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
ECSA Health Community
InSTEDD Innovative Support To Emergencies Diseases and Disasters
IQVIA
ONEHEALTH TRUST

Year: 2022

Sierra Leone (2016-2018)

SIERRA LEONE

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
CAPTURA	Capturing Data on AMR Patterns and Trends in Use in Regions of Asia
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
GAP-AMR	Global Action Plan on Antimicrobial Resistance
GDP	Gross Domestic Product
HIS	Hospital Information System
InSTEDD	Innovative Support to Emergencies, Diseases and Disasters
KIIs	Key Informant Interviews
LIS	Laboratory Information System
LMIC	Low-and Middle-Income Country
LQMS	Laboratory Quality Management System
MAAP	Mapping Antimicrobial resistance and Antimicrobial use Partnership
MoH	Ministry of Health
NCD	Non-Communicable Disease(s)
OR	Odds Ratio
PBSL	Pharmacy Board of Sierra Leone
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 prevent needless suffering and the reversal of medical advancements in fighting infectious diseases. A clear link has been shown between the misuse of antimicrobials and the emergence of AMR. However, owing to technological hurdles and the limited capacity of health systems, comprehensive and robust AMR, antimicrobial use (AMU) and antimicrobial consumption (AMC) data are generally lacking in many low- and middle-income countries (LMICs). Therefore, 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 the national capacity for AMR, AMC and AMU surveillance as well as the rates and trends of AMR and the flow of antimicrobials in Sierra Leone from 2016-2018.

Sierra Leone had approximately 179 laboratories in the national laboratory network during the study period, of which seven were reported to have bacteriology testing capacity. Based on self-reported information, the functioning and quality compliance practices in seven laboratories were assessed to understand laboratory preparedness for AMR surveillance.

The resistance rates presented here are based on an analysis of historical data (2016-2018). Antimicrobial susceptibility data were obtained for 723 positive cultures. However, owing to the limited amount of data, resistance rates at a national level could not be assessed for the bacterial priority pathogens that are listed by the World Health Organisation (WHO). The most reported pathogens in each study year were Staphylococcus species and Staphylococcus aureus, which were frequently tested for susceptibility to penicillins (including anti-staphylococcal penicillins), fluoroquinolones, aminoglycosides, tetracyclines and macrolides. Escherichia coli was also commonly reported in 2018 and frequently tested for susceptibility to aminoglycosides and nitrofurans.

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. AMU data were not obtained due to the lack of unique patient identifiers and tracking systems across hospital departments. National AMC data for 2016 were not obtained or analysed as the data files were improperly archived, leading to damage or loss. The average national total AMC level in Sierra Leone between 2017-2018 was 115.5 defined daily doses (DDD) per 1 000 inhabitants per day (DID), ranging from 78.3 in 2017 to 152.7 in 2018. Based on the WHO Anatomical Therapeutic Chemical (ATC) classification, penicillins with extended spectrum were the most consumed antimicrobial class in Sierra Leone (68.9% in 2017 and 38.9% in 2018), followed by tetracyclines (2.1% in 2017 and 20.5% in 2018) and combinations of sulfonamides and trimethoprim, including derivatives (1.5% in 2017 and 13.1% in 2018). The top five most consumed antimicrobials were amoxicillin, tetracycline, sulfamethoxazole/trimethoprim, ampicillin/cloxacillin and ampicillin. Together these antimicrobials accounted for 78% of the total consumption, suggesting a lack of variation. This consumption trend could potentially increase AMR.

Based on the WHO Access, Watch and Reserve (AWaRe) categorisation, 89.7% of the antimicrobials consumed in Sierra Leone were in the 'Access' category and 10.3% were in the 'Watch' category. No 'Reserve' antibiotics (0%) were consumed. Between 2017 and 2018, the use of 'Access' category antibiotics exceeded the WHO minimum recommended consumption threshold of 60%. The lack of consumption of 'Reserve' category antibiotics implied a possible unavailability of these last-resort antibiotics in Sierra Leone. Three fixed-dose combinations (FDC) of two or more broad-spectrum antibiotics that are not recommended for clinical use were consumed in Sierra Leone. Of those, the ampicillin/cloxacillin combination was the most consumed (mean DID of 5.3).

Owing to inadequate AMR data, the drug resistance index (DRI) for Sierra Leone could not be determined. The DRI represents a simple metric to convey the level of drug resistance in a country to decision-makers. A DRI score of zero is equivalent to 100% susceptibility, while a score of 100 indicates 100% resistance. Furthermore, information on patient-level factors was not available, so the drivers of AMR could not be assessed.

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

- To strengthen the delivery of services by the laboratories, we recommend that all laboratories are mapped across a range of indicators, including population coverage, infectious disease burden, testing capabilities and quality compliance. This would inform decision makers on unmet needs and decide a way forward for the expansion of the laboratory network.
- For high-quality microbiology testing and reporting, it is essential to train staff on laboratory standards, identification of common pathogens and data management. Capacity building of staff may be done by leveraging in-house expertise or may be outsourced to external organisations or tertiary facilities.
- To strengthen AMR surveillance, it is essential to curate the right data and generate evidence. We recommend the collection of data in 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 tracking patients over time.
- Due to limitations in the number of facilities assessed, MAAP, in alignment with the WHO guide on facility AMU assessment, recommends that future AMU and AMC surveillance attempts in the country be conducted through large-scale point-prevalence surveys to give a nationally representative portrait of antimicrobial use in the country.
- MAAP recommends that a comprehensive guiding policy for routine AMC data surveillance is required in the country. The policy should aim to guide on, at the minimum, AMC data reporting variables and 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 switching to electronic systems and ensuring that such systems have the capabilities to transfer data across systems and/or produce user-friendly reports on AMC.
- MAAP recommends that the country's Antimicrobial Resistance Coordinating Committee (AMRCC) should consider introducing facility-level antimicrobial stewardship programmes (ASPs) to regulate the use of 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 among the top five