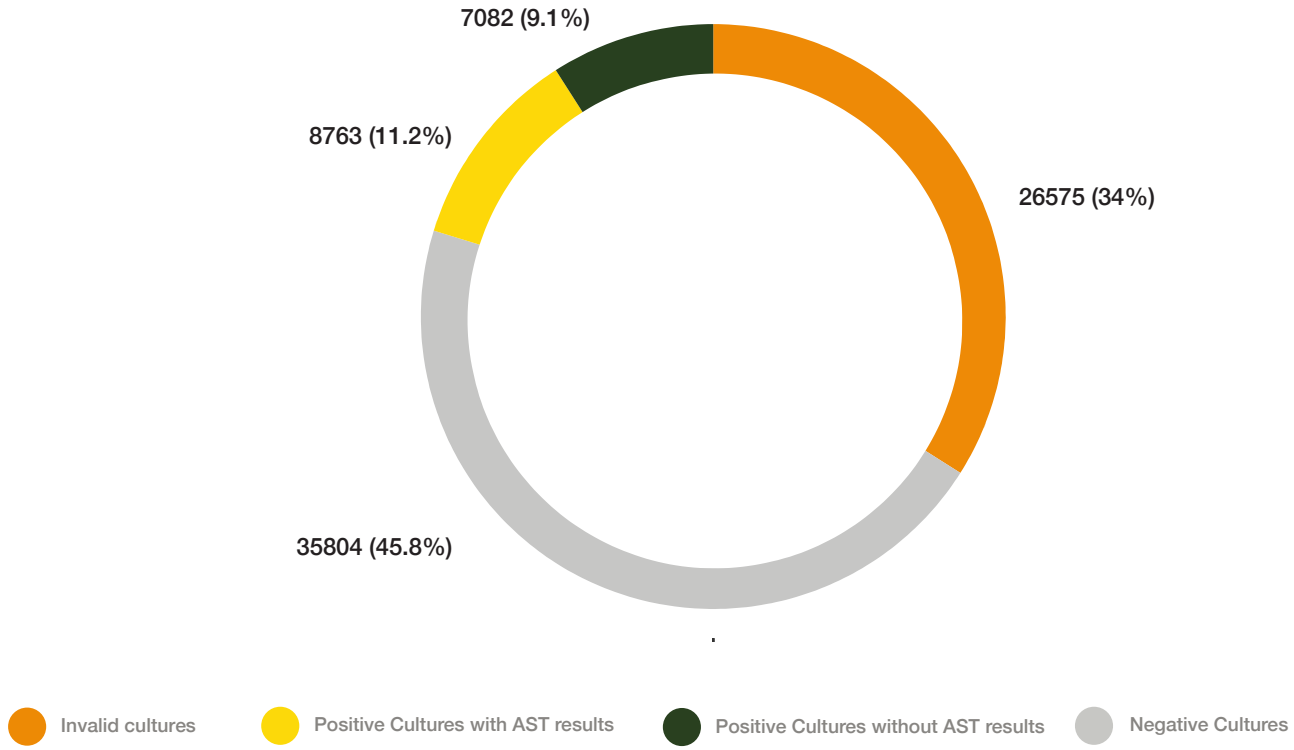


Figure 8: Quantum of cultures across all selected laboratories in Senegal from 2016 -2018

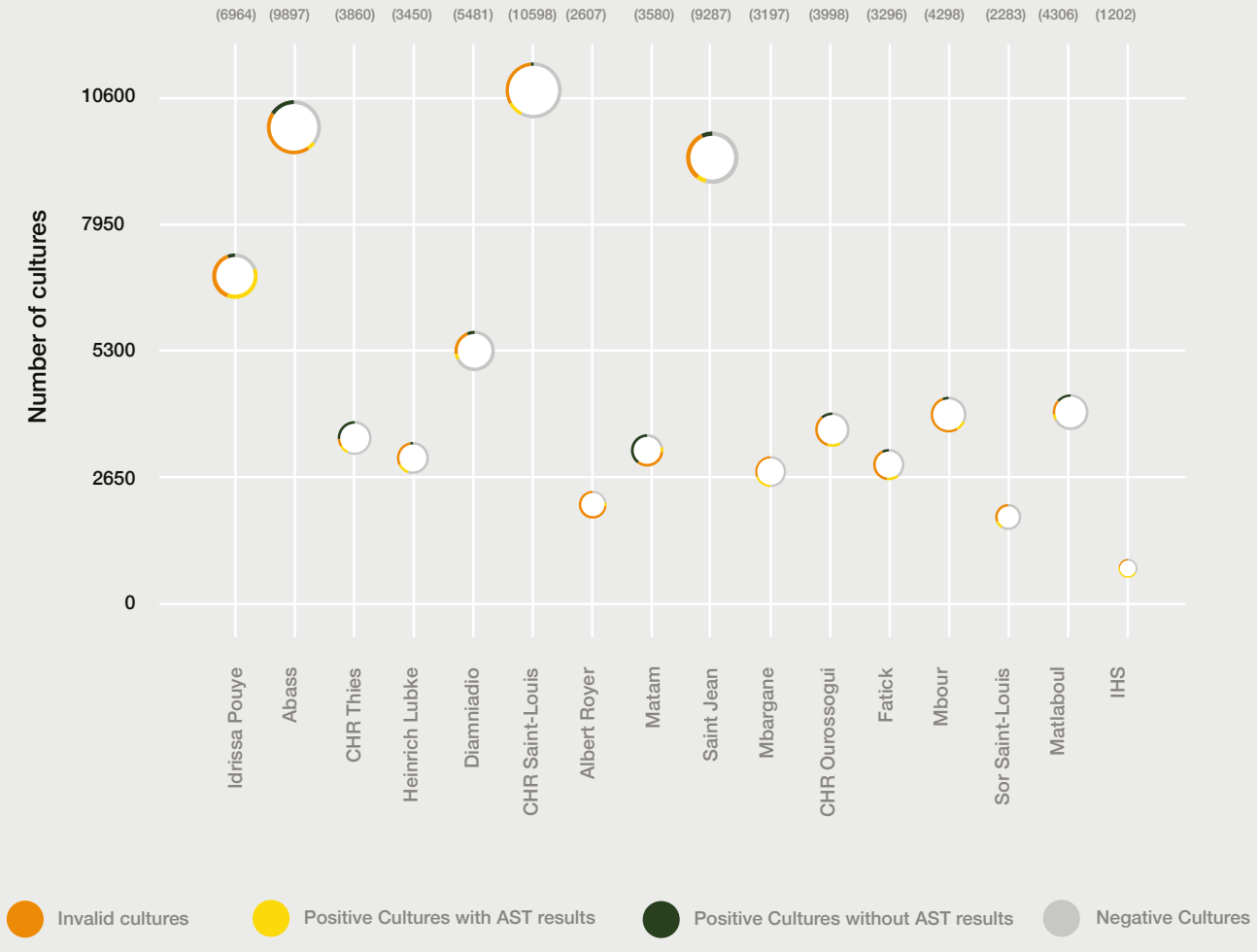


Figure 9: Quantum of cultures for each of the 16 selected laboratories in Senegal, 2016-2018

2. Culture characteristics

Bacterial pathogens (8 721) were more commonly reported than fungal pathogens. Information on age was missing from 10.9% of cultures, but where available, data showed a median age of 47 years (range 0–100 years) with most cultures (3 324) obtained from patients 18–49 years old. Both genders contributed evenly to the quantum of positive cultures with AST results. More data came from 2018 (4 993) than other years (Table 6, Supplementary Table 3).

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

Characteristics	Positive cultures with AST results n=8 763 n (%)
Gender	
Male	4 393 (50.1)
Female	4 356 (49.7)
Unknown	14 (0.2)
Age, years	
Less than 1	325 (3.7)
1 to 17	710 (8.1)
18 to 49	3 324 (37.9)
50 to 65	1 294 (14.8)
Above 65	2 151 (24.5)
Unknown age	959 (10.9)
Years	
2016	189 (2.2)
2017	3 581 (40.9)
2018	4 993 (57.0)
Pathogen	
Bacteria	8 721 (99.5)
Fungi	42 (0.5)

3. Inappropriate testing

Of the 16 selected laboratories, six reported using EUCAST standards for AST testing while the others reported compliance to a combination of CASFM/EUCAST standards. However, during a review of AST results, the following instances of inappropriate testing were noted:

Bacteria were tested against antifungals and fungi were tested against antibiotics (Supplementary Figure 2a). S. aureus was tested against Vancomycin using the disk diffusion method and Enterobacterales were tested against oxacillin and penicillin G (Supplementary Figure 2b).

4. Clinical information

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

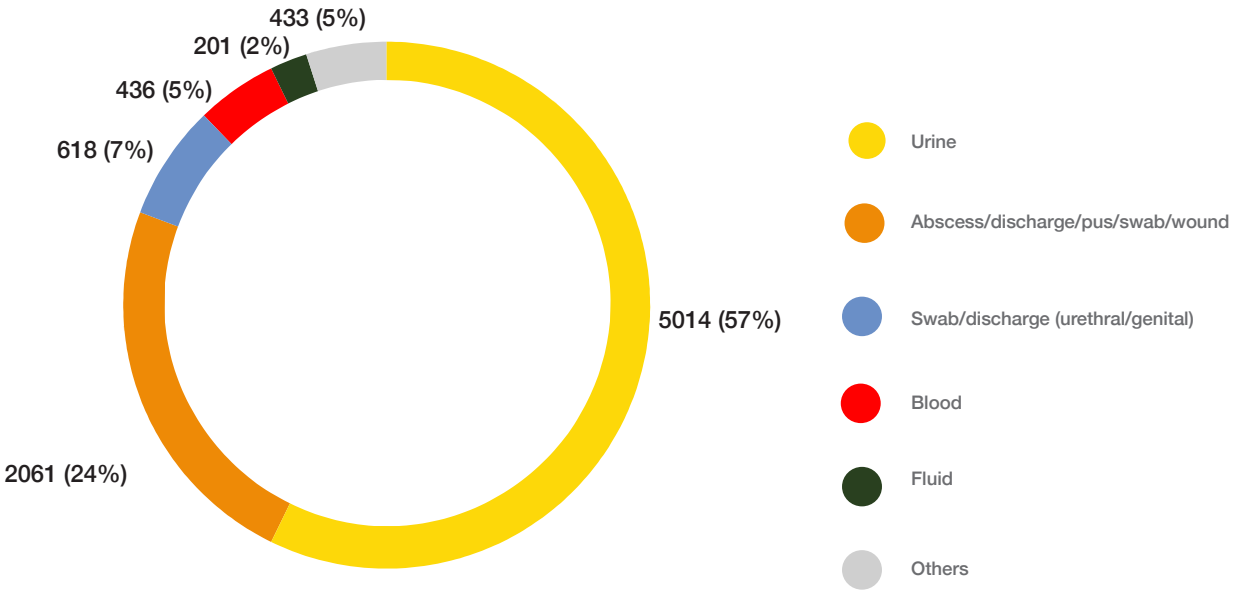
Table 7: Clinical information

Laboratory	Positive cultures with AST results N=4 394	Diagnosis data	Infection origin data*	Indwelling device data	AMU data
Idrissa Pouye	2 528 (87.1)	789	0	0	0
Abass	464 (23.0)	43	0	3	0
Thies	355 (26.1)	149	0	6	7
Heinrich Lubke	418 (81.6)	179	2	0	0
Diamniadio	264 (43.6)	253	9	0	0
CHR Saint-Louis	960 (84.7)	788	0	9	0
Albert Royer	113 (99.1)	0	0	0	0
Matam	177 (11.2)	20	0	0	0
Saint Jean	558 (46.5)	0	0	0	1
Mbargane	608 (99.8)	0	0	0	0
CHR Ourossogui	508 (53.2)	465	0	0	0
Fatick	414 (64.1)	13	0	0	0
Mbour	414 (63.4)	213	0	0	0
Sor Saint-Louis	960 (84.7)	788	0	9	0
Matlaboul	223 (28.3)	73	0	0	0
IHS	IHS	533 (98.0)	532	0	0

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

5. Specimen characteristics

Urine, purulent discharge, and genito-urethral specimens accounted for most of the positive cultures in each study year (Figure 10, Supplementary table 4).



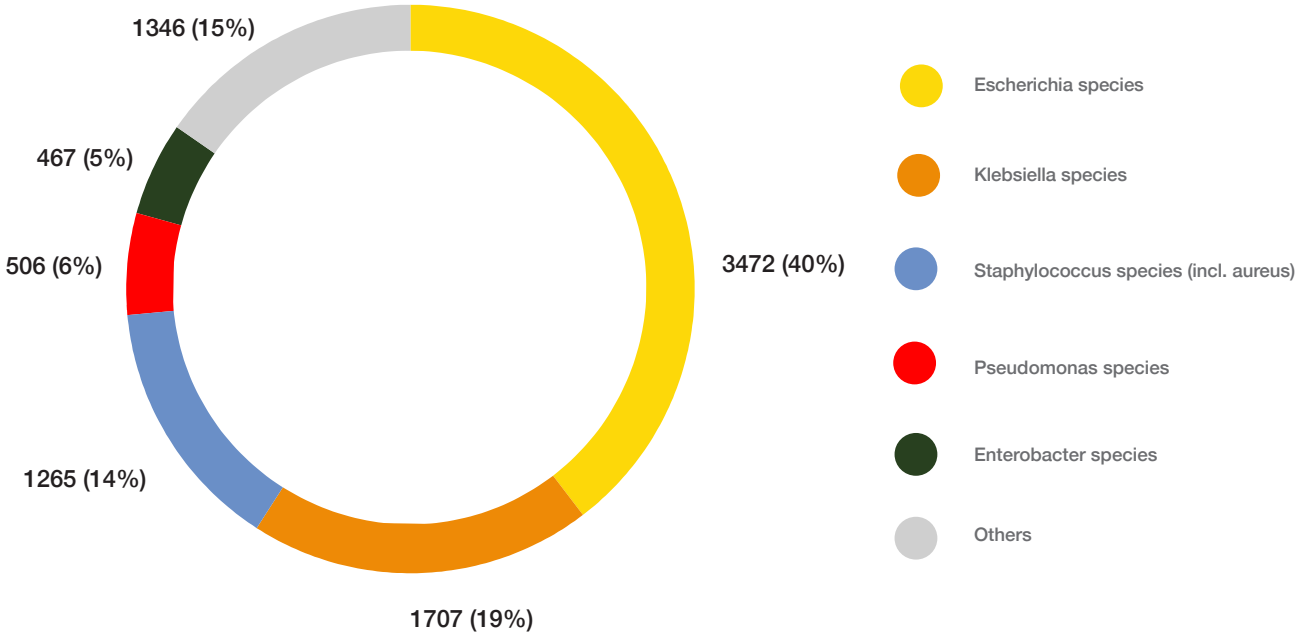
* Others include all other specimens excluding the top 5 mentioned here

Figure 10: Specimen characteristics

6. Identified pathogens

Escherichia species (40%), Klebsiella species (19%) and Staphylococcus species (14%) largely contributed to the quantum of positive cultures.

In 2016, of the 189 positive cultures with AST results, Escherichia species (40.7%) and Klebsiella species (21.2%) were the most reported. In 2017, of the 3 581 positive cultures with AST results, Escherichia species (40.2%) and Klebsiella species (20.9%) were again the most reported. In 2018, information was available for a greater number of cultures (4 993) although pathogen distribution remained similar to prior years (Figure 11, Supplementary Table 5).



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

7. Quality of data

The country data quality score of the 51 771 valid culture records obtained from the 16 laboratories in Senegal was 3.9 and was rated as good for AMR analysis. For individual laboratory data quality scores from each contributing laboratory, see Supplementary Table 6.

Section III: AMR rates

Objective

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

Methodology

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

Estimation of AMR rates

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

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

AMR rates were estimated for the WHO priority pathogens14 where the number of tested isolates exceeded 30 regardless of the specimen type (AMR Appendix 5). AMR trends were mapped for the WHO priority pathogens, depending on data availability.

In addition, AMR rates were estimated for the following:

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

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

Removal of duplicate records

Before AMR rates were calculated, duplicate AST results were removed such that only the results of the first pathogen isolate per patient per year, irrespective of AST profile (and body site or specimen type in the case of WHO priority pathogens) were included. This approach follows the CLSI M39A4 criteria.15,16 Duplicate removal was based on the availability of unique patient identifiers. When no patient identifiers were available, the results of all isolates were included. The AST data from all laboratories were then aggregated and rates were calculated as the proportion of non-susceptible isolates.

AMR estimates statistics

Confidence intervals (CIs) were calculated at the 95% level of confidence to quantify the uncertainty in the estimated resistance rates. Typically, CIs for AST data have been constructed using the Wilson score method. This is a binomial calculation that assumes that all samples are independent.[17] However, there are likely correlations between data within each laboratory and between laboratories that draw from similar populations. Thus, where appropriate, the Wilson cluster robust CI method was employed to account for a lack of data independence, such that each laboratory represented a cluster.[18]

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

Online data visualisation

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

Data were also uploaded to CDDEP's ResistanceMap platform, a publicly available repository for aggregated country-level data.19 Spatio-temporal analysis for the combined AMR and AMC-AMU datasets were built on the ResistanceMap framework. Current capabilities include maps, trend line charts and frequency bar charts.

Results

(i) AMR rates and trends for WHO priority pathogens

AMR rates for the WHO priority pathogens were calculated as the proportion of isolates that were non-susceptible over each one-year interval. Across 2016–2018, AMR rates for some organisms remained consistent; the rates for others varied. Moderately high AMR rates were noted for 3rd generation cephalosporin-resistant Enterobacterales (40-42%), and methicillin-resistant S. aureus (MRSA) (28-42%). Rates for carbapenem-resistant Enterobacterales (<5%) and carbapenem-resistant P. aeruginosa (<10%) were lower (Table 8, Figures 12 and 13). Statistics for vancomycin-resistant and intermediate Staphylococcus species are not included.

Table 8: AMR rate estimates for WHO priority pathogens

		2016				2017				2018			
Pathogen	Antibiotic, class	N	n (%)	95% CI	Labs* (range)	N	n (%)	95% CI	Labs* (range)	N	n (%)	95% CI	Labs* (range)
A. baumannii	Carbapenems	-	-	-	-	6	0	-	4 (1 - 3)	11	2	-	3 (1 - 7)
P. aeruginosa	Carbapenems	7	0	-	2 (1 - 6)	158	9 (5.7)	1.4-20.9	12 (1 - 67)	114	9 (7.9)	3.6-16.4	10 (1 - 62)
Enterobacter ales	Carbapenems	168	2 (1.2)	0.1-14.1	4 (1 - 90)	2 183	50 (2.3)	1.2-4.3	15 (11 - 605)	2 015	85 (4.2)	1.6-10.6	14 (1 - 661)
Enterobacter ales	Cephalosporins(3rd generation)	213	86 (40.4)	15.8-71	5 (3 - 96)	2 942	1 161 (39.5)	32-47.4	16 (13 - 850)	2 807	1 172 (41.8)	34.9-49	16 (21 - 884)
E. faecium	Vancomycin	-	-	-	-	-	-	-	-	-	-	-	-
H. influenzae	Ampicillin	-	-	-	-	-	-	-	-	-	-	-	-
H. pylori	Clarithromycin	-	-	-	-	-	-	-	-	-	-	-	-
N. gonorrhoeae	Cephalosporins (3rd generation)	-	-	-	-	5	0	-	3 (1 - 3)	4	3	-	2 (1 - 3)
N. gonorrhoeae	Fluoroquinolones	-	-	-	-	2	0	-	2 (1 - 1)	3	3	-	2 (1 - 2)
Campylobacter species	Fluoroquinolones	-	-	-	-	-	-	-	-	-	-	-	-
Salmonella species	Fluoroquinolones	-	-	-	-	17	2	-	7 (1 - 5)	10	1	-	6 (1 - 3)
Shigella species	Fluoroquinolones	-	-	-	-	4	2	-	3 (1 - 2)	4	1	-	3 (1 - 2)
S. aureus	Methicillin	31	13 (41.9)	6.2-88.8	3 (1 - 15)	442	145 (32.8)	22.1-45.6	15 (1 - 169)	346	95 (27.5)	16-42.9	14 (1 - 84)
S. pneumoniae	Beta-lactam combinations	-	-	-	-	5	1	-	2 (1 - 4)	-	-	-	-
S. pneumoniae	Penicillins	2	2	-	1 (2)	8	4	-	5 (1 - 4)	-	-	-	-

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

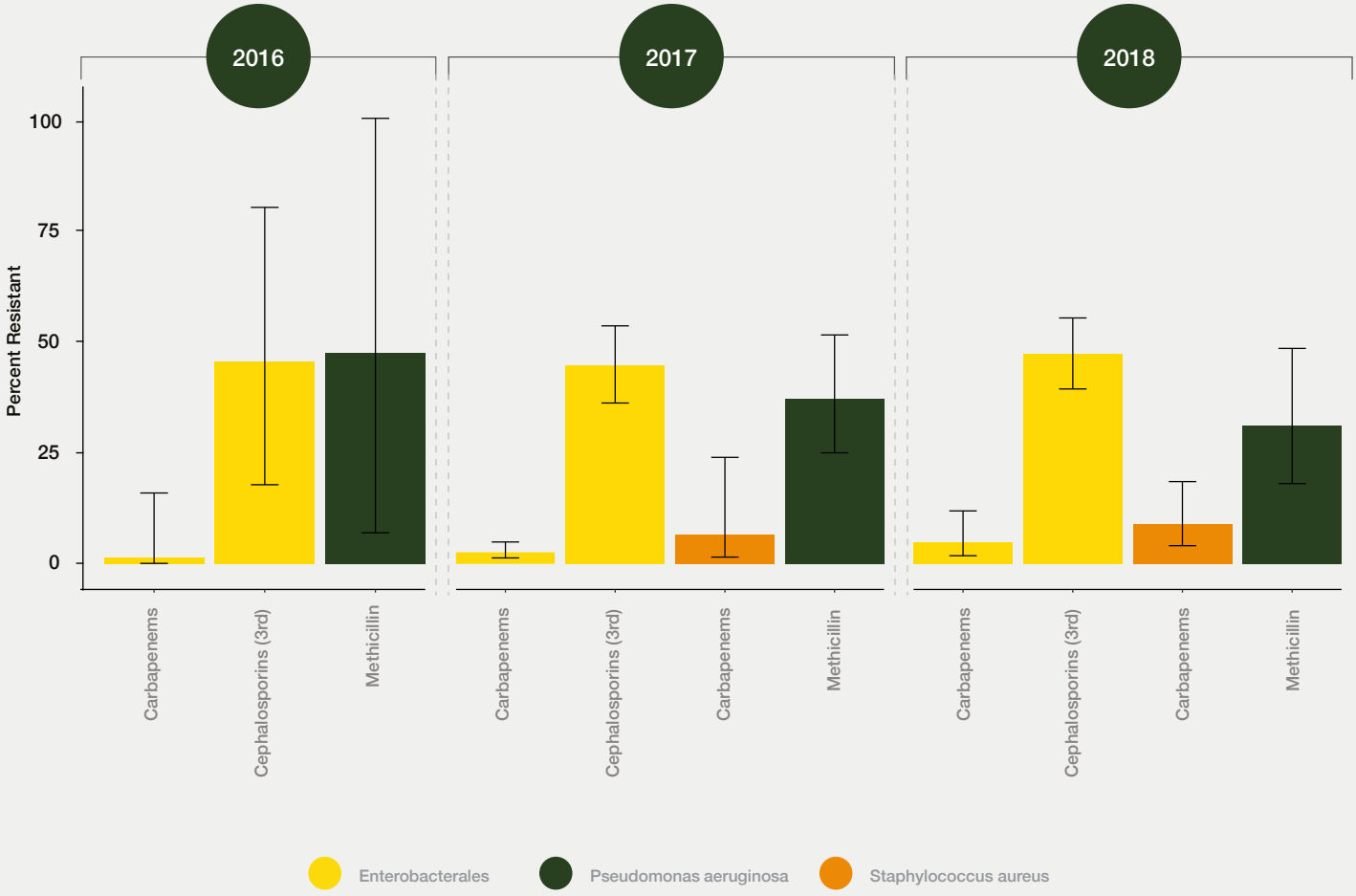


Figure 12: AMR rate estimates for WHO priority pathogens

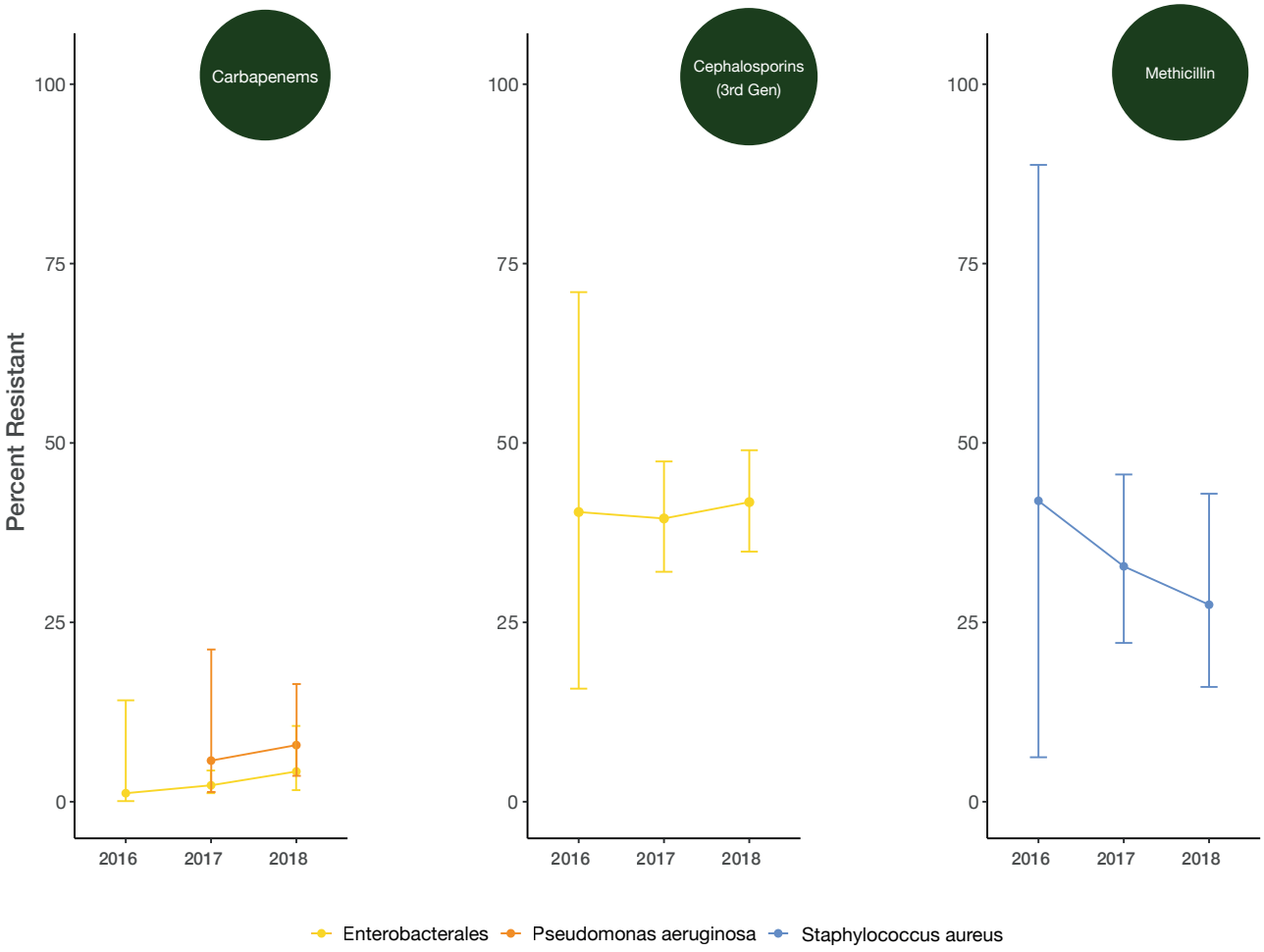


Figure 13: AMR trends for WHO priority pathogens

(ii)AMR rates for other pathogens of clinical importance

Analysis of AST data from blood and CSF isolates revealed 3rd-generation cephalosporin-resistant Klebsiella species (73-83%). The AMR rate for methicillin-resistant Staphylococcus species was over 90% in 2018 (Table 9).

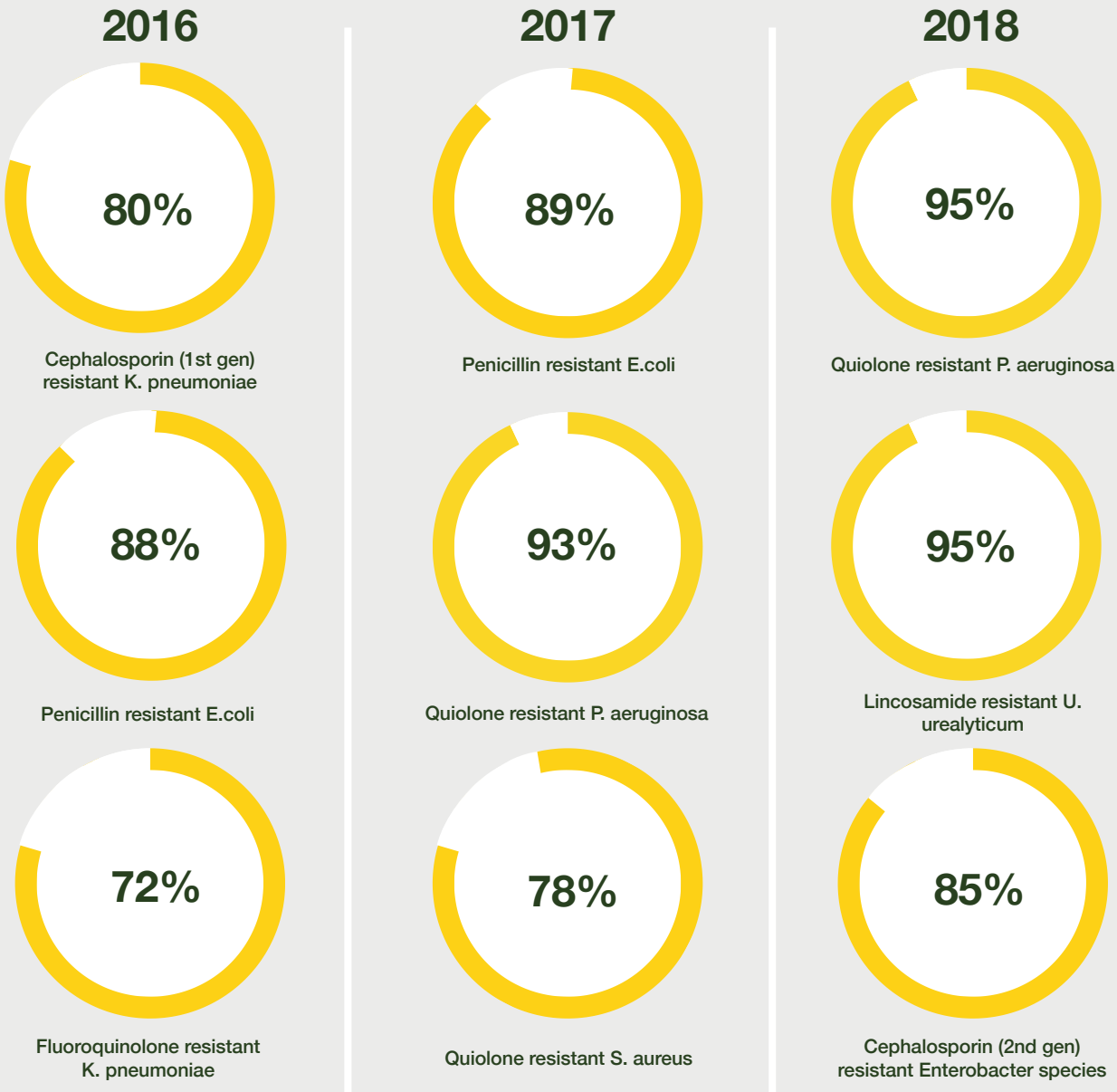
*Table 9: AMR rate estimates for other clinically important pathogens**

		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	2	1	-	1 (2)	-	-	-	-	3	0	-	2 (1 - 2)
Acinetobacter species	Lipopeptides	-	-	-	-	-	-	-	-	-	-	-	-
Enterococcus species	Aminoglycosides (high level)	1	0	-	1 (1)	-	-	-	-	3	2	-	1 (3)
Enterococcus species	Vancomycin	4	1	-	3 (1 - 2)	-	-	-	-	4	1	-	2 (1 - 3)
H. influenzae	Ampicillin	-	-	-	-	-	-	-	-	-	-	-	-
H. influenzae	3rd generation cephalosporins	-	-	-	-	-	-	-	-	-	-	-	-
Klebsiella species	Carbapenems	23	2	-	5 (1 - 15)	18	0	-	1 (18)	41	1 (2.4)	0.2-25.7	5 (1 - 25)
Klebsiella species	Cephalosporins (3rd generation)	41	30 (73.2)	47.2-89.3	6 (1 - 21)	22	19	-	1 (22)	57	47 (82.5)	77-86.8	7 (1 - 36)
N. meningitidis	Ampicillin	4	1	-	2 (1 - 3)	-	-	-	-	-	-	-	-
N. meningitidis	Cephalosporins (3rd generation)	3	0	-	2 (1 - 2)	-	-	-	-	-	-	-	-
Pseudomonas species	Carbapenems	7	0	-	4 (1 - 2)	7	0	-	1 (7)	11	3	-	3 (1 - 7)
Pseudomonas species	Lipopeptides	-	-	-	-	-	-	-	-	-	-	-	-
Salmonella species	Fluoroquinolones	-	-	-	-	-	-	-	-	-	-	-	-
Salmonella species	Macrolides	-	-	-	-	-	-	-	-	-	-	-	-
Salmonella species	3rd generation cephalosporins	-	-	-	-	-	-	-	-	-	-	-	-
Staphylococcus aureus	Methicillin	-	-	-	-	-	-	-	-	-	-	-	-
Staphylococcus species (excluding aureus)	Methicillin	5	4	-	2 (1 - 4)	-	-	-	-	30	29 (96.7)	38.2-99.9	3 (2 - 25)
S. pneumoniae	Penicillins	2	1	-	2 (1 - 1)	2	2	-	1 (2)	-	-	-	-
S. pneumoniae	Beta-lactam combinations	1	0	-	1 (1)	-	-	-	-	-	-	-	-
S. pneumoniae	Macrolides	1	0	-	1 (1)	2	0	-	1 (2)	-	-	-	-
S. pneumoniae	Vancomycin	1	0	-	1 (1)	1	0	-	1 (1)	-	-	-	-

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

(iii) AMR rates for highly resistant pathogens

Based on the available data, very high resistance (>90%) was estimated for clinically important pathogens like P. aeroginosa (vs. quinolones) and U. urealyticum (vs. lincosamides) (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 Senegal, 2016 -2018

(iv) AMR rates for fungal pathogens

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. To determine the association between AMR and its potential drivers, the following patient and country-level factors were considered:

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

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

Statistical analysis

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

To explore the association between country factors (continuous variables) and AMR, correlation analysis (Pearson's) was performed with reporting at a continental level. All results should be interpreted with caution because they were derived from data aggregated from facilities with varying capabilities in addition to the data from the laboratories being varied.

Results

Two variables (age and gender) were evaluated for possible association with AMR. The data availability of these variables was gender (99.9%) and age (68.4%). Both the univariate and multiple logistic regression analyses did not reveal any significant association between the variables (age and gender) and AMR (Table 10, Supplementary Table 7).

Section IV: Drivers of antimicrobial resistance

Results

Three variables namely, age, gender and diagnosis were evaluated for possible association with AMR. The data availability for these variables was age: 89.9%: gender: 94.7%; and diagnosis: 41.0%. The univariate logistic regression results showed that males were more likely to have a resistant infection (OR 1.32, 95% CI 1.16 – 1.51). Patients in the following age groups: <1 year (OR 1.74, 95% CI 1.27 – 2.38), 50 – 65 years (OR 1.36, 95% CI 1.20 – 1.53) and >65 years (OR 1.55, 95% CI 1.33 – 1.78), were also more likely to have resistant infections. Lastly, patients diagnosed with injuries (OR 0.66, 95% CI 0.52 - 0.84) and other non-communicable diseases (OR 0.69, 95% CI 0.56 - 0.87) were less likely to have resistant infections. H0wever, patients diagnosed with neoplasm were more likely to have resistant infections (OR 1.80, 95% CI 1.13 – 2.86) (Supplementary Table 7).

Gender, age and diagnosis were included in the multiple logistic regression model based on the defined inclusion criteria. When controlling for the effect of age, males were more likely to have a resistant infection (OR 1.18, 95% CI 1.05 – 1.33). Furthermore, when adjusting for gender, the following age groups: <1 year (OR 1.65, 95% CI 1.19 – 2.30), 50 – 65 years (OR 1.27, 95% CI 1.14 – 1.42) and >65 years (OR 1.41, 95% CI 1.25 – 1.59) were more likely to have resistant infections. Finally, when controlling for the effects of both age and gender, patients diagnosed with

Table 10: Multiple logistic regression analysis

Variable	Options	N	NS (%)	Adjusted OR (95% CI)	P-value
Gender	Female	9 390	41.0	Ref	
	Male	10 314	48.1	1.18 (1.05 - 1.33)	0.005
Age	<1	634	53.0	1.65 (1.19 - 2.30)	0.003
	1-17	1 518	41.0	1.01 (0.83 - 1.25)	0.885
	18-49	7 829	39.7	Ref	
	50-65	3 980	46.8	1.27 (1.14 - 1.42)	0.000
	>65	5 473	50.2	1.41 (1.25 - 1.59)	0.000
Diagnosis	Infection/Inflammation	2 531	44.0	Ref	
	Cardiovascular	60	45.0	1.11 (0.56 - 2.18)	0.766
	Diabetes	79	36.7	0.77 (0.54 - 1.11)	0.162
	Injuries	581	33.2	0.72 (0.61 - 0.86)	0.000
	Neoplasm	151	57.6	1.50 (0.94 - 2.43)	0.087
	Nonspecific	2 833	44.1	1.02 (0.84 - 1.25)	0.842
	Other non-communicable diseases	1 164	35.65	0.87 (0.69 - 1.08)	0.202
	Renal	1 272	43.5	0.94 (0.82 - 1.07)	0.368

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

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

Part B: Antimicrobial (antibiotic) Consumption

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

Overuse and misuse of antimicrobials are crucial factors in the complex web of AMR causation. Widespread and unregulated antimicrobials usage exert a selective pressure by reducing the reproductive success of some of the microorganisms and consequently accelerating the development of AMR.[20,21] Therefore, close surveillance on how antimicrobials are utilised is a key step for stewardship programmes to stem AMR. The surveillance mechanisms recommended by WHO include the monitoring of AMC and AMU. This aligns with MAAP's aim to expand the volume of data presently available on AMR and AMC or AMU across Africa and aligns with the country's National multisectoral Action Plan (2017-2021) for surveillance and fight against AMR.[22]

Definition of AMC and AMU

AMC is defined as the quantification of antimicrobials used within a specified setting (e.g., national-level, hospital or community healthcare-level) over a specified period. AMC is calculated from aggregated data such as import, wholesalers, insurance, facility dispensing or procurement data sources. AMU tracks whether antimicrobials are prescribed appropriately for the right infections and according to treatment guidelines. AMC and AMU are terminologies that are sometimes used interchangeably and incorrectly so. It is therefore prudent to delineate these definitions further through clarification that AMC data describe quantities of antimicrobials dispensed (e.g., at national stores or pharmacies). AMU data describe how and why antimicrobials are used (e.g., if required laboratory tests and clinical assessments were done prior to issuing a prescription and if the right antimicrobial was prescribed at the correct strength and frequency over an appropriate duration to treat the right indication as per country guidelines and finally, whether the patient correctly and/or completely consumed the prescribed antimicrobial).[23]

Link between the antimicrobial usage and AMR

The unwarranted use of antimicrobials contributes to the emergence of AMR and explains the association between AMU and AMR. This association implies that a reduction in the unnecessary consumption of antimicrobials could, in turn, reduce AMR levels.[20] The inappropriate use of antimicrobials refers to the use of the wrong type of antimicrobial and/or at the wrong dose, frequencies or duration and/or for the wrong indication. For the past few decades there has been a global increase in the consumption of antimicrobials and a shift in consumption towards the use of both broad-spectrum and last-resort antimicrobials, particularly in LMICs. These shifts are because of improved access and increased economic purchasing power within countries. However, AMR can also develop as a result of a lack of access to antimicrobials, leading to the prolonged use of a particular antimicrobial over a long time and thus permitting selective pressure to favour microbes that evade these predominantly used antimicrobials. This is often the picture in several LMICs where inequities in access to antimicrobials persists.[24] This complicated picture demonstrates the need for the research and development of new agents that counteract emerging AMR, but also strongly indicates the need to use the available antimicrobials appropriately and ensure their accessibility.

In view of obtaining an elaborate and complete picture of the link between AMC or AMU and AMR in Senegal, the identification of prevalent gaps, as well as areas for targeted intervention to encourage rational use of antimicrobials and a surveillance system for consumption, is of paramount importance. In this regard, one of the MAAP's key objectives was to evaluate the ability to conduct AMC and AMU surveillance (data collection and analysis) in Senegal that would equip the country with valuable information to support the appropriate use of antimicrobials. The objective was to identify gaps that may exist in establishing a comprehensive surveillance system and provide the country with the needed information to support the setup of such a monitoring system.

AMC and AMU surveillance impact

To ensure the successful treatment of infectious diseases in patients, optimising the correct usage of antimicrobials is one of the strategic objectives within the WHO Global Action Plan (GAP).[8] For the successful implementation of the above objective, there is a need to understand country's pattern of antimicrobials use and quantification of their consumption. At present, there are only few published reports on AMC surveillance and AMU in Africa[25-29] including one report on AMU in Senegal.[30] The process of obtaining AMC or AMU data for a country equips the country with local information on various problems that exist with antimicrobial use and allows for monitoring the accessibility of antimicrobials. Furthermore, obtaining of AMC or AMU data permits the continuous local assessment of correlations between antimicrobial usage to emerging local AMR which permits for proper mitigation policies and activities to be planned using the relevant data. Data obtained from local surveillance exercises also presents the opportunity to better inform stewardship programmes.

Therefore, MAAP set out to quantify consumption and analyse AMC and AMU trends at selected facilities as well as at the national level to better inform the design of future stewardship programmes and policies which will optimise the use of antimicrobials in Senegal. Additionally, this will provide the country with a reference point to measure the impact and success of future implemented interventions.

The aim of this work

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

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

Section II: AMC or AMU surveillance status

Objective

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

Methodology

AMC and AMU data sources

Through open-structured key informant interviews (KIIs) (AMC Appendix 1), the AMRCC contacts shared their insights about the current landscape of AMC surveillance in the country as well as from where national AMC data can best be surveilled . Consequently, the National Supply Pharmarcy (PNA) mechanism for public procurement and the IQVIA™ datasets which include data from the private sector (by means of the supply records of distributors and wholesalers) were identified as potential sources for national AMC data in Senegal. As the approval letters from AMRCC or MoH were issued for the years (2017-2019), MAAP data collection period was redefined to include the years (2017-2019).

Under the guidance of the Senegal AMRCC, MAAP also targeted to recruit and obtain the data from twice as many pharmacies as the selected AST laboratories (i.e., a total of 32 pharmacies) to obtain aggregated pharmacy level AMC data. Here, AMC data was targeted for collection from pharmacies that were co-located in the same facility with AST laboratories (n=16) (AMC Appendix 2 for tool used). Additionally, we recruited community pharmacies (n=16) that were nominated by the co-located pharmacies based on their to the AST laboratories. Selection of community pharmacies was also based on the fact that they serve as the preferred patient purchase source or as a backup prescription fulfilment source in case of stockouts in the main hospital pharmacy. Furthermore, the availability of retrospective data from 2017-2019 and willingness to share data were key criteria considered for selection.

Besides AMC data collection, AMU data were targeted for collection from the hospital pharmacies (n=16) and this was to be abstracted from the facilities' prescription or patient medical records. To clarify, community pharmacies, which are also known as retail pharmacies, are licensed commercial pharmaceutical stores that retail medicinal products (prescription only and over-the-counter medicines) to a specific community group or region and excludes unregulated and informal medicine dispensers. Hospital pharmacies, on the other hand, are pharmacies located within a hospital for the provision of medicinal products to inpatients and outpatients who visit the hospital.

Data collection scope

MAAP purposively selected data collection on J01 (antibiotics for systemic use) consumption trends. J01 medicines are one of the WHO core monitoring ATC medicine categories for AMC surveillance. In addition, as per the country's request, selected P01AB (nitroimidazole derivates) and/or selected J02 (antimycotics for systemic use) were also included in the scope for AMC data collection (See Appendix 3 for a full list of selected antimicrobials in Senegal). P01AB and J02 ATC antimicrobials are part of the WHO core and optional monitored medicine classes respectively for AMC surveillance (World Health Organization, 2016). AMC data from the above medicine categories was collected from January 2017 to December 2019.

Data collection

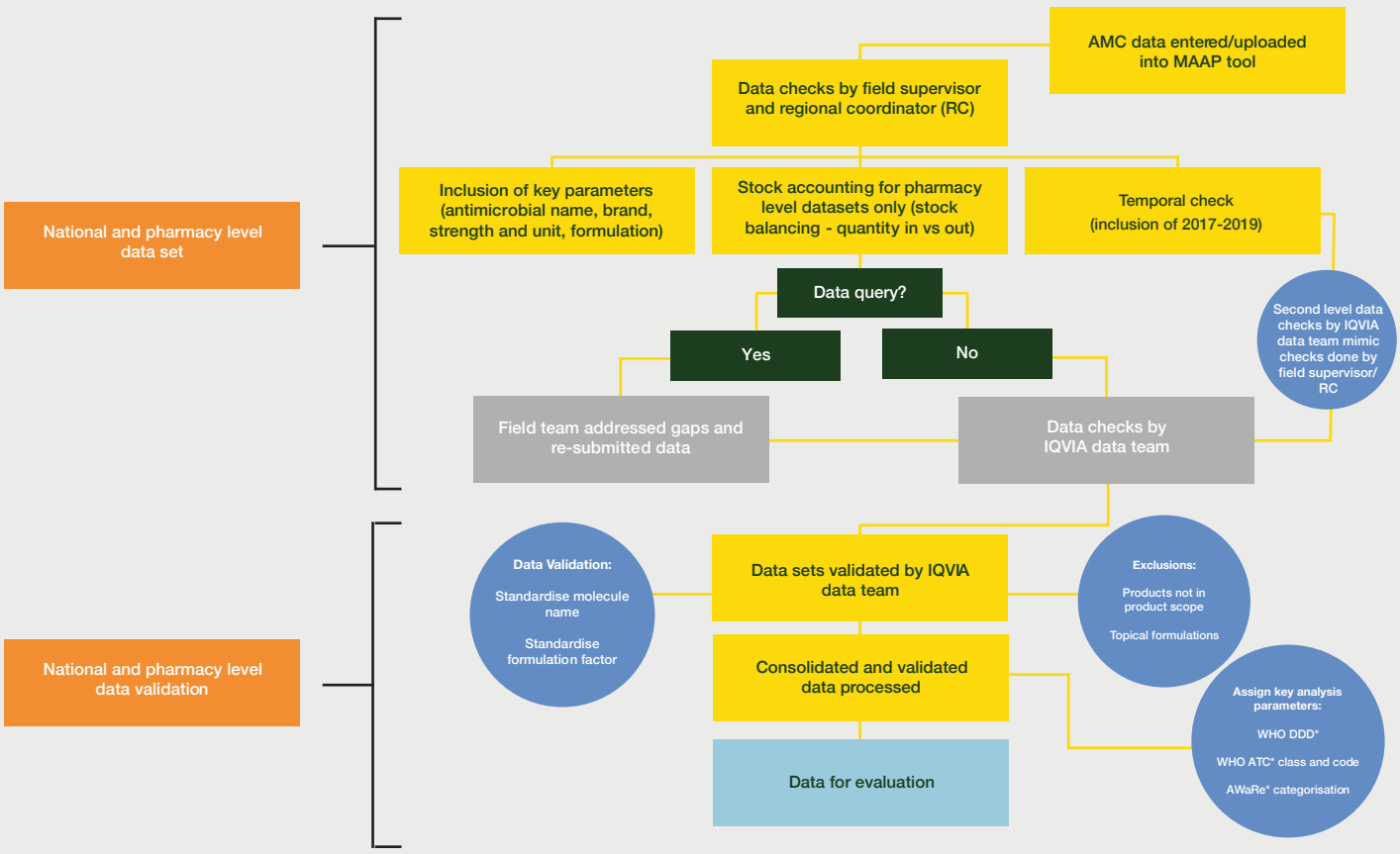
TThe national-level datasets from PNA and syndicated IQVIA™ datasets were requested for the data collection period (2017-2019). The dat sets were provided to the field supervisor in the form of a Microsoft Excel™ sheet. The data collection team reviewed and cleaned the datasets using Microsoft Excel™ which was then transferred securely through the MAAP tool that captured the medicines by their standard molecular name and/or product brand, pack size, strength and formulation (e.g., tablets or capsules, suspensions or syrups). AMC Appendix 4 captures the full list of data variables collected in order to tally national and pharmacy-level AMC.

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

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

Data cleaning and validation

The national level AMC datasets were categorised in this report as generally representing the private sector or public sector if they were sourced from the IQVIA™ syndicated datasets or PNA, respectively. Once all national AMC datasets were received, both the national- and pharmacy- level AMC data were then subjected to a series of data validation checks to ensure accuracy and consistency (AMC Appendix 6). Here, pharmacy and national AMC data were subjected to secondary and tertiary checks by field supervisors, regional coordinators and the IQVIA data team as outlined in Figure 15.



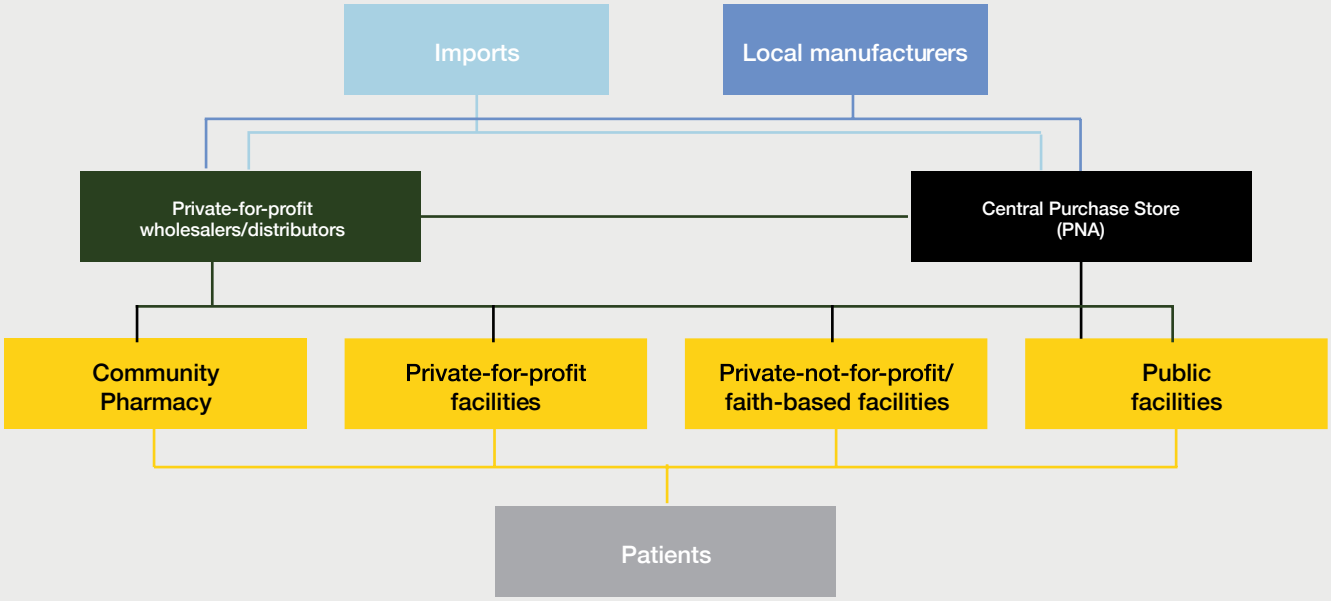
*WHO World Health Organisation - *DDD Defined Daily Dose - * AWaRe Access, Watch, and Reserve

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

Results

Flow of antimicrobials in the country

To characterise the pathway through which the antimicrobials get to the patients in the country KIIs were conducted with stakeholders in the Directorate of Laboratories, members of the national AMRCC, the Directorate of Pharmacy and Medicine (DPM) and the PNA. In Senegal, medicines including antimicrobials are imported as well as locally manufactured. DPM controls all imports of medicines including the antimicrobials.. Therefore each importer must first obtain an import permit before medicines are allowed into the country. PNA is mainly responsible for public sector procurement through both local manufacturers and international supplier's purchases. While the private sector mainly gets their medicines from local private for-profit wholesalers/distributors. After importation or local production, PNA and private for-profit wholesalers or distributors then pass along the antimicrobials to community pharmacies. Community pharmacies, private (both for-profit and non-profit) and public facilities then issue the antimicrobials to patients. The flowchart below (Figure 16) illustrates the route through which antimicrobials get to patients in Senegal.



CHAG: Christian Health Association of Senegal

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

Regulation of antimicrobials consumption

In Senegal, antimicrobials for human consumption are regulated under the Medicines Regulating Law 2005, which also reviews the registration of suppliers of antimicrobials and other medicines for human consumption.12 This law stipulates that requisite antimicrobials can only be sourced from registered suppliers upon issuance of a valid prescription and that sales are to be recorded in an antimicrobial register. Overuse and misuse of antimicrobials are significant contributors towards the emergence of AMR. Therefore, to address the above issues and other prevalent gaps, Senegal developed the national multisectoral action plan for surveillance and fight against AMR (2017-2021), that seeks to further build regulations around AMC in an effort to curb the growth or emergence of AMR.

Availability of data for AMU surveillance

Attempts were made to obtain AMU data from participating pharmacies that were co-located with AST laboratories that also offer clinical services (n=11). Unfortunately, no AMU data were obtained during MAAP data collection. This inability to collect AMU data was due to the nature of the data sources at the participating pharmacies (i.e., stock issuance record cards), which did not allow for retrieval of AMU variables (i.e., patient characteristics and indication for which the antimicrobial is being used, appropriateness of prescription in relation to national guidelines including conducting of any relevant laboratory testing and clinical assessment prior to prescribing, and assessment of dose, strength, frequency, and duration of prescription). The available stock issuance records do not track patients and the medicines they received. As a result, MAAP was unable to collect AMU data in Senegal from the selected health facilities.

Availability of data for AMC surveillance

National-level data

The national AMC data were obtained from PNA and syndicated IQVIA™ Senegal datasets for the period of review (2017-2019). The resultant national data collected and analysed represented approximately 100% of the total antimicrobials market during the reviewed period (2017-2019). The national level data had all the variables required to conduct AMC analysis (including date of transaction, antibiotic name, pack size, strength, and formulation (e.g. tablets capsuleor s, suspensions or syrups and injections). MAAP was able to collect data from January 2017 – December 2019 as planned within the scope of the study.

Facility-level data

Pharmacy data collection was successfully conducted in 17 out of the 32 targeted pharmacies. This included hospital pharmacies (n=11) and community pharmacies (n=6). A total of (n=11) AST laboratories were recruited for the data collection. Furthermore, pharmacy data collection was successfully conducted in (n=6) targeted community pharmacies. The remaining (n=10) targeted community pharmacies were unwilling to share their AMC data and were therefore excluded from data collection. As the total number of hospital/community pharmacies in Senegal could not be established, data representativeness at facility level could not be assessed.

In the case of pharmacy-level data, necessary variables were available in stock cards or electronic records of 17 pharmacies where the data were collected. However, there were instances in each of the visited facilities for few line items or transactions where were missing from the stock cards. These information gaps were addressed by re-visiting the facilities and gathering information from the facility staff or through secondary desk research using the available product details. In all the 11 hospital pharmacies, MAAP was able to collect data across the three years. Three of the community pharmacies did not provide data for the three years (either 2017 or 2019 was missing) due to declining to share the data, or the absence of archived data for the respective years in the system.

It was noted that there was an absence of any national AMC surveillance policy or structured AMC surveillance system during the reviewed period and that none of the recruited pharmacies actively reported AMC data regionally or centrally. Table 11 below summaries the core characteristics of the hospital pharmacies where AMC data was collected from.

Table 11: Characteristics of the recruited hospital pharmacies adjoined with the antimicrobial susceptibility testing (AST) laboratories and the community pharmacies in Senegal.

	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)	Centre Hospitalier Universitaire de Abass Ndao	Tertiary	Public	Dakar	Electronic	No	No
	Centre Hospitalier National D'enfants Albert Royer	Tertiary	Public	Dakar	Manual	No	No
	Centre Hospitalier Régional de Ourossogui	Secondary	Public	Matam	Electronic	No	No
	Centre Hospitalier Régional de Saint-Louis	Secondary	Public	Saint-Louis	Electronic	No	No
	Centre Hospitalier Régional de Thiès	Secondary	Public	Thiès	Electronic	No	No
	EPS 3 Matlaboul Fawzaini	Tertiary	Public	Diourbel	Electronic	No	No
	EPS Institut d'Hygiène Sociale Polyclinique (IHS)	Secondary	Public	Dakar	Manual	No	No
	Etablissement Public de Santé de niveau 1 (EPS 1) de Mbour	Secondary	Public	Thiès	Electronic	No	No
	Hôpital d'Enfants de Diamniadio	Tertiary	Public	Dakar	Electronic	No	No
	Hôpital Regional De Matam	Secondary	Public	Matam	Electronic	No	No
	Hôpital Youssou Mbargane Diop	Secondary	Public	Dakar	Electronic	No	No
Community pharmacies	Pharmacie Continentale Ababacar Sy	Dispensing	Private	Dakar	Manual	N/A	No
	Pharmacie Dardenelle	Dispensing	Private	Dakar	Manual	N/A	No
	Pharmacie El Hadj Malick Sy	Dispensing	Private	Dakar	Electronic	N/A	No
	Pharmacie Mame Fatou Diop Yoro	Dispensing	Private	Dakar	Manual	N/A	No
	Pharmacie Mariama	Dispensing	Private	Dakar	Electronic	N/A	No
	Pharmacie Mouhamed (PSL)	Dispensing	Private	Dakar	Electronic	N/A	No

*For the review period i.e., 2017-2019. AMC: Antimicrobial consumption.
† Refers to ability for pharmacy to link dispensing records with the patient's hospital records to obtain patient diagnostic and characteristic information.
#Secondary care services are delivered at government district and private hospitals and provide primary care services for the local population along with outpatient (for patient refereed from peripheral health units) and inpatient services i.e., admission facilities, diagnostic services, management of accident and emergencies. Tertiary care services are delivered at government regional level and at some private hospitals, are involved in specialist surgeries such as internal medicine, obstetrics and gynaecology as well as paediatrics.

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 national- and pharmacy- levels

Methodology

Statistical analysis

Data analysis for MAAP was conducted according to WHO's protocol for conducting AMC analysis using the DDD-ATC-AWaRe methodology.[31,32] Figure 17 provides a high-level summary of the AMC analysis that was conducted. Each of these WHO methodologies are described below as well as the additional analysis conducted. In addition, and where possible, associations were drawn between AMC and AMR. Details of this analysis can be found in Part A, Section II:3c.

i. Defined Daily Dose (DDD)

DDDs or related metrics are utilised to study AMC analysis. Considering different doses (in milligram) for each antibiotic for managing infections, the DDD metric helps in standardising for easy comparison. Additionally, it is recommended to use drug utilisation figures such as DDD using a relevant denominator for the health context e.g., DDDs/1000 inhabitants/day, DDD/inhabitant/year or as DDDs/100 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 a change (+/-) in the consumption patterns over the study period or pre-defined base period.

Using the WHO 2020 DDD guide, the total DDDs were the quotient of the total l consumed milligrams per antimicrobial divided by the standard DDD value issued by WHO. [33] The total DDDs were then adjusted for the country population size[34] in the year of data collection (2017-2019) and presented as DDDs/1000 inhabitants/day (DID). Pharmacy-level AMC data were to be adjusted as DDD/ number of inpatients and presented as DDD/100 patient bed days. However, the use of WHO DDD per 100 patient bed days presented limitations at the point of analysis as patient bed days were not an appropriate denominator to use across the pharmacy-level AMC data sets. In addition, for most of the hospital facilities, patient bed days and patient days information were not easily accessible. Secondly, this metric would not allow for comparison between hospital pharmacy consumption and community pharmacy consumption as in the latter the patient bed days metric is not applicable. Therefore, the pharmacy-level AMC data are presented as absolute DDD to aid comparison between the hospital and community pharmacies. Detailed DDD calculations can be found in Appendix 7. All calculations were conducted in Excel ™ .

ii. Anatomic Therapeutic Chemical (ATC) Classification

Using the standard list of antimicrobial names, data collected were coded in the Excel TM analysis database in accordance with the 2020 WHO ATC codes and then analysed to characterise the macro (above-molecule) AMC trends. The description of ATC codes is presented in Appendix 7. Furthermore, an attempt was made to conduct statistical testing to determine the year-on-year differences within each ATC class, however, this was not possible as some of the datasets were missing core components for analysis i.e., month of transaction.

iii. WHO Access, Watch and Reserve (AWaRe)

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

Through WHO AWaRe analysis, the total AMC by DDDs per antibiotic molecule were labelled as either 'Access', 'Watch' or 'Reserve' in accordance with the 2019 WHO AWaRe list[35] in Excel ™. Total DDDs per WHO AWaRe category were then analysed to determine the proportion of AMC per category and over time i.e. yearly and monthly (where possible). The WHO recommends that at least 60% of a country's total AMC should come from the 'Access' category of antibiotics. Finally, an analysis was conducted to identify the top five antibiotics consumed in each WHO AWaRe category.

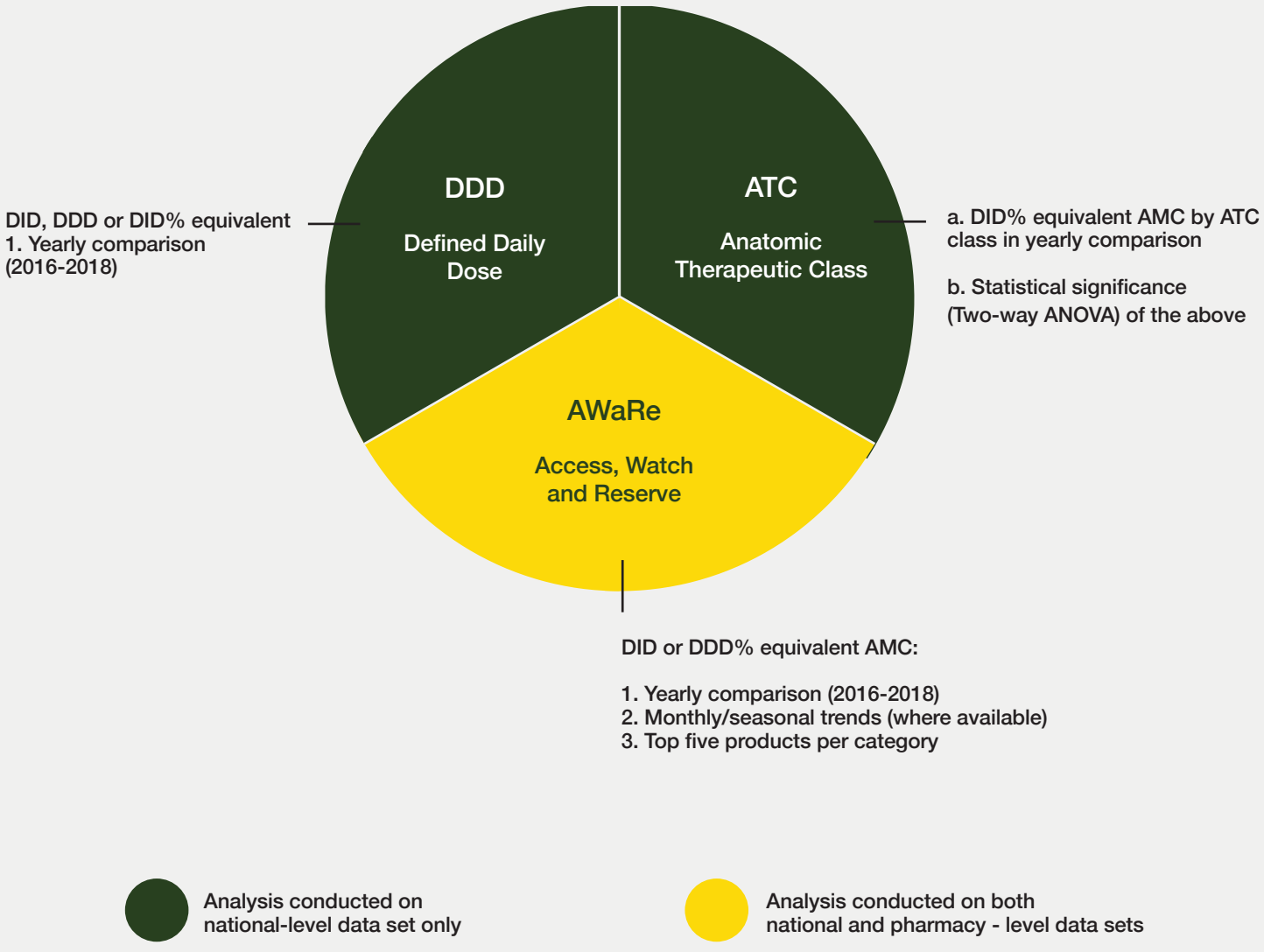


Figure 17: Methods and indicators used for the analysis of the data collected in Senegal. Defined Daily Dose (DDD) indicators utilised for volume metric standardisation was sourced from WHOCC 2020, ATC Classification utilised to categorise the antibiotics according to the organ or system on which they act, and their therapeutic, pharmacological and chemical properties sourced from WHOCCC ATC database. The Access, Watch and Reserved categorisation was sourced from 2019 WHO AWaRe classification.

iv. Review of Essential Medicines List (EML)

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

Results

National AMC datasets analyzed by DDD per year

The average total in-country AMC between 2017 and 2019 was 43.8 DDD per 1 000 inhabitants per day (DID). A 250% increase in total consumption of antimicrobials from the year 2017 to 2018 and a 12% reduction in consumption from 2018 to 2019 was noted (Figure 18). The increase in AMC from 2017 to 2019 was largely driven by a notable increase in public sector medicine consumption from 9.4 to 51.5 DID. Further disaggregation of the national AMC data across the two sectors i.e., public sector (PNA) and private sector (IQVIA ™ syndicated datasets) found that the public sector accounted for 73.4% of national AMC, while the private sector accounted for the rest (26.7%).

Figure 18: Bar graphs represents the total DID and percentage variation from the year 2017 to 2019 for the national level AMC data analysed in Senegal. It further describes the disaggregation of consumption of antimicrobials across the public (represented in orange) and private sectors (represented in green) in Senegal, as total DID and percentage share of total consumption for each year (2017 to 2019).

National AMC analysed by ATC classification

Penicillins with extended spectrum (J01CA) were the most frequently consumed ATC class in Senegal at 42.2% in 2017, 57.3% in 2018 and 35.0% in 2019, with amoxicillin being the most consumed antibiotic within this class (Figure 19). Tetracyclines (J01AA) demonstrated a higher consumption when compared to penicillins with extended spectrum for the year 2019 at 47.2%. Furthermore, across the reviewed period, tetracyclines and fluoroquinolones (J01MA) were the second and third leading ATC classes overall, with doxycycline and ciprofloxacin leading the consumption within these ATC classes, respectively. The top five most consumed antimicrobials were Amoxicillin, Doxycycline, Ciprofloxacin, sulfamethoxazole/trimethoprim and Amoxicillin/Clavulanic acid. Together they accounted for 92% of total consumption share. A detailed list of national AMC by antimicrobial molecule and by ATC class is mentioned in AMC Appendix 8 and Appendix 9, respectively.

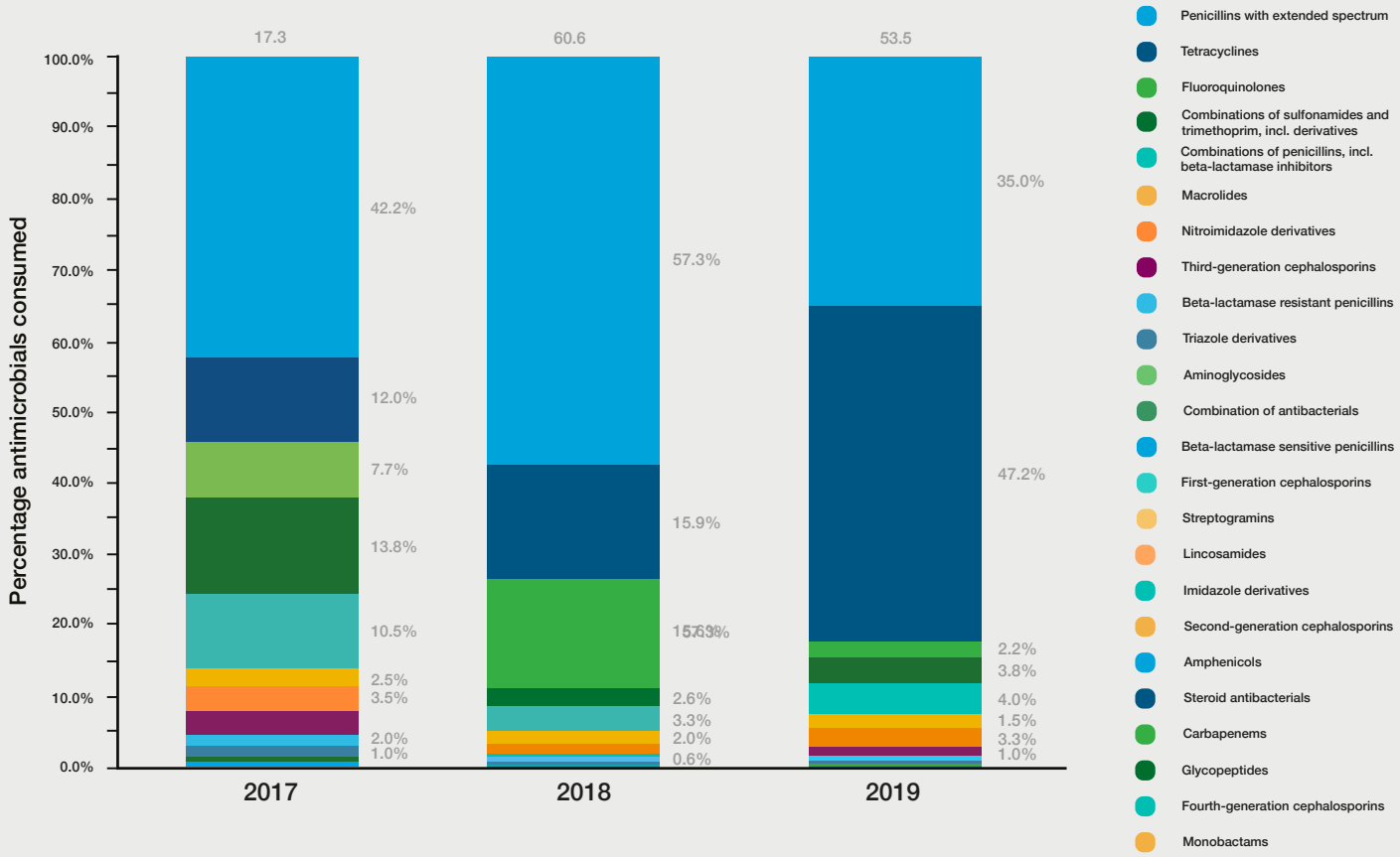


Figure 19: Results of national level AMC data analysed in Senegal are presented by the total DID and percentage of antimicrobials consumed by ATC classes from the years 2017 to 2019. Penicillins with an extended spectrum class of molecules were the highest consumed antimicrobials across all the reviewed years (2017, 2018 and 2019). Statistical testing was not carried out due to the nature of the data obtained. See AMC Appendix 9 for a more detailed breakdown of AMC by ATC classes.

Pharmacy AMC analysed by WHO AWaRe categorization

The average national consumption of antibiotics across the three years analysed was 87.4% 'Access', 12.6% 'Watch' and <0.1% 'Reserve'. Annual AMC trends indicated a decrease of 5.6% in consumption share of Access antibiotics between 2017 and 2018 and an increase of 14.3% between 2018 and 2019. This is against a corresponding proportional increase of 5.6% in the share of consumption of 'Watch' antibiotics between 2017 and 2018, that was followed by a decrease of 14.3% between 2018 and 2019 (Figure 20). Both the overall (for three years) and within each year analysed consumption of 'Access' category antibiotics in Senegal exceeded the 60% minimum consumption threshold set by WHO. This analysis of national AMC by WHO AWaRe categories omits 0.8% (0.3 DID) of total AMC that are not categorised within the WHO AWaRe list of 2019.

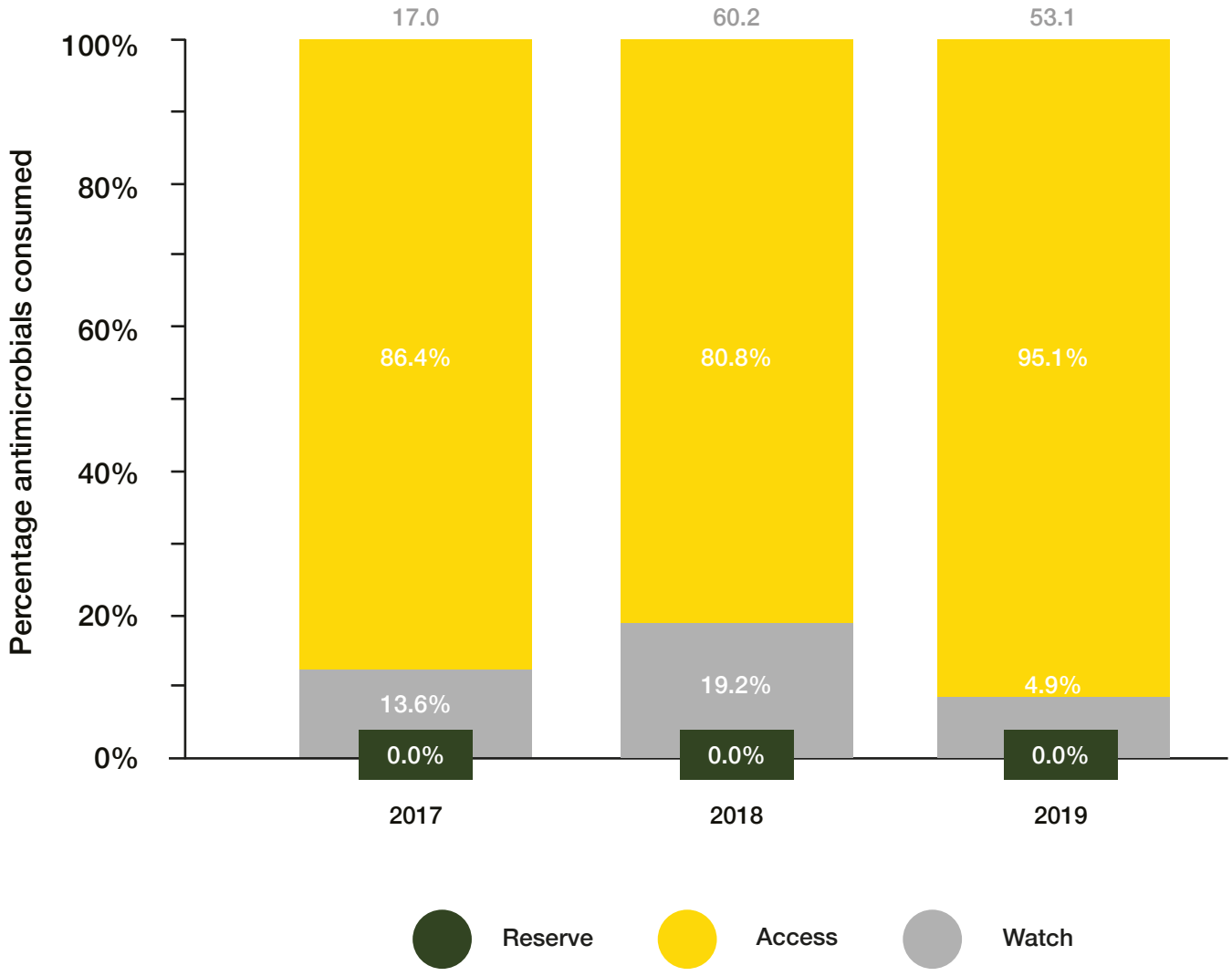


Figure 20: Results for the AMC data analysed in Senegal are presented by the total DID and percentage of antibiotics consumed by WHO AWaRe categories across all the reviewed years 2017 to 2019. Also, it shows the percentage change in consumption of 'Access' and 'Watch' category antibiotics from the year 2017 to 2019

In addition, further analysis was conducted to disaggregate the WHO AWaRe category antibiotics consumption across the two sectors represented in the national-level data i.e., public against private sector. There were minimal differences in consumption of antimicrobials by WHO AWaRe categories between the private and public sector (Figure 21).

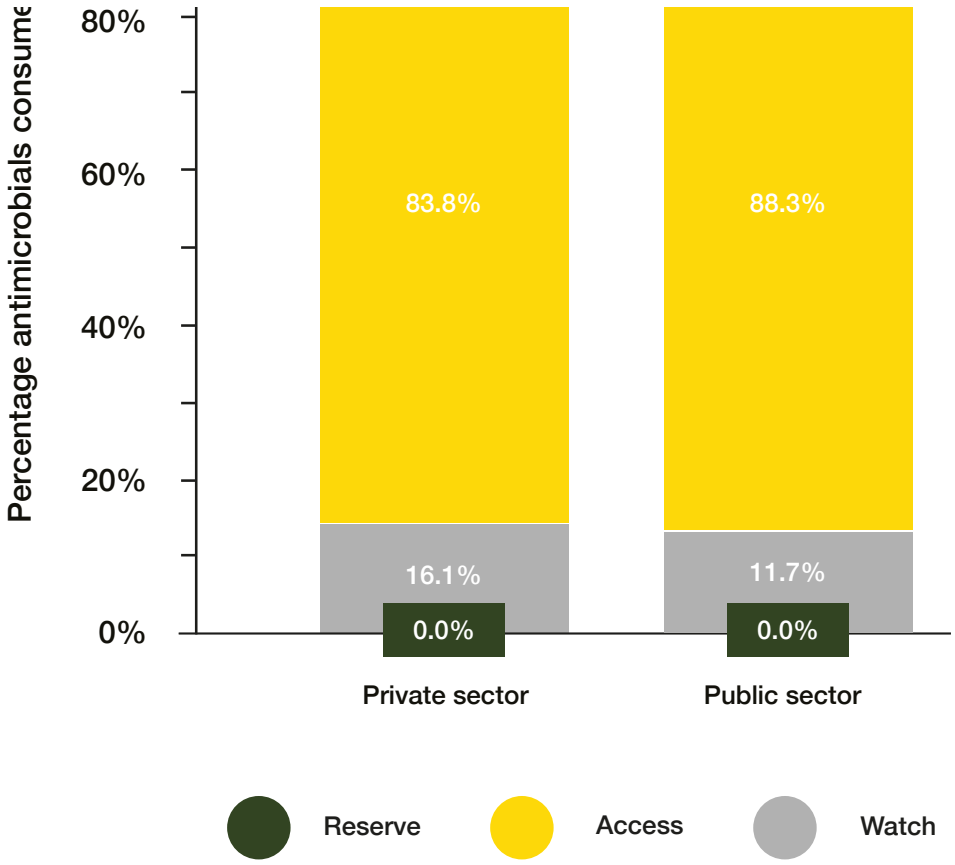
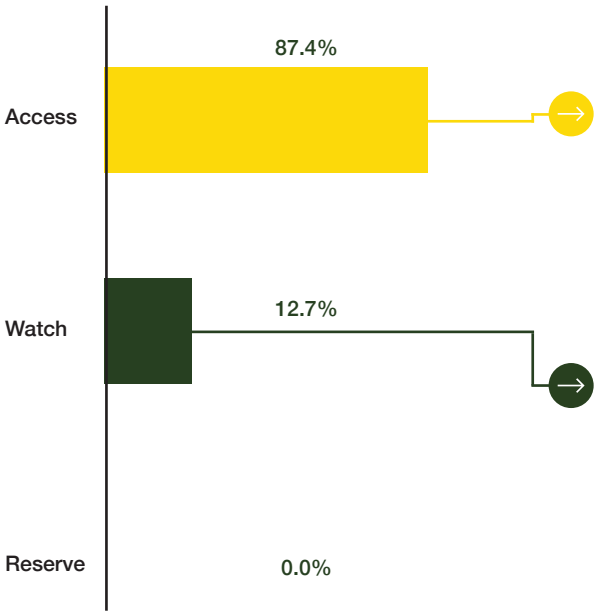


Figure 20: Results for the AMC data analysed in Senegal are presented by the total DID and percentage of antibiotics consumed by WHO AWaRe categories across all the reviewed years 2017 to 2019. Also, it shows the percentage change in consumption of 'Access' and 'Watch' category antibiotics from the year 2017 to 2019

Further analysis was conducted to identify the most frequently consumed antibiotics nationally within each WHO AWaRe category (Figure 22). In the 'Access' category, the top five consumed antibiotics, as listed in Figure 22, accounted for 97.9% of all AMC within this group. In the 'Watch' category, the top five antibiotics accounted for 93.1% of all consumption within this group. In the 'Reserve' category, national consumption was only recorded for one antibiotic, Aztreonam, representing 100% of the consumption within this category. Similarly, disaggregated AMC data by the sector showed that the top five consumed antibiotics in each WHO category were the same across the two sectors.



Molecule Name	% Total	Mean DDD
Amoxicillin	52.9%	20.1
Doxycycline	32.4%	12.3
Sulfamethoxazole/ Trimethoprim	5.3%	2.0
Amoxicillin/Clavulaniic Acid	5.2%	2.0
Metronidazole	2.1%	0.8

Molecule Name	% Total	Mean DDD
Cerfuroxime	70.5%	3.9
Cefixime	8.3%	0.5
Erythromycin	8.2%	0.5
Azithromycin	4.4%	0.2
Ceftriaxone	1.7	0.1

Molecule Name	% Total	Mean DDD
Aztreonam	100%	0.0

Figure 22: Breakdown of the 'Access', 'Watch' and 'Reserve' categories of antibiotics consumed at the national level by percentage and total DID across all the reviewed years 2017 to 2019 in Senegal. It also depicts the top five consumed antibiotics in their respective categories

Within the WHO AWaRe database exists a list of 'antibiotics not recommended'. This group of antibiotics consists of FDC multiple broad-spectrum antibiotics that are neither evidence-based, nor recommended by international guidelines. In this regard, the WHO does not recommend their use in clinical practice. Furthermore these antibiotics are represented as 'uncategorised' WHO AWaRe category antibiotics by MAAP and are not included in the computation of category percentages. These non-recommended FDC comprised of (n=8) antibiotics which represented 0.3% consumption of total national AMC (see list in Table 12 below). Ciprofloxacin/Tinidazole was the most frequently consumed (accounting for 38.7% of the consumption from the total consumption of the listed FDC antibiotics). Appendix 8 details the full list of drugs categorised under each WHO AWaRe category.

Table 12: List and AMC rank of antimicrobials categorised as 'not recommended' for clinical utility by WHO.*

AMC rank*	Molecule
17	Ciprofloxacin/Tinidazole
22	Azithromycin/Fluconazole/Secnidazole
24	Norfloxacin/Metronidazole
28	Amoxicillin/Metronidazole
37	Ofloxacin/Ornidazole
39	Amoxicillin/Cloxacillin
46	Ceftriaxone/Sulbactam
56	Amoxicillin/Sulbactam

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

The pharmacy-level data from the (n=26) participating pharmacies were disaggregated and examined by the type of pharmacy (community against hospital), the service level of the hospitals (secondary care against tertiary care and private versus public) and proportional consumption of the WHO AWaRe category antibiotics (Table 13). Both hospital and community pharmacies, on average, met the WHO threshold of 60% consumption of antibiotics represented within the 'Access' category at 75.4% and 84.5%, respectively. Hospital pharmacies consumed, on average, 9.1% more 'Watch' category antibiotics compared to community pharmacies (hospital pharmacies consumption: 24.6%; community pharmacies: 15.5%). Also, within the hospital pharmacies, the private faith-based hospital pharmacies consumed only 2.1% more 'Watch' category antibiotics compared to the public hospital pharmacies. Within the public hospital pharmacies, the tertiary care hospital pharmacies consumed 10.8% more 'Watch' category antibiotics compared to the secondary care hospital pharmacies. A closer look at the pharmacies found that while 100% of the hospital pharmacies met the WHO 'Access' threshold, 40% (n=6) of the community pharmacies failed to meet the WHO 'Access' threshold.

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

Table 13: Percentage share in the consumption of antibiotics by WHO AWaRe categories for the recruited hospital and community pharmacies between the years (2017-2019) in Senegal

Pharmacy Type	AWaRe Categorisation	
	Access	Watch
	Percentage share (Absolute DDD)	
Community pharmacies (6/17)	78.4% (288,199)	21.6% (794,98)
Hospital pharmacies (11/17)	90.4% (2,287,9293)	9.6% (2,420,390)
Secondary care facilities (7/11)	90.6 % (2,269,7065)	9.4 % (2,353,005)
Tertiary care facilities (4/11)	73.0 % (18,22,28)	27.0 % (67,385)
Grand Total	90.3% (2,316,7492)	9.7%(2,499,888)

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

The WHO EML includes 39 antibiotics across the AWaRe categories. A total of 82 antibiotics were documented during national- and pharmacy-level data collection. Figure 23 shows the number of antibiotics in the WHO EML and Senegal EML each AWaRe category , thereby indicating whether the antibiotic was documented during data collection.

It was determined that two antibiotics in the 'Access' category and three in the 'Watch' category are listed in the WHO EML and were documented during data collection, although they are not part of the Senegal EML. In addition, six 'Access' category, one 'Watch' category and seven 'Reserve' category antibiotics are part of the WHO EML, yet they are not listed in the Senegal EML nor documented during data collection. One 'Reserve' category antibiotic is listed in both the WHO and Senegal EMLs but was not documented during data collection. For each AWaRe category, including the uncategorised, antibiotics were documented during data collection which are neither part of the WHO EML or Senegal EML. The detailed breakdown of antibiotics documented and their inclusion in the WHO EML and Senegal EML is provided in Appendix 10.

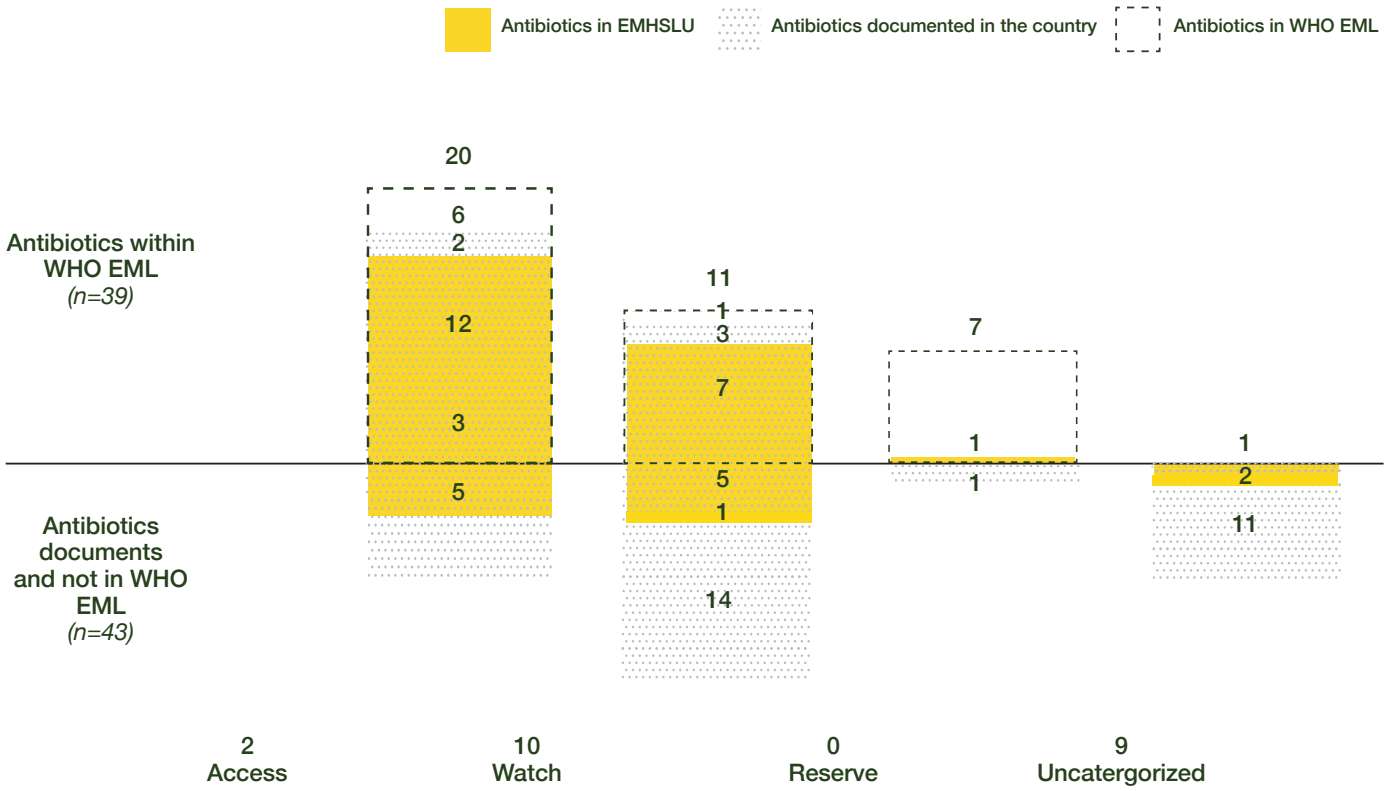


Figure 23: AWaRe analysis of documented antibiotics in national- and pharmacy-level data for the years 2017 to 2019 compared to WHO- and Senegal EML definitions

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 was not available) across select pathogen-antimicrobial combinations (Pathogens - A. baumannii, E. coli, K. pneumoniae, P. aeruginosa, S. aureus, E. faecium and E. faecalis; antibiotics - aminoglycosides, broad-spectrum penicillins, carbapenems, cephalosporins, glycopeptides, narrow-spectrum penicillins and quinolones). The DRI estimates were generated using a previously published methodology[36,37] (AMR Appendix 8) and help communicate the effectiveness of antibiotic therapy to decision makers. DRI values range from 0 (100% susceptibility) to 100 (100% resistance). Available AST results for at least 30 tested isolates and for at least 15 of the 25 combinations were prerequisites for the estimation of the DRI. To generate CIs for the DRI as the variance of the product of variables, the variance of the proportions of non-susceptible isolates was combined with a uniform standard deviation based on the estimated DDD. [38,39]

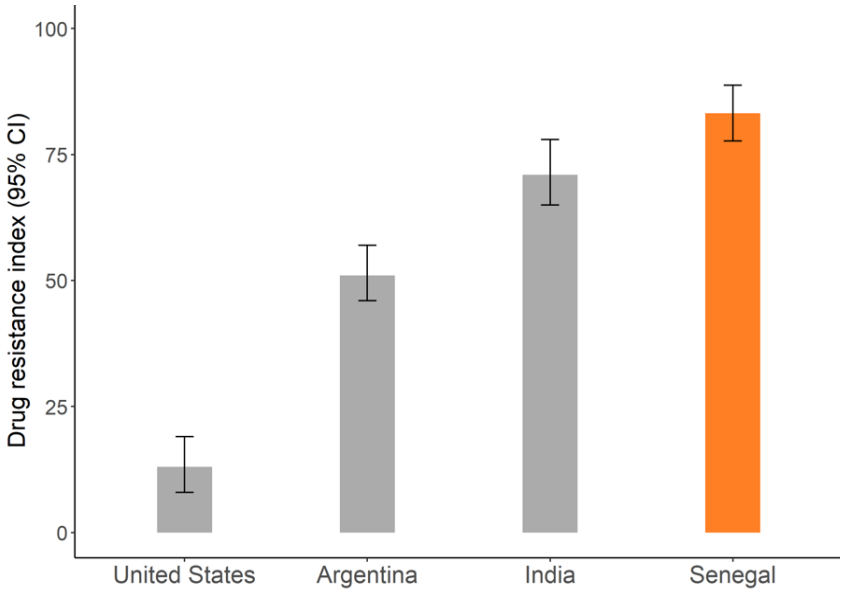
Apart from the DRI, correlation between AMC and AMR was conducted. Data on AMC were obtained from facilities and based on the total DDD over the entire study period. The AMC of a particular antimicrobial class was correlated with a composite resistance rate (covering all pathogens tested against the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

Based on previously described methodology, the resistance of all pathogens 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 high at 80.0% (95% CI, 73.7-86.1%) implying low antibiotic effectiveness, which is a threat to effective infectious disease management and calls for urgent policy intervention (Figure 24).

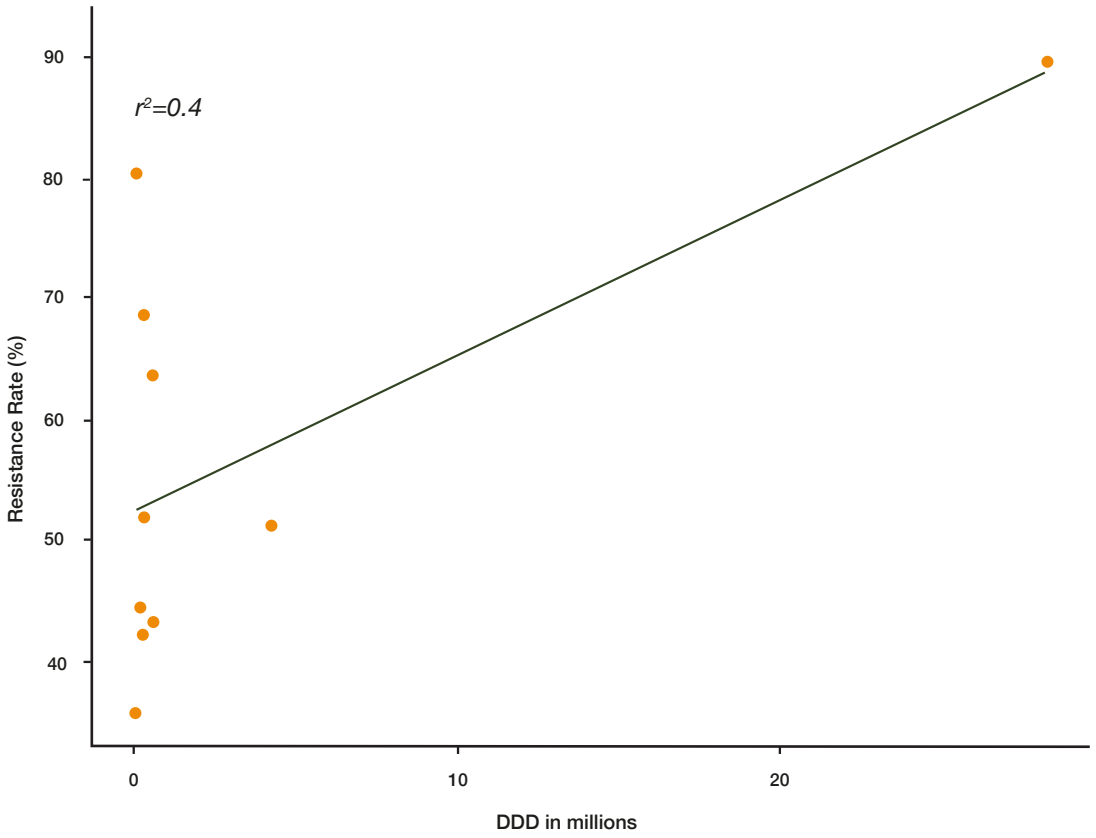


AMC and AMR correlation

The top three consumed antibiotic classes at facility level were aminopenicillins, fluoroquinolones and tetracyclines. The AMR rates were highest for aminopenicillins (89.8%), penicillins (80.4%) and folate pathway inhibitors (68.4%) (Table 14) Pearson's correlation analysis revealed a moderate positive correlation (r2=0.4) between AMR and AMC, implying that antibiotic consumption is a potential driver of AMR in Senegal (Figure 24).

Table 14: AMC and AMR rates across antibiotic classes

Antibiotic class	Year	Total DDD in thousands	Resistance rate (%)
Aminopenicillins	2016-18	28.24	89.7
Fluoroquinolones	2016-18	4.31	51.2
Tetracyclines	2016-18	0.60	63.6
Aminoglycosides	2016-18	0.59	43.1
Folate pathway inhibitors	2016-18	0.33	68.4
Beta-lactam combinations	2016-18	0.32	51.8
Cephalosporins (3rd- generation)	2016-18	0.29	42.2
Macrolides	2016-18	0.22	44.3
Penicillins	2016-18	0.08	80.4
Methicillin	2016-18	0.02	35.4

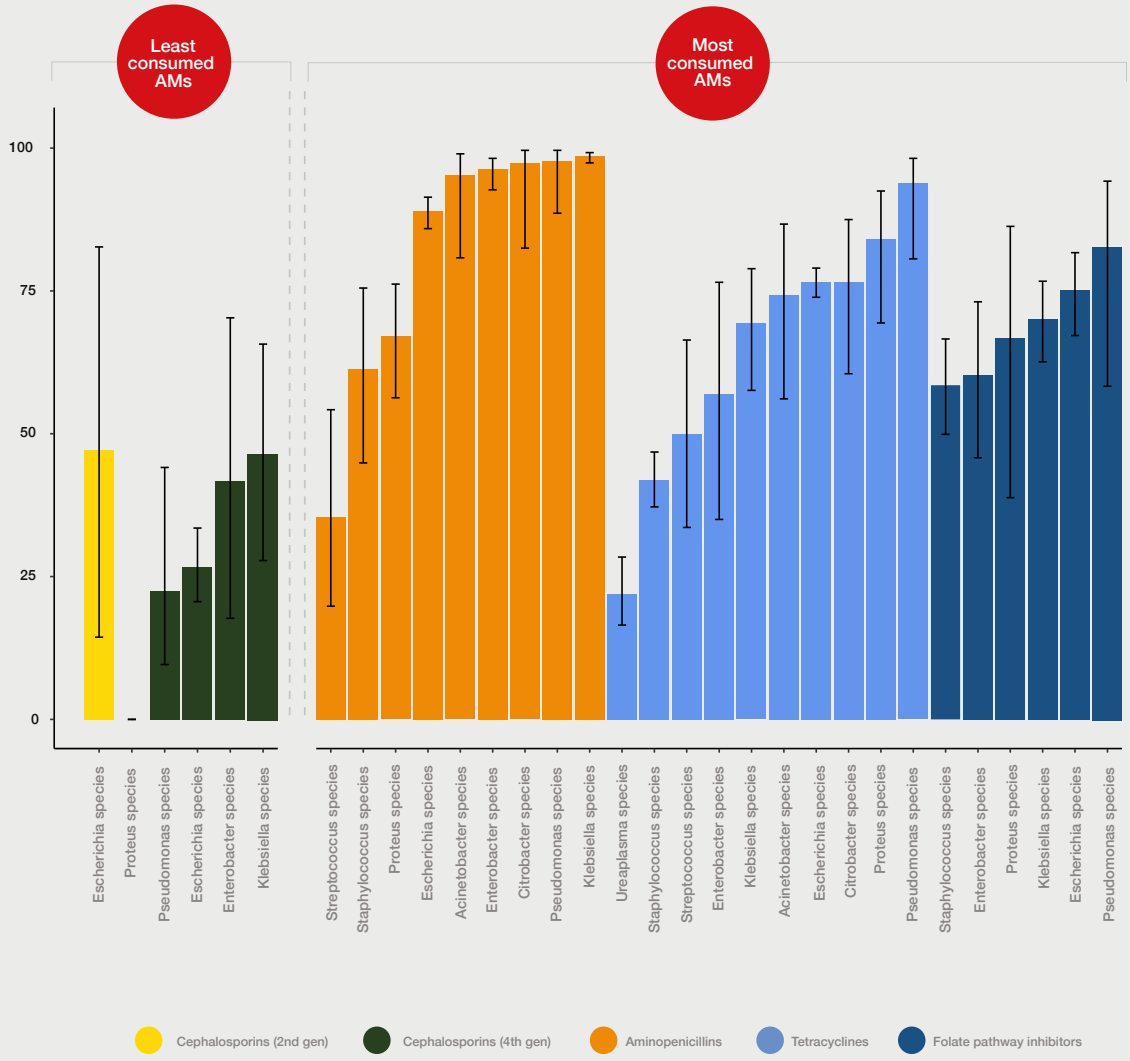


DDD=defined daily dose
Figure 24: Correlation between AMR and AMC

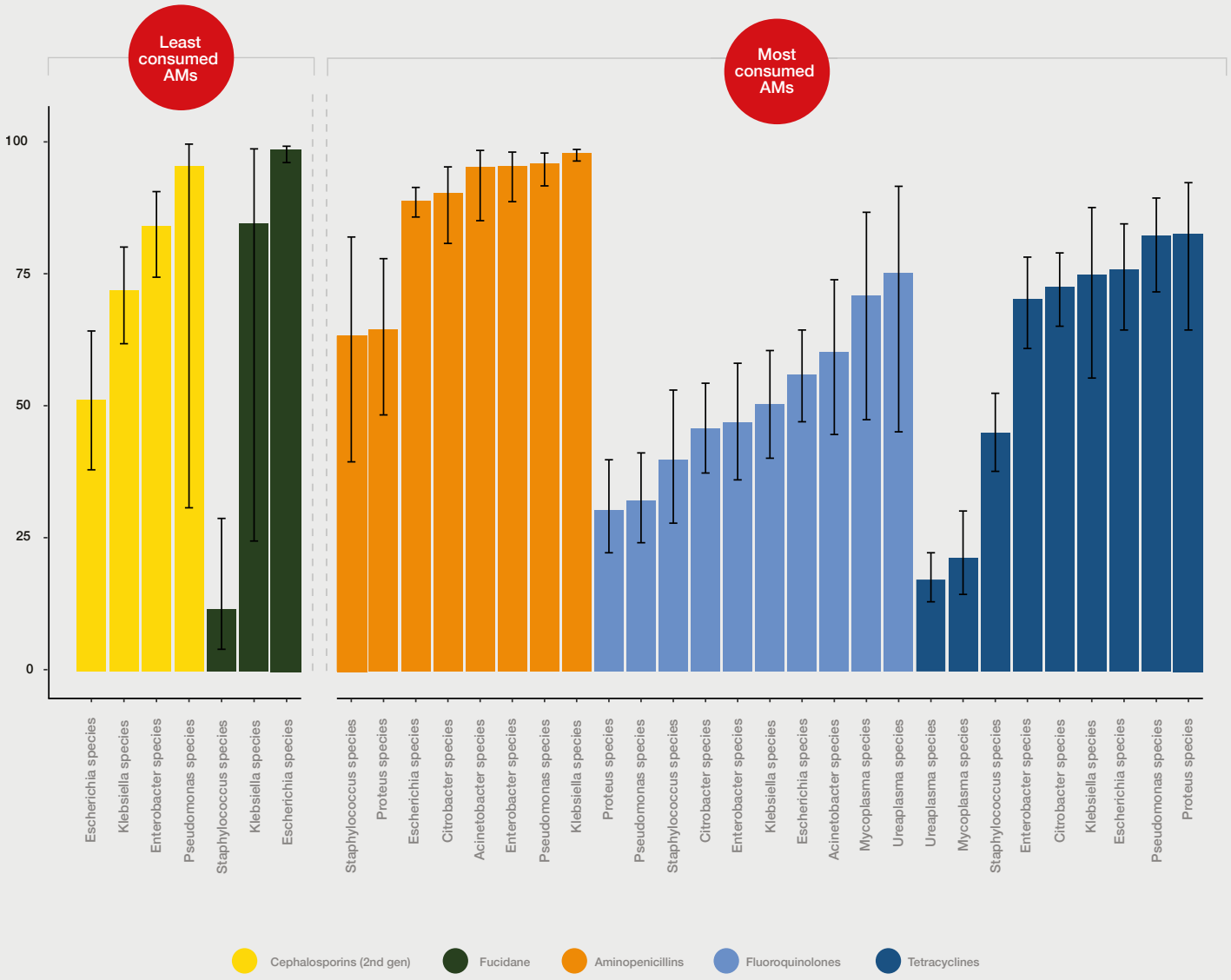
Resistance profiles of most and least consumed antimicrobial classes

The most consumed antimicrobial classes across the study years were aminopenicilins, tetracyclines, folate pathway inhibitors, and flouroquinolones. In 2017, high resistance rates (>75%) were noted for aminopenicillin-resistant Klebsiella species, Pseudomonas species, Citrobacter species, Enterobacter species, Acinetobacter species and Escherichia species, tetracycline-resistant Pseudomonas species and Proteus species, and folate pathway inhibitor-resistant Pseudomonas species. In 2018, highest resistance rates (>75%) were observed for tetracycline-resistant Pseudomonas species and Proteus species, aminopenicillin-resistant Klebsiella species, Pseudomonas species, Enterobacter species, Acinetobacter species, Citrobacter species and Escherichia species (Figure 25 and 26).

The least consumed antimicrobial classes across the study years were cephalosporins (4th-generation), cephalosporins (2nd-generation), phenicols and fucidane. Although the consumption of these antimicrobial classes was low, high resistance rates were noted across many pathogen-antimicrobial class combinations. In 2017, resistance rates were more than 25% for cephalosporins (4th-generation) resistant Klebsiella species, Enterobacter species and cephalosporins (2nd-generation) resistant Escherichia species. In 2018, resistance rates were more than 75% for cephalosporins (2nd generation)-resistant Pseudomonas species and Enterobacter species and fucidane-resistant Escherichia species and Klebsiella species (Figure 25 and 26).



AMs=antimicrobial class; 3rd gen.=Third generation
Figure 24: AMR rates for the least (left) and most (right) consumed antimicrobial classes in Senegal in 2016



AMs=antimicrobial class; 3rd gen.=Third generation
Figure 26: AMR rates for least (left) and most (right) consumed antimicrobial classes (AMs) in 2018

Part D: Recommendations

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

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

Significance of AMR and DRI data and recommendations

Analysis of available AMR data from Senegal revealed moderately high levels of resistance for 3rd generation cephalosporin-resistant Enterobacterales (40-42%), and methicillin-resistant S. aureus (MRSA) (28-42%).

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

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

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

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

Service delivery

The laboratory network in Senegal was found to consist of 200 laboratories, of which 31 were identified as bacteriological laboratories and 22 with confirmed AST capabilities. While most of the surveyed laboratories reported implementing QMS, not all were certified or accredited. Considering a country population of over 16.7 million, the laboratories did not equitably cover the country's population. The testing load (quantum of cultures) at most participating laboratories was found to be less and suggested a lack of routine microbiology testing. Hence, this risks overestimating the AMR rates as the majority of tests would have been conducted on special patient categories (such as failure of first line therapy or admission to intensive care).

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

Health workforce

As reported by the surveyed laboratories, most of them had an experienced laboratory scientist or technologist, 59% had up-to-date records on training and competence and 73% had at least one qualified microbiologist. For high quality microbiology testing and reporting, staff training on laboratory standards, ability to identify common pathogens and data management skills are essential.[41] Capacity-building of staff may be completed through in-house expertise or outsourced to external organisations or tertiary facilities.

Information systems

The Regional Grant was a step towards the collection and digitisation of data. We observed that most of the surveyed laboratories relied on paper-based records and very few had linkages to patients' clinical records. In the current study, susceptibility results could be collected for just 8 763 positive cultures.

In order to strengthen AMR surveillance, it is essential to curate the right data and generate evidence. We recommend data collection through standardised formats at all levels (laboratories, clinics and pharmacies) as well as the use of automation for data analyses. For the current study, we used WHONET for data digitisation. Empirical guidelines for management of infectious diseases should be based on epidemiology specific to patient settings and resistance data should be shared with national and supra-national platforms. We also recommend establishing a system of assigning permanent identification numbers for patient tracking over time. This would help to collect data on a patients' clinical profile, antimicrobial history as well as pathogens' molecular profile (where available), thus offering more context to the AMR epidemiology than stand-alone antimicrobial susceptibility data.

Medicines and technologies

While there are various determinants of patient care, the importance of quality diagnostics can never be undermined. Even though laboratory audit was not the scope of the current study, we observed instances of inappropriate testing and hence, data unfit for analysis. Such results can be misleading and impact patient care.

In order to strengthen AMR surveillance, it is imperative to generate reliable laboratory results through appropriate testing methods, using authorised surrogates and ensuring the uninterrupted availability of reagents, including antibiotics, for susceptibility testing. Improving supply chains for essential reagents should be a country priority and interruptions in routine testing must be minimal. Standardisation of testing methods across laboratories can aid in this process as purchases can be pooled and coordinated by the MoH. All laboratories and testing centres must conform to AST quality standards and aim for accreditation and quality certification status.

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

Significance of AMC and AMU data including recommendations

This section discusses the significance of our AMC and AMU findings and puts forth suggested recommendations for Senegal to possibly consider in order to optimise the observed trends in consumption of antimicrobials and thus facilitate future surveillance activities.

Feasibility of obtaining AMC and AMU data in Senegal and recommendations

MAAP successfully collected and analysed national and pharmacy-level AMC data for Senegal. This implies that surveillance of AMC data is possible and that Senegal can respond to WHO's call to participate in GLASS, which now has an AMC reporting component. However, considerable data verification and cleaning was required to be performed on PNA data before its use. A comprehensive guiding policy for routine AMC data surveillance is required in the country to guide on, at the minimum, reporting AMC data variables, routine data cleaning and reporting practices. This would minimise the amount of time spent standardising and cleaning the data before routine surveillance exercises. This approach would ensure that the data used is accurate and appropriate for informing country policies.

Despite the success in obtaining full coverage of national AMC data, at the pharmacy level, a majority of the targeted community pharmacies declined to share the data. In this regard, it would be best if the AMRCC in Senegal prioritises negotiation with the private-not-for-profit, public and private-for-profit medication supply stakeholders to convince them on the importance of sharing and reporting AMC.

MAAP was unable to obtain AMU data in Senegal which would have helped to characterise antimicrobials prescriptions at the facility level in line with WHO's drug use research methodology.[42] This inability to collect AMU data from participating pharmacies that were co-located in health facilities with AST laboratories was due to the fact that AMC data sources (i.e., stock record cards at the pharmacy) did not allow for tracing back to individual patients to whom antimicrobials were issued. Hence, it was not possible to retrieve the relevant clinical and laboratory files for patients who received antimicrobials. Nevertheless, a cross sectional survey which reported AMU data in Senegal has been documented.[30] This study took place at a single location, sampled 400 individual participants and the prevalence of antibiotic consumption was estimated based on the respondent's statements. Therefore, the conclusions drawn from it cannot be assumed to represent the national AMU or the sampled MAAP pharmacies. The success of this AMU study implies that the retrieval of AMU data where sub-optimal data systems exist can only be achieved through the set-up of prospective studies, where data collection procedures are intentionally set up to assess the patient in real-time through the cascade of care.

MAAP, in alignment with the WHO guidance on facility AMU assessment, would recommend that future AMU surveillance attempts in the country be conducted through point prevalence surveys on a larger scale to give a nationally representative portrait of antimicrobial use in the country.[32] However, this approach recommended by WHO is time-consuming, unlike retrospective data collection, and often requires the engagement of trained data collection teams, thus making it expensive and challenging in resource-limited settings. Retrospective AMU data collection may still be an option if the facilities targeted for data collection are selected based on the existence of electronic patient records, the presence of cross-department unique patient identifiers and a functional and efficient patient record retention system.

Overview of AMC consumption trends and recommendations

The total AMC levels documented in this report give a useful benchmark to be compared against future country consumption levels following the implementation of country stewardship programmes. Compared to studies from other countries in the region, the observed AMC levels in Senegal exceed those described in literature for Burundi, Burkina Faso, Cote d'Ivoire20 and Sierra Leone,[25] but were lower than the levels described for Tanzania.[42] The data for Senegal included public and private-not-for-profit consumption data, in comparison, Burundi used data from the public sector, which represents the use in hospitals. For Tanzania, import data was used to calculate the DDD for the population, which lacks local production data. This could be a reason why the Senegal AMC levels appear lower than those of Tanzania, yet higher than those of Burundi.

The disparities in AMC within the compared countries might further be due to a different relative burden of infectious diseases within the countries, limited availability of laboratories or point-of-care diagnostics at the health facility level. This may lead to presumptive treatment and unnecessary prescriptions 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.[20] Due to the relatively higher rates of AMC in Senegal, AMU point prevalence surveys are recommended to better understand the country AMC levels and eventually guide any future antimicrobials stewardship programmes (ASPs) to optimize the antimicrobials consumption if any overuse or misuse is detected. During our period of AMC analysis, an overall increase in the national AMC was observed. It is difficult to comprehensively assess and characterize all the possible reasons for this increase, however, the initiation of the Yeksina programme (an initiative launched in 2018 by the Ministry of Health that aims at ensuring an appropriate range of medicines are available in all health facilities) may have contributed to the increase in consumption of antimicrobials from the year 2017 to 2018.[44] Furthermore, the establishment of regular AMC surveillance will allow for the examination of AMC trends against the baseline results presented herein.

The evaluation of antibiotics consumption according to WHO AWaRe categories showed that the proportion of narrow spectrum antibiotics in the 'Access' category well exceeded the minimum WHO recommended consumption threshold[35] and minimal consumption of broader spectrum 'Watch' category antibiotics was observed. Therefore, this consumption trend implies that the Senegal EML, that mostly comprises of 'Access' category antibiotics, are widely available in country.[45] A similar trend of AMC was also observed when examining the consumption of 'Access' and 'Watch' category antibiotics from aggregated pharmacy-level AMC data. This finding is quite commendable as it implies that emerging AMR trends due to misuse or overuse will likely be restricted to a narrow spectrum of antibiotics, sparing the lesser used broader-spectrum and last-resort antibiotics in the 'Watch' and 'Reserve' categories.

Interestingly, the consumption of 'Watch' category antibiotics between the public and private sector was largely comparable. In addition, a closer examination of the spectrum of antibiotics used within each AWaRe category revealed that an overwhelming majority of antibiotics consumed within the 'Access' and 'Watch' categories were in the top five antibiotics in each category. Such a consumption pattern could be postulated to be sub-optimal as evolutionary pressure-driving resistance would only be focused on the narrow band of antibiotics consumed.[46] This narrow consumption of antibiotics within the 'Access' and 'Watch' categories of antibiotics can also make the country susceptible to stock-outs if manufacturing and supply chain issues are encountered for these few antibiotics. Considering these observations, it is therefore recommended that the country's ASP explores ways to ensure a wider spread in the consumption of the antibiotics within each WHO AWaRe category (such as offering incentives for the importation and distribution of other antibiotics in the WHO categories, in line with the country's EML) to avoid such a limited spectrum of consumed antibiotics. This should go hand-in-hand with ensuring appropriate use.

Finally, although no consumption of WHO 'Reserve' category antibiotics was observed within any of the sampled hospital or community pharmacies over the three years reviewed, consumption was recorded at national level. Furthermore, the national-level consumption of Aztreonam (a 'Reserve' category antibiotic) was recorded within the private sector datasets but is neither listed within the WHO or Senegal-EMLs. Interestingly, the country's EML has one listed WHO 'Reserve' antibiotic (i.e., Linezolid). However, the consumption of this antibiotic was not documented during data collection. There is potential to increase the range of 'Reserve' antibiotics in the Senegal EML. The current 'Reserve' antibiotics representation in the Senegal national datasets imply their limited accessibility rather than the regulation of their consumption or lack of need for their use. Therefore, MAAP recommends an urgent review be conducted by the MoH and AMRCC to assess the availability of the 'Reserve' category antibiotics in the country that may subsequently lead to the revision of the country's EML and treatment guidelines to include these vital antibiotics. This approach will ensure that the most vital antibiotics are available for all patients.

The WHO also provides guidance on antibiotics that are 'not recommended' for use in clinical practice due to their multiple broad-spectrum activity and the lack of evidence-based clinical cases that advocate for their use.[35] In Senegal, the use of eight such FDCs 'not recommended' by WHO nor included in the country's EML were detected. Of these combinations, the use of combination of ciprofloxacin/tinidazole was most prevalent. It is recommended that the AMRCC identify the reasons for the prescription and dispensing of these FDCs and the locations that commonly prescribe or dispense the identified FDC antibiotics. This will allow the country's MoH and associated medicine regulatory bodies to embark on sensitising prescribers on recommended treatments for those ailments to correct this prescribing practice.

AMC and AMU summary and way forward

Data generated from AMC and AMU surveillance trends can provide unique insights for national stewardship programmes and for the formulation of policies to stem the emergence of AMR. Senegal should be commended for exceeding the minimum threshold of consumption of at least 60% of antibiotics from the WHO 'Access' (narrow spectrum, first choice antibiotics) category. However, only five antibiotics make up for 92% of the consumption, which indicates the opportunity for more diversification. Table 15 describes the next steps for AMC and AMU surveillance.

Table 15: Next steps for AMC and AMU surveillance

A.

Leadership and Governance

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

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

The DPM regulatory authority, Directorate of Pharmacy and Medicine, could reconsider the registration status of unapproved fixed- dose antibiotic combinations.

The national stewardship programmes could work to review the Senegal EML 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 that have unique patient identifiers and fully electronic medical records capabilities, or, as a limited number of facilities have such systems in place, the country could aim to prospectively collect this data as guided by WHO methodology for point prevalence surveys.[32]

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 country could establish nNational sStewardship programmes shcould and collaborate with pharmacists and medicine importers to increase the availability of 'Reserve' category antibiotics in selected facilities, as per the revised country's EML.

Part E: Limitations

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

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

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

3. The participating laboratories may not fully represent the true resistance rates in the country as they only encompassed a small proportion of the country's population (over 16.7 million). Furthermore, as routine testing does not appear to be the norm in most hospitals and laboratories, the data may overestimate the resistance rates as infections that fail therapy may be more likely to be tested.

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

5. To better understand whether the national AMC trends were mirrored by pharmacy-level AMC trends, a sample of 16 pharmacies were purposively selected for data collection. This sample size was a relatively small proportion of the total pharmacies in Senegal and did not represent all regions and health zones in Senegal, unlike the national AMC dataset which represented consumption across the country. Therefore, a more systematic sampling strategy that factors in populations serviced and geographical locations is required to make conclusions from pharmacy-level data more representative.

6. MAAP was unable to collect AMC data from all targeted community pharmacies. This was mainly due to their unwillingness to share data, the inability to access the data from their systems or as a result of them not meeting the inclusion criteria.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

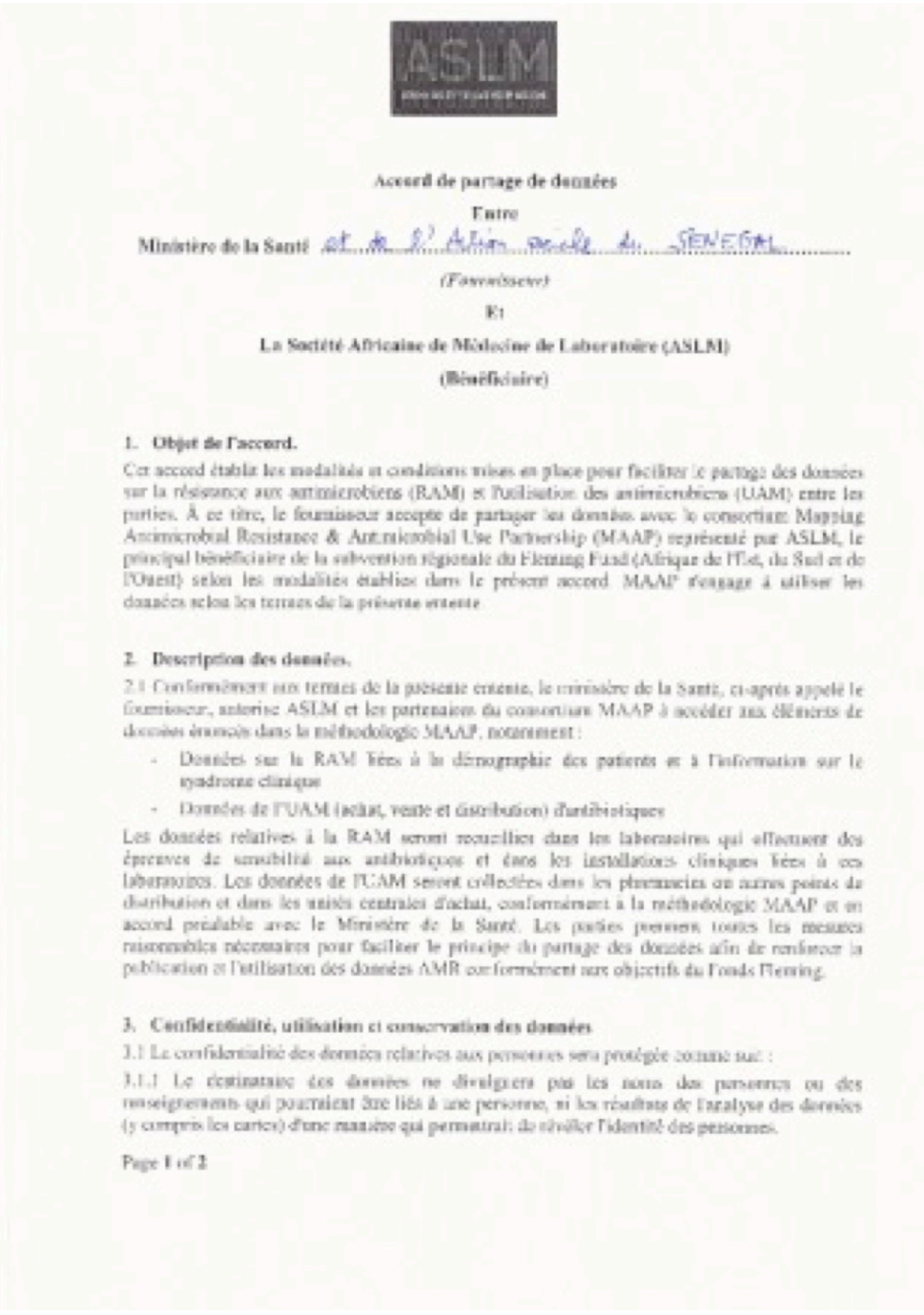
Quality Management Systems:
It is a systematic, integrated set of activities to establish and control the work processes from pre-analytical through post-analytical processes, manage resources, conduct evaluations, and make continual improvements to ensure consistent quality results.

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

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

AMR Appendices and Supplementary Data

Appendix 1: Terms of Reference and Data Sharing Agreements



ASLM

Accord de partage de données

Entre

Ministère de la Santé et de l'Action sociale du SENEGAL

(Fournisseur)

Et

La Société Africaine de Médecine de Laboratoire (ASLM)

(Bénéficiaire)

1. Objet de l'accord.

Cet accord établit les modalités et conditions mises en place pour faciliter le partage des données sur la résistance aux antimicrobiens (RAM) et l'utilisation des antimicrobiens (UAM) entre les parties. À ce titre, le fournisseur accepte de partager les données avec le consortium Mapping Antimicrobial Resistance & Antimicrobial Use Partnership (MAAP) représenté par ASLM, le principal bénéficiaire de la subvention régionale du Fleming Fund (Afrique de l'Est, du Sud et de l'Ouest) selon les modalités établies dans le présent accord. MAAP s'engage à utiliser les données selon les termes de la présente entente

2. Description des données.

2.1 Conformément aux termes de la présente entente, le ministère de la Santé, ci-après appelé le fournisseur, autorise ASLM et les partenaires du consortium MAAP à accéder aux éléments de données énoncés dans la méthodologie MAAP, notamment :

- Données sur la RAM liées à la démographie des patients et à l'information sur le syndrome clinique
- Données de l'UAM (achat, vente et distribution) d'antibiotiques

Les données relatives à la RAM seront recueillies dans les laboratoires qui effectuent des épreuves de sensibilité aux antibiotiques et dans les installations cliniques liées à ces laboratoires. Les données de l'UAM seront collectées dans les pharmacies ou autres points de distribution et dans les unités centrales d'achat, conformément à la méthodologie MAAP et un accord préalable avec le Ministère de la Santé. Les parties prennent toutes les mesures raisonnables nécessaires pour faciliter le principe du partage des données afin de renforcer la publication et l'utilisation des données AMR conformément aux objectifs du Fonds Fleming.

3. Confidentialité, utilisation et conservation des données

3.1 La confidentialité des données relatives aux personnes sera protégée comme suit :

3.1.1 Le destinataire des données ne divulguera pas les noms des personnes ou des renseignements qui pourraient être liés à une personne, ni les résultats de l'analyse des données (y compris les cartes) d'une manière qui permettrait de révéler l'identité des personnes.

Appendix 2: Laboratory Eligibility Questionnaire

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

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

Part 4. Personnel and Training

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

Part 5. Specimen Management

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

<200	200-1000	1000-3000	>3000

Part 6. Laboratory Information System and Linkage to Clinical Data

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

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

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

Appendix 3: Laboratory Readiness Assessment

The EQ questions were scored for laboratory readiness as follows:

Part 1: Site Information (Maximum score=0)

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

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

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

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

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

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

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

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

Part 5. Specimen Management (Maximum Score=3)

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

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

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

Appendix 4: Key AMR Variables

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

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

Appendix 5: WHO Priority Pathogens

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

**Previously known as Enterobacteriaceae.*

Appendix 6: Other clinically important pathogens

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

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

Appendix 7: Pathogen Phenotype Definitions

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

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

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

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

Appendix 8: Pathogens and antimicrobials for AMR drivers and DRI

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

AMR Supplementary Tables

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

Affiliation	Surveyed N=22 n (%)	Reference N = 6 n (%)	Regional/ Intermediate N =14 n (%)	District/ Community N = 0 n (%)	Unspecified N = 2 n (%)
Government	20 (90.91)	6 (100.0)	12 (85.7)	0	2 (100.0)
Private	1 (4.55)	0	1(7.1)	0	0
NGO	0	0	0	0	0
Others	1 (4.55)	0	1(7.1)	0	0

Supplementary Table 2: Assessment of preparedness for AMR surveillance

Parameters	Surveyed laboratories N=22 n (%)
Commodity and equipment status	
Regular power supply and functional back up	18 (81.8)
Continuous water supply	19 (86.4)
Certified and functional biosafety cabinets	10 (45.5)
Automated methods for pathogen identification	3 (13.6)
Automated methods for antimicrobial susceptibility testing	3 (13.6)
Methods for testing antimicrobial resistance mechanisms	12 (54.5)
QMS implementation	
Reported QMS Implementation	
• Reported QMS tool (n=44)	**16 (72.7)**
• LQMS	**0 (0)**
• SLIPTA	**13 (81.2)**
• SLMTA	**0 (0)**
• Mentoring	**0 (0)**
• Combination‡	**1 (6.3)**
• Others	**1 (6.3)**
Quality Certification	**2 (9.1)**
• Reported certification type (n=16)	
• SLIPTA	-
• College of American Pathologists	-
• Others	-
Accreditation	0 (0.0)
Participation in proficiency testing	13 (59.1)
Utilization of reference strains	11 (50.0)
Reported consistent maintenance of QC records	11 (50.0)
Designated focal quality person	16 (72.7)
Reported compliance to standard operating procedures	20 (90.9)
Reported compliance to antimicrobial susceptibility testing standards	15 (68.2)
Personnel and training status	
Presence of at least one qualified microbiologist	16 (72.7)
Presence of an experienced laboratory scientist/technologist	18 (81.8)
Up-to-date and complete records on staff training and competence	13 (59.1)
Specimen Management status	
Reported compliance to standard operating procedures on specimen collection and testing	19 (86.4)
Reported compliance to standard operating procedures on specimen rejection	21 (95.5)
Availability on average number of specimens processed for culture and sensitivity in year 2018	18 (81.8)
Laboratory Information System and Linkage to Clinical Data	
Assigned specimen (laboratory) identification number	22 (100.0)
Availability of system/database to store patient data	22 (100.0)
• System/database format (n=19)	
• Paper-based	11 (50.0)
• Electronic	3 (13.6)
• Mixed	8 (36.4)
Captured patients' demographics and clinical information on test request forms	21 (95.5)
• Retrievable test request forms (n=20)	11 (52.4)

**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		**2744**	**20693**	**28334**	**608**	**6538**	**8699**	**189**	**3581**	**4993**
Pathogen type	bacteria				593 (97.5)	5607 (85.8)	7330 (84.3)	189 (100.0)	3569 (99.7)	4963 (99.4)
	fungi				15 (2.5)	931 (14.2)	1369 (15.7)	-	12 (0.3)	30 (0.6)
Age, years	Less than 1	858 (31.3)	1151 (5.6)	1149 (4.1)	176 (28.9)	219 (3.3)	224 (2.6)	43 (22.8)	107 (3.0)	175 (3.5)
	1 to 17	636 (23.2)	2500 (12.1)	2575 (9.1)	75 (12.3)	461 (7.1)	455 (5.2)	26 (13.8)	306 (8.5)	378 (7.6)
	18 to 49	599 (21.8)	9825 (47.5)	12994 (45.9)	145 (23.8)	3158 (48.3)	4807 (55.3)	81 (42.9)	1283 (35.8)	1960 (39.3)
	50 to 65	154 (5.6)	2095 (10.1)	3349 (11.8)	65 (10.7)	748 (11.4)	936 (10.8)	16 (8.5)	502 (14.0)	776 (15.5)
	Above 65	126 (4.6)	2544 (12.3)	3988 (14.1)	53 (8.7)	1168 (17.9)	1362 (15.7)	16 (8.5)	927 (25.9)	1208 (24.2)
	Unknown Age	371 (13.5)	2578 (12.5)	4279 (15.1)	94 (15.5)	784 (12.0)	915 (10.5)	7 (3.7)	456 (12.7)	496 (9.9)
Gender	Male	1522 (55.5)	8232 (39.8)	10744 (37.9)	317 (52.1)	2549 (39.0)	2658 (30.6)	92 (48.7)	1973 (55.1)	2328 (46.6)
	Female	1207 (44.0)	12370 (59.8)	17541 (61.9)	286 (47.0)	3970 (60.7)	6034 (69.4)	97 (51.3)	1599 (44.7)	2660 (53.3)
	Unknown gender	15 (0.5)	91 (0.4)	49 (0.2)	5 (0.8)	19 (0.3)	7 (0.1)	-	9 (0.3)	5 (0.1)
Laboratory	Matlaboul	-	1726 (8.3)	1975 (7.0)	-	418 (6.4)	371 (4.3)	-	152 (4.2)	71 (1.4)
	Sor Saint-Louis	-	706 (3.4)	866 (3.1)	-	84 (1.3)	142 (1.6)	-	84 (2.3)	142 (2.8)
	Abass	578 (21.1)	1928 (9.3)	3064 (10.8)	208 (34.2)	577 (8.8)	1234 (14.2)	-	56 (1.6)	408 (8.2)
	CHR Saint-Louis	1 (0.0)	3737 (18.1)	3513 (12.4)	-	597 (9.1)	536 (6.2)	-	465 (13.0)	495 (9.9)
	Mbour	-	1610 (7.8)	414 (1.5)	-	419 (6.4)	234 (2.7)	-	231 (6.5)	183 (3.7)
	CHR Ouros-sogui	1 (0.0)	1449 (7.0)	1199 (4.2)	1 (0.2)	497 (7.6)	456 (5.2)	1 (0.5)	296 (8.3)	211 (4.2)
	Saint Jean	-	-	6248 (22.1)	-	-	1201 (13.8)	-	-	558 (11.2)
	Fatick	-	922 (4.5)	1018 (3.6)	-	358 (5.5)	288 (3.3)	-	235 (6.6)	179 (3.6)
	IHS	526 (19.2)	162 (0.8)	254 (0.9)	128 (21.1)	162 (2.5)	254 (2.9)	117 (61.9)	162 (4.5)	254 (5.1)
	Mbargane	-	-	2205 (7.8)	-	-	609 (7.0)	-	-	608 (12.2)
	Diamniadio	1634 (59.5)	1394 (6.7)	1291 (4.6)	267 (43.9)	160 (2.4)	178 (2.0)	67 (35.4)	57 (1.6)	140 (2.8)
	Idrissa Pouye	4 (0.1)	1660 (8.0)	2594 (9.2)	4 (0.7)	1306 (20.0)	1593 (18.3)	4 (2.1)	1200 (33.5)	1324 (26.5)
	Heinrich Lubke	-	1272 (6.1)	1145 (4.0)	-	285 (4.4)	227 (2.6)	-	250 (7.0)	168 (3.4)
	Albert Royer	-	-	697 (2.5)	-	-	114 (1.3)	-	-	113 (2.3)
	Matam	-	908 (4.4)	1490 (5.3)	-	432 (6.6)	1147 (13.2)	-	75 (2.1)	102 (2.0)
	Thies	-	3219 (15.6)	361 (1.3)	-	1243 (19.0)	115 (1.3)	-	318 (8.9)	37 (0.7)

Supplementary Table 4: Specimen characteristics

Specimen Type	All years* N= 8763 n (%)	2016 N = 189 n (%)	2017 N = 3581 n (%)	2018 N = 4993 n (%)
Abscess (abdominal)	1 (0)	-	1 (0)	-
Abscess/Discharge/Pus/Swab/Wound	2058 (23.5)	13 (6.9)	935 (26.1)	1110 (22.2)
Aspirate/discharge	2 (0)	-	1 (0)	1 (0)
Blood	436 (5)	66 (34.9)	118 (3.3)	252 (5)
Catheter (unspecified)	7 (0.1)	-	4 (0.1)	3 (0.1)
Catheter (urinary)	7 (0.1)	-	3 (0.1)	4 (0.1)
CSF	36 (0.4)	2 (1.1)	21 (0.6)	13 (0.3)
Fluid (pleural)	54 (0.6)	-	25 (0.7)	29 (0.6)
Fluid (scrotal)	103 (1.2)	-	68 (1.9)	35 (0.7)
Fluid (unspecified)	44 (0.5)	-	35 (1)	9 (0.2)
Respiratory-Lower	57 (0.7)	-	57 (1.6)	-
Respiratory-Upper	121 (1.4)	1 (0.5)	33 (0.9)	87 (1.7)
Semen	7 (0.1)	-	2 (0.1)	5 (0.1)
Stool	65 (0.7)	-	44 (1.2)	21 (0.4)
Swab (rectal)	1 (0)	-	1 (0)	-
Swab (urethral)	6 (0.1)	1 (0.5)	5 (0.1)	-
Swab (vaginal)	611 (7)	-	129 (3.6)	482 (9.7)
Swab/discharge (urethral)	1 (0)	1 (0.5)	-	-
Tissue/biopsy	1 (0)	-	1 (0)	-
Unknown	131 (1.5)	-	18 (0.5)	113 (2.3)
Urine	5014 (57.2)	105 (55.6)	2080 (58.1)	2829 (56.7)

**Indicates positive cultures with AST results*

Supplementary Table 5: Pathogen identification

Pathogen				
Positive cultures with specific pathogen name	2 861 (65.1)	626 (63.5)	963 (59.3)	1 272 (71.3)
Acinetobacter baumannii	25 (0.3)	-	6 (0.2)	19 (0.4)
Acinetobacter calcoaceticus	1 (0)	-	-	1 (0)
Aeromonas hydrophila	2 (0)	-	1 (0)	1 (0)
Burkholderia cepacia	6 (0.1)	-	1 (0)	5 (0.1)
Candida albicans	30 (0.3)	-	7 (0.2)	23 (0.5)
Candida auris	1 (0)	-	1 (0)	-
Cedecea lapagei	1 (0)	-	-	1 (0)
Chlamydia trachomatis	4 (0)	-	-	4 (0.1)
Chryseomonas luteola	3 (0)	-	-	3 (0.1)
Citrobacter amalonaticus	5 (0.1)	-	-	5 (0.1)
Citrobacter diversus	4 (0)	-	4 (0.1)	-
Citrobacter freundii	94 (1.1)	1 (0.5)	34 (0.9)	59 (1.2)
Citrobacter koseri	52 (0.6)	-	20 (0.6)	32 (0.6)
Clostridium absonum	1 (0)	-	1 (0)	-
Clostridium malenominatum	1 (0)	-	1 (0)	-
Corynebacterium jeikeium	19 (0.2)	-	19 (0.5)	-
Corynebacterium urealyticum	5 (0.1)	-	5 (0.1)	-
Edwardsiella tarda	1 (0)	-	-	1 (0)
Enterobacter amnigenus	7 (0.1)	-	-	7 (0.1)
Enterobacter cloacae	156 (1.8)	-	54 (1.5)	102 (2)
Enterobacter gergoviae	15 (0.2)	-	2 (0.1)	13 (0.3)
Enterococcus durans	1 (0)	-	-	1 (0)
Enterococcus faecalis	17 (0.2)	-	4 (0.1)	13 (0.3)
Enterococcus faecium	1 (0)	-	-	1 (0)
Escherichia coli	3470 (39.6)	77 (40.7)	1440 (40.2)	1953 (39.1)
Gardnerella vaginalis	20 (0.2)	-	5 (0.1)	15 (0.3)
Klebsiella aerogenes	7 (0.1)	-	1 (0)	6 (0.1)
Klebsiella oxytoca	189 (2.2)	2 (1.1)	65 (1.8)	122 (2.4)
Klebsiella pneumoniae	1488 (17)	38 (20.1)	670 (18.7)	780 (15.6)
Kluyvera intermedia	1 (0)	-	-	1 (0)

Morganella morganii	30 (0.3)	-	19 (0.5)	11 (0.2)
Mycoplasma hominis	154 (1.8)	-	14 (0.4)	140 (2.8)
Neisseria gonorrhoeae	10 (0.1)	-	5 (0.1)	5 (0.1)
Neisseria meningitidis	4 (0)	-	4 (0.1)	-
Pantoea (enterobacter) agglomerans	5 (0.1)	-	2 (0.1)	3 (0.1)
Proteus hauseri	1 (0)	-	-	1 (0)
Proteus mirabilis	158 (1.8)	2 (1.1)	58 (1.6)	98 (2)
Proteus penneri	2 (0)	-	2 (0.1)	-
Proteus vulgaris	53 (0.6)	-	25 (0.7)	28 (0.6)
Providencia alcalifaciens	3 (0)	-	3 (0.1)	-
Providencia rettgeri	11 (0.1)	1 (0.5)	1 (0)	9 (0.2)
Providencia stuartii	5 (0.1)	-	3 (0.1)	2 (0)
Pseudomonas aeruginosa	408 (4.7)	9 (4.8)	184 (5.1)	215 (4.3)
Raoultella ornithinolytica	1 (0)	-	-	1 (0)
Salmonella enterica	3 (0)	-	2 (0.1)	1 (0)
Salmonella paratyphi	1 (0)	-	-	1 (0)
Salmonella typhi	4 (0)	-	4 (0.1)	-
Serratia liquefaciens	3 (0)	-	3 (0.1)	-
Serratia marcescens	8 (0.1)	2 (1.1)	3 (0.1)	3 (0.1)
Serratia odorifera	2 (0)	-	1 (0)	1 (0)
Shigella dysenteriae	1 (0)	-	-	1 (0)
Shimwellia (Escherichia) blattae	1 (0)	-	1 (0)	-
Staphylococcus arlettae	1 (0)	-	-	1 (0)
Staphylococcus aureus	1027 (11.7)	34 (18)	459 (12.8)	534 (10.7)
Staphylococcus cohnii	1 (0)	-	1 (0)	-
Staphylococcus epidermidis	42 (0.5)	-	22 (0.6)	20 (0.4)
Staphylococcus haemolyticus	1 (0)	-	-	1 (0)
Staphylococcus saprophyticus	128 (1.5)	-	56 (1.6)	72 (1.4)
Staphylococcus simulans	1 (0)	-	-	1 (0)
Staphylococcus warneri	2 (0)	-	-	2 (0)
Streptococcus agalactiae	6 (0.1)	-	1 (0)	5 (0.1)
Streptococcus pneumoniae	11 (0.1)	2 (1.1)	4 (0.1)	5 (0.1)
Streptococcus pyogenes	2 (0)	-	1 (0)	1 (0)

Ureaplasma urealyticum	192 (2.2)	-	35 (1)	157 (3.1)
Yersinia enterocolitica	1 (0)	-	1 (0)	-
Positive cultures with non-specific pathogen name	853 (9.7)	21 (11.1)	326 (9.1)	506 (10.1)
Acinetobacter Sp.	103 (1.2)	1 (0.5)	49 (1.4)	53 (1.1)
Aeromonas Sp.	1 (0)	-	1 (0)	-
Candida Sp.	10 (0.1)	-	4 (0.1)	6 (0.1)
Chlamydia Sp.	1 (0)	-	1 (0)	-
Citrobacter Sp.	33 (0.4)	2 (1.1)	14 (0.4)	17 (0.3)
Enterobacter Sp.	289 (3.3)	14 (7.4)	128 (3.6)	147 (2.9)
Enterococcus Sp.	26 (0.3)	1 (0.5)	14 (0.4)	11 (0.2)
Escherichia Sp.	2 (0)	-	1 (0)	1 (0)
Flavobacterium Sp.	1 (0)	-	-	1 (0)
Haemophilus Sp.	1 (0)	-	-	1 (0)
Klebsiella Sp.	23 (0.3)	-	13 (0.4)	10 (0.2)
Mobiluncus Sp.	1 (0)	-	-	1 (0)
Morganella Sp.	3 (0)	-	1 (0)	2 (0)
Mycoplasma Sp.	11 (0.1)	-	-	11 (0.2)
Non fermenting Ggram- negative bacilli	38 (0.4)	-	8 (0.2)	30 (0.6)
Others	4 (0)	-	3 (0.1)	1 (0)
Pantoea Sp.	3 (0)	-	2 (0.1)	1 (0)
Peptostreptococcus Sp.	1 (0)	-	-	1 (0)
Proteus Sp.	10 (0.1)	-	4 (0.1)	6 (0.1)
Providencia Sp.	11 (0.1)	-	4 (0.1)	7 (0.1)
Pseudallescheria Sp.	1 (0)	-	-	1 (0)
Pseudomonas Sp.	98 (1.1)	1 (0.5)	17 (0.5)	80 (1.6)
Salmonella Sp.	20 (0.2)	-	9 (0.3)	11 (0.2)
Serratia Sp.	11 (0.1)	-	7 (0.2)	4 (0.1)
Shigella Sp.	7 (0.1)	-	4 (0.1)	3 (0.1)
Staphylococcus Sp.	62 (0.7)	-	11 (0.3)	51 (1)
Streptococcus Sp.	76 (0.9)	2 (1.1)	27 (0.8)	47 (0.9)
Unspecified (Gram positive cocci)	1 (0)	-	-	1 (0)
Unspecified (Gram positive coccobacilli)	1 (0)	-	1 (0)	-
Ureaplasma Sp.	1 (0)	-	-	1 (0)
Yersinia Sp.	3 (0)	-	3 (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
Idrissa Pouye	4	4	4	4
Abass	-	4	4	4
Thies	-	4	4	4
Heinrich Lubke	-	4	4	4
Diamniadio	4	3	3	3.3
CHR Saint-Louis	-	4	4	4
Albert Royer	-		4	4
Matam	-	4	4	4
Saint Jean	-	-	4	4
Mbargane	-	-	4	4
CHR Ourossogui	4	4	4	4
Fatick	-	4	4	4
Mbour	-	4	4	4
Sor Saint-Louis	-	4	4	4
Matlaboul	-	4	4	4
IHS	4	4	4	4

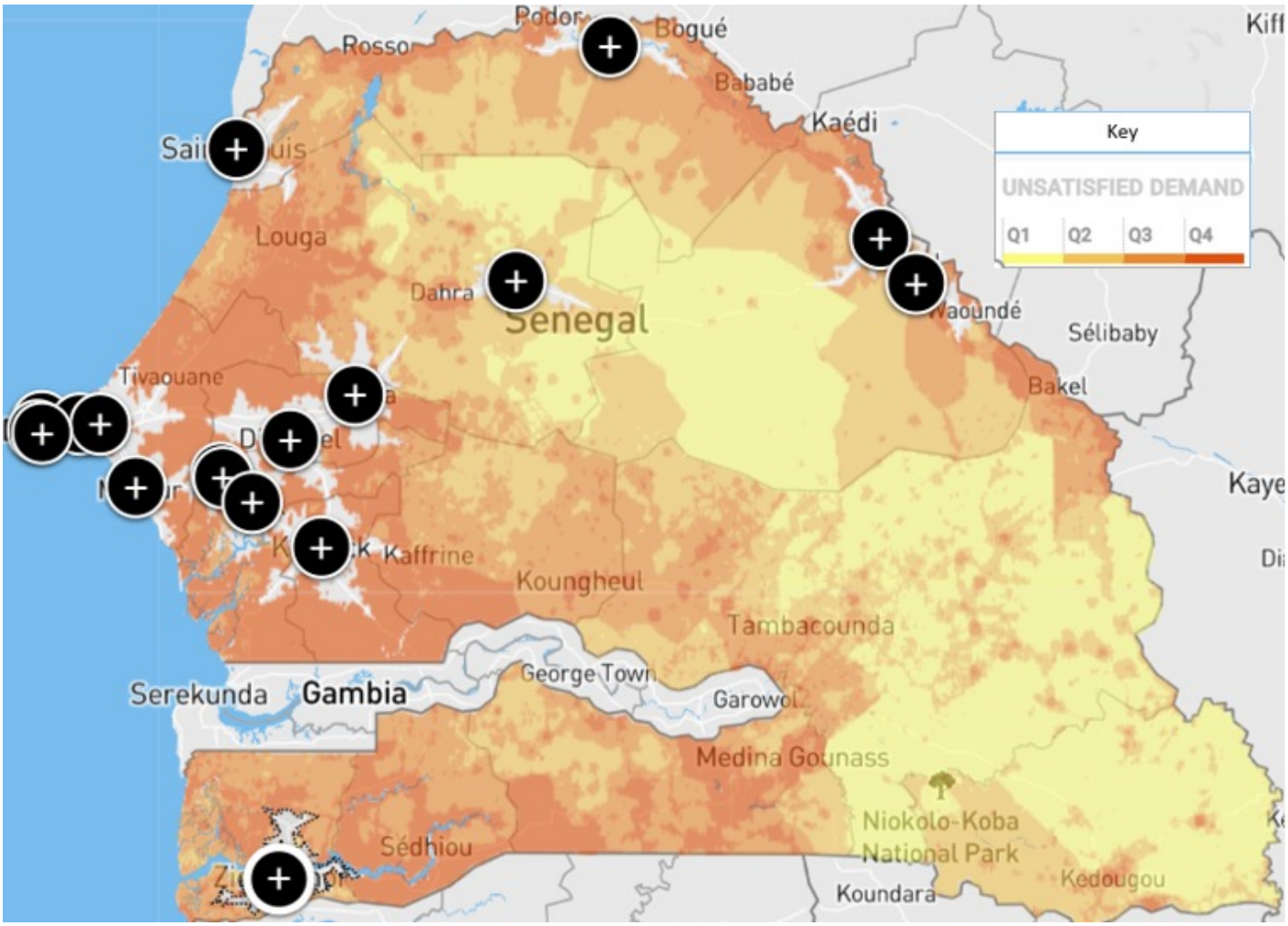
Supplementary Table 7: Univariate logistic regression analysis

Variable	Options	N	NS (%)	Crude OR (95% CI)	P-value
Gender	Female	2415	63.5	Ref	0.185
	Male	818	61.7	0.93 (0.83 – 1.04)	
Age, years	<1	109	58.7	0.77 (0.57 – 1.06)	0.1848
	1-17	439	64.2	0.98 (0.63 – 1.51)	
	18-49	1170	64.8	Ref	
	50-65	272	60.7	0.83 (0.66 – 1.07)	
	>65	221	67.0	1.10 (0.81 – 1.50)	
Diagnosis	Infection/Inflammation	2755	44.0	Ref	0.0000
	Cardiovascular	90	42.2	0.93 (0.60 - 1.44)	
	Diabetes	93	37.6	0.77 (0.54 - 1.10)	
	Injuries	603	34.2	0.66 (0.52 - 0.84)	
	Neoplasm	157	58.6	1.80 (1.13 - 2.86)	
	Nonspecific	2994	44.1	1.00 (0.80 - 1.26)	
	Other non-communicable diseases	1207	35.3	0.69 (0.56 - 0.87)	
	Renal	1344	44.5	1.02 (0.84 - 1.24)	

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

AMR Supplementary Figures

Supplementary Figure 1: Population coverage of laboratories



Supplementary Figure 2a: Inappropriate testing A

Organism Name	Antimicrobial Agent	Agent Code	Interpreted Results	Antimicrobial Susceptibility Method	Year
Staphylococcus aureus	Clotrimazole	CTR_ED10	R	Disk	2017
Staphylococcus pneumoniae	Clotrimazole	CTR_ED10	R	Disk	2017
Escherichia coli	Clotrimazole	CTR_ED10	R	Disk	2017
Escherichia coli	Clotrimazole	CTR_ED10	R	Disk	2017
Staphylococcus aureus	Clotrimazole	CTR_ED10	R	Disk	2017
Candida albicans	Amoxicillin	AMC_ED20	R	Disk	2017
Candida sp.	Amoxicillin	AMC_ED25	R	Disk	2017
Candida sp.	Amoxicillin	AMX_ED10	R	Disk	2017
Candida sp.	Aztreonam	ATM_ED30	R	Disk	2017
Candida sp.	Ceftriaxone	CRO_ED30	R	Disk	2017

Supplementary Figure 2b: Inappropriate testing B

Organism Name	Antimicrobial Agent	Agent Code	Interpreted Results	Antimicrobial Susceptibility Method	Year
Escherichia coli	Vancomycin	VAN_ND30	R	Disk	2016
Escherichia coli	Vancomycin	VAN_ND30	R	Disk	2017
Escherichia coli	Penicillin G	PEN_ND10	R	Disk	2016
Escherichia coli	Oxacillin	OXA_ND1	R	Disk	2017
Escherichia coli	Oxacillin	OXA_ND1	R	Disk	2017
Klebsiella pneumoniae.	Oxacillin	OXA_ND1	R	Disk	2017
Escherichia coli	Penicillin G	PEN_ND10	R	Disk	2017
Escherichia coli	Oxacillin	OXA_ND1	R	Disk	2017
Enterobacter sp.	Oxacillin	OXA_ND1	R	Disk	2017
Escherichia coli	Penicillin G	PEN_ND10	R	Disk	2018
Shigella sp.	Penicillin G	PEN_ND10	R	Disk	2018
Klebsiella pneumoniae	Penicillin G	PEN_ND10	R	Disk	2018
Staphylococcus aureus	Vancomycin	VAN_ND30	I	Disk	2016
Staphylococcus aureus	Vancomycin	VAN_ND30	R	Disk	2016
Staphylococcus aureus	Vancomycin	VAN_ND30	R	Disk	2018
Staphylococcus aureus	Vancomycin	VAN_ND30	R	Disk	2018

AMC Appendices

Appendix 1: Key Informant Interview (KII) tool

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

Domestic Producers and Importers

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

Procurement, Storage and Distribution

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

Public Sector

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

Private Sector

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

Donor Funded Supply

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

2. Data and Information Systems

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

3. Informal Supply Chains

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

Appendix 2: Eligibility questionnaire for pharmacies

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

Instructions

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

Eligibility questionnaire for Community Pharmacies:

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

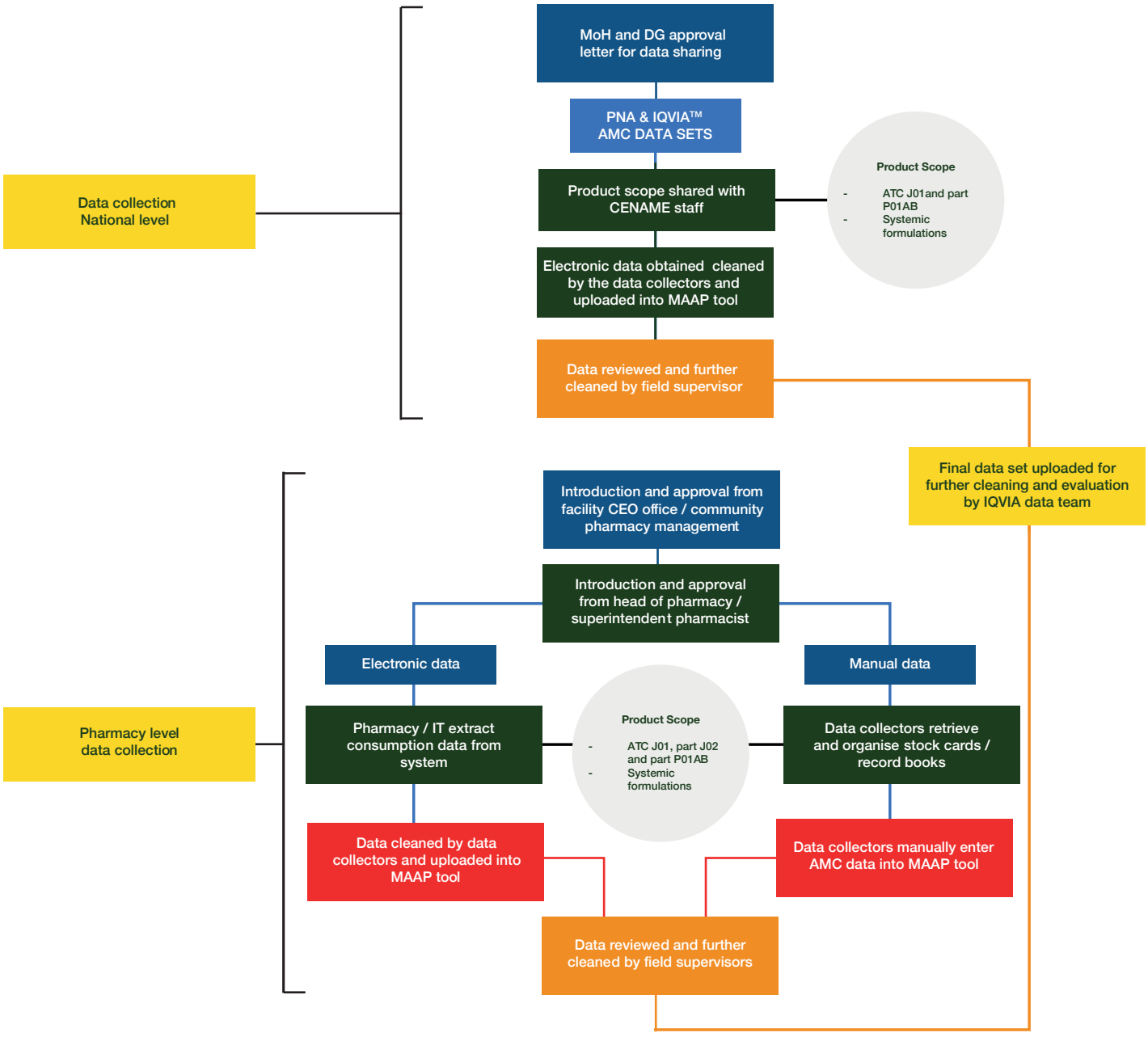
Ciprofloxacin/Metronidazole	J01RA10	U
Ciprofloxacin/Tinidazole	J01RA11	U
Ciprofloxacin/Ornidazole	J01RA12	U
Norfloxacin/Tinidazole	J01RA13	U
Vancomycin	J01XA01	W
Teicoplanin	J01XA02	W
Telavancin	J01XA03	R
Dalbavancin	J01XA04	R
Oritavancin	J01XA05	R
Colistin	J01XB01	R
Polymyxin B	J01XB02	R
Fusidic Acid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

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

Appendix 4: Key AMC specific variables

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

Appendix 5: Data collection process flowchart



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

Appendix 6: Description of AMC analysis methodology

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

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

***WHO approved DDDs for antibiotics:**

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

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

The below formula summarizes how this calculation was done:

DDD/1000 Inhabitants/day =

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

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

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

DDD equivalent (%) =

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

*WHO approved DDDs for antibiotics:

WHO Anatomical Therapeutic Chemical (ATC) classification

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

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

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

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

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

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

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

Description of the AWaRe categories below:

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

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

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

Appendix 7: National AMC by Antimicrobial molecules

ATC Class Rank	AWaRe category	Molecule	2017	2018	2019	Mean DDD/1000 inhabitants/day
			DDD/1000 inhabitants/day (%*)			
J01 Class		Total	16.51 (100)	60.33 (100)	51.48 (100)	42.77
1	Access	Amoxicillin	7.22 (43.7)	34.40 (57)	18.62 (36.2)	20.08
2	Access	Doxycycline	2.07 (12.5)	9.63 (16)	25.23 (49)	12.31
3	Watch	Ciprofloxacin	1.23 (7.4)	9.3 (15.4)	1.07 (2.1)	3.87
4	Access	Sulfamethoxazole/ Trimethoprim	2.38 (14.4)	1.58 (2.6)	2.04 (4)	2.00
5	Access	Amoxicillin/ Clavulanic Acid	1.81 (11)	1.99 (3.3)	2.14 (4.2)	1.98
6	Watch	Cefixime	0.41 (2.5)	0.53 (0.9)	0.44 (0.9)	0.46
7	Watch	Erythromycin	0.12 (0.7)	0.85 (1.4)	0.38 (0.7)	0.45
8	Access	Flucloxacillin	0.34 (2.1)	0.36 (0.6)	0.35 (0.7)	0.35
9	Watch	Azithromycin	0.18 (1.1)	0.26 (0.4)	0.28 (0.6)	0.24
10	Access	Ampicillin	0.08 (0.5)	0.26 (0.4)	0.09 (0.2)	0.14
11	Access	Gentamicin	0.04 (0.3)	0.28 (0.5)	0.08 (0.1)	0.13
12	Watch	Ceftriaxone	0.05 (0.3)	0.15 (0.3)	0.07 (0.1)	0.09
13	Watch	Ofloxacin	0.07 (0.4)	0.10 (0.2)	0.08 (0.2)	0.08
14	Access	Phenoxymethylpenicillin	0.06 (0.4)	0.07 (0.1)	0.07 (0.1)	0.07
15	Watch	Clarithromycin	0.05 (0.3)	0.05 (0.1)	0.06 (0.1)	0.06
16	Watch	Spiramycin	0.04 (0.3)	0.05 (0.1)	0.05 (0.1)	0.05
17	Uncategorized	Ciprofloxacin/Tinidazole	0.03 (0.2)	0.04 (0.1)	0.05 (0.1)	0.04
18	Access	Benzathine benzylpenicillin	0.03 (0.2)	0.04 (0.1)	0.04 (0.1)	0.04
19	Watch	Streptomycin	0.02 (0.1)	0.06 (0.1)	0.002 (0)	0.03
20	Watch	Spiramycin/Metronida-zole	0.02 (0.1)	0.03 (0)	0.03 (0.1)	0.03
21	Watch	Levofloxacin	0.03 (0.2)	0.03 (0)	0.03 (0.1)	0.03
22	Uncategorized	Azithromycin/ Fluconazole/Secnidazole	0.02 (0.1)	0.02 (0)	0.03 (0.1)	0.02
23	Watch	Roxithromycin	0.02 (0.1)	0.02 (0)	0.02 (0)	0.02
24	UncategorizedUn-categorised	Norfloxacin/ Metronidazole	0.02 (0.1)	0.02 (0)	0.02 (0)	0.02
25	Access	Cefadroxil	0.03 (0.2)	0.02 (0)	0.01 (0)	0.02
26	Watch	Cefotaxime	0.02 (0.1)	0.02 (0)	0.02 (0)	0.02
27	Watch	Pristinamycin	0.01 (0.1)	0.02 (0)	0.02 (0)	0.02

28	Uncategorized	Amoxicillin/Metronidazole	0.01 (0.1)	0.02 (0)	0.02 (0)	0.02
29	Access	Cefalexin	0.01 (0.1)	0.01 (0)	0.02 (0)	0.02
30	Watch	Lincomycin	0.01 (0.1)	0.02 (0)	0.01 (0)	0.01
31	Watch	Cefpodoxime proxetil	0.01 (0.1)	0.01 (0)	0.01 (0)	0.01
32	Access	Metronidazole	0.02 (0.1)	0 (0)	0.01 (0)	0.01
33	Watch	Josamycin	0.01 (0)	0.01 (0)	0.01 (0)	0.01
34	Watch	Cefuroxime	0.01 (0.1)	0.01 (0)	0.01 (0)	0.01
35	Access	Benzylpenicillin	0.01 (0)	0.01 (0)	0.01 (0)	0.01
36	Access	Pivmecillinam	0.01 (0)	0.01 (0)	0.01 (0)	0.01
37	Uncategorized	Ofloxacin/Ornidazole	0.002 (0)	0.01 (0)	0.01 (0)	0.004
38	Watch	Norfloxacin	0.004 (0)	0.004 (0)	0.004 (0)	0.004
39	Uncategorized	Amoxicillin/Cloxacillin	0.004 (0)	0.004 (0)	0.003 (0)	0.004
40	Access	Thiamphenicol	0.003 (0)	0.003 (0)	0.003 (0)	0.003
41	Watch	Fusidic Acid	0.002 (0)	0.003 (0)	0.003 (0)	0.003
42	Access	Oxacillin	0.003 (0)	0.001 (0)	0.003 (0)	0.002
43	Access	Cefazolin	0.0002 (0)	0.004 (0)	0.001 (0)	0.002
44	Watch	Minocycline	0.001 (0)	0.001 (0)	0.001 (0)	0.001
45	Watch	Sparfloxacin	0.002 (0)	0.001 (0)	0.001 (0)	0.001
46	Uncategorized	Ceftriaxone/Sulbactam	0.001 (0)	0.001 (0)	0.001 (0)	0.001
47	Watch	Imipenem/Cilastatin	0.001 (0)	0.001 (0)	0.001 (0)	0.001
48	Access	Amikacin	0.00004 (0)	0.001 (0)	0.001 (0)	0.0005
49	Access	Cefradine	0.00027 (0)	0.00038 (0)	0.0003 (0)	0.0003
50	Watch	Vancomycin	0.00004 (0)	0.00019 (0)	0.00024 (0)	0.0002
51	Access	Cloxacillin	0 (0)	0.00006 (0)	0.00038 (0)	0.0001
52	Watch	Cefaclor	0.00025 (0)	0.00011 (0)	0.00004 (0)	0.0001
53	Watch	Moxifloxacin	0.00014 (0)	0.00003 (0)	0 (0)	0.00006
54	Watch	Ceftazidime	0.00003 (0)	0.00002 (0)	0.00005 (0)	0.00003
55	Watch	Cefepime	0 (0)	0 (0)	0.00003 (0)	0.000009
56	Uncategorized	Amoxicillin/Sulbactam	0.00001 (0)	0 (0)	0 (0)	0.000005
57	Reserve	Aztreonam	0 (0)	0 (0)	0 (0)	0.000002
J02 Class		Total	0.18 (100)	0.22 (100)	0.23 (100)	0.21
1	Uncategorized	Fluconazole	0.18 (100)	0.22 (100)	0.23 (100)	0.21
2	Uncategorized	Voriconazole	0 (0)	0 (0)	0 (0)	0
P01AB Class		Total	0.61 (100)	0.02 (100)	1.74 (100)	0.79
1	Access	Metronidazole	0.60 (98)	0 (0)	1.73 (99.1)	0.78
2	Uncategorized	Metronidazole/ Diloxanide	0.009 (1.5)	0.011 (72.4)	0.01 (0.6)	0.01
3	Uncategorized	Secnidazole	0.002 (0.4)	0.003 (22.4)	0.004 (0.2)	0.003
4	Uncategorized	Tinidazole	0.001 (0.1)	0.001 (5.2)	0.001 (0.1)	0.001

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

Appendix 8: Breakdown of national AMC by ATC classes

	% consumption		
ATC class	2017	2018	2019
Penicillins with extended spectrum	42.2%	57.3%	35.0%
Tetracyclines	12.0%	15.9%	47.2%
Fluoroquinolones	7.7%	15.6%	2.2%
Combinations of sulfonamides and trimethoprim, incl. derivatives	13.8%	2.6%	3.8%
Combinations of penicillins, incl. beta-lactamase inhibitors	10.5%	3.3%	4.0s%
Macrolides	2.5%	2.0%	1.5%
Nitroimidazole derivatives	3.5%	0.0%	3.3%
Third-generation cephalosporins	2.8%	1.2%	1.0%
Beta-lactamase sensitive penicillins	2.0%	0.6%	0.7%
Triazole derivatives	1.0%	0.4%	0.4%
Aminoglycosides	0.4%	0.6%	0.1%
Combinations of antibacterials	0.6%	0.2%	0.3%
Beta-lactamase sensitive penicillins	0.6%	0.2%	0.2%
First-generation cephalosporins	0.2%	0.1%	0.1%
Streptogramins	0.1%	<0.1%	<0.1%
Lincosamides	0.1%	<0.1%	<0.1%
Imidazole derivatives	0.1%	0.0%	<0.1%
Second-generation cephalosporins	0.1%	<0.1%	<0.1%
Amphenicols	<0.1%	<0.1%	<0.1%
Steroid antibacterials	<0.1%	<0.1%	<0.1%
Carbapenems	<0.1%	<0.1%	<0.1%
Glycopeptides	<0.1%	<0.1%	<0.1%
Fourth-generation cephalosporins	0.0%	0.0%	<0.1%
Monobactams	<0.1%	<0.1%	<0.1%

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

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

Standardised Molecule Name	WHO AWaRe Categorisation	WHO ATC Code	WHO EML	National EML	Documented Data
Amikacin	Access	J01GB06	Y	Y	Y
Amoxicillin	Access	J01CA04	Y	Y	Y
Amoxicillin/Clavulanic Acid	Access	J01CR02	Y	Y	Y
Amoxicillin/Cloxacillin	Access	J01CR50	N	N	Y
Amoxicillin/Metronidazole		J01RA--	N	N	Y
Amoxicillin/Pivsulbactam		J01CR02	N	N	Y
Amoxicillin/Sulbactam		J01CR02	N	N	Y
Amphotericin-B		J02AA01	N	Y	N
Ampicillin		J01CA01	Y	Y	Y
Azithromycin	Access	J01FA10	Y	Y	Y
Azithromycin/Fluconazole/	Watch				
Secnidazole		J01RA07	N	N	Y
Aztreonam		J01DF01	N	N	Y
Benzathine benzylpenicillin	Reserve	J01CE08	Y	Y	Y
Benzylpenicillin	Access	J01CE01	Y	Y	Y
Cefaclor	Access	J01DC04	N	N	Y
Cefadroxil	Watch	J01DB05	N	N	Y
Cefalexin	Access	J01DB01	Y	N	Y
Cefazolin	Access	J01DB04	Y	Y	Y
Cefepime	Access	J01DE01	N	N	Y
Cefiderocol	Watch	J01DI04	Y	N	N
Cefixime	Reserve	J01DD08	Y	Y	Y
Cefotaxime	Watch	J01DD01	Y	Y	Y
Cefpodoxime proxetil	Watch	J01DD13	N	N	Y
Cefradine	Watch	J01DB09	N	N	Y
Ceftazidime	Access	J01DD02	Y	N	Y
Ceftazidime/avibactam	Watch	J01DD52	Y	N	N
Ceftriaxone	Reserve	J01DD04	Y	Y	Y
Ceftriaxone/Sulbactam	Watch	J01DD63	N	N	Y
Cefuroxime		J01DC02	Y	Y	Y
Chloramphenicol	Watch	J01BA01	Y	N	N
Ciprofloxacin	Access	J01MA02	Y	Y	Y
Ciprofloxacin/Tinidazole	Watch	J01RA11	N	N	Y
Clarithromycin		J01FA09	Y	N	Y
Clindamycin	Watch	J01FF01	Y	N	N
Cloxacillin	Access	J01CF02	Y	N	Y
Colistin	Access	J01XB01	Y	N	N
Doxycycline	Reserve	J01AA02	Y	Y	Y
Erythromycin	Access	J01FA01	N	Y	Y
Flucloxacillin	Watch	J01CF05	N	Y	Y
Fluconazole	Access	J02AC01	N	Y	Y
Fosfomycin (IV)		J01XX01	Y	N	N
Fusidic Acid	Reserve	J01XC01	N	N	Y
Gentamicin	Watch	J01GB03	Y	Y	Y
Imipenem/Cilastatin	Access	J01DH51	N	Y	Y
Josamycin	Watch	J01FA07	N	N	Y
Kanamycin	Watch	J01GB04	N	Y	N
Ketoconazole	Watch	J02AB02	N	Y	N
Levofloxacin		J01MA12	N	Y	Y
Lincomycin	Watch	J01FF02	N	N	Y
Linezolid	Watch	J01XX08	Y	Y	N
Meropenem	Reserve	J01DH02	Y	N	N
Meropenem/vaborbactam	Watch	J01DH52	Y	N	N
Metronidazole	Reserve	P01AB01, J01XD01	Y	Y	Y
Metronidazole/Diloxanide	Access	P01AB51	N	N	Y
Minocycline		J01AA08	N	N	Y
Moxifloxacin	Watch	J01MA14	N	Y	Y
Nitrofurantoin	Watch	J01XE01	Y	N	N

Norfloxacin	Watch	J01MA06	N	N	Y
Norfloxacin/Metronidazole		J01RA--	N	N	Y
Ofloxacin	Watch	J01MA01	N	N	Y
Ofloxacin/Ornidazole		J01RA09	N	N	Y
Oxacillin	Access	J01CF04	N	Y	Y
Phenoxymethylpenicillin	Access	J01CE02	Y	Y	Y
Piperacillin/Tazobactam	Access	J01CR05	Y	N	Y
Pivmecillinam	Watch	J01CA08	N	N	Y
Plazomicin	Access	J01GB14	Y	N	N
Polymyxin-B	Reserve	J01XB02	Y	N	N
Pristinamycin	Reserve	J01FG01	N	Y	Y
Procaine benzylpenicillin	Watch	J01CE09	Y	N	N
Roxithromycin	Access	J01FA06	N	N	Y
Secnidazole		P01AB07	N	N	Y
Sparfloxacin	Watch	J01MA09	N	N	Y
Spectinomycin	Watch	J01XX04	Y	N	N
Spiramycin	Access	J01FA02	N	N	Y
Spiramycin/Metronidazole	Watch	J01RA04	N	N	Y
Streptomycin	Watch	J01GA01	N	N	Y
Sulfamethoxazole/ Trimethoprim	Watch	J01EE01	Y	Y	Y
Thiamphenicol	Access	J01BA02	N	Y	Y
Tinidazole		P01AB02	N	N	Y
Trimethoprim	Access	J01EA01	Y	N	N
Vancomycin	Watch	J01XA01	Y	Y	Y
Voriconazole		J02AC03	N	N	Y

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

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AMC Data Collection Tool

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

Expired Drug and Losses Tool

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

MAAP
Mapping AMR & AMU Partnership

The Fleming Fund
Regional Grants

UKaid
from the British people

African Union

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

ASLM
AFRICAN SOCIETY FOR LABORATORY MEDICINE

ECOWAS

ECSA
HEALTH COMMUNITY

InSTEDD
Innovative Support To Emergencies Diseases and Disasters

IQVIA

ONEHEALTH
TRUST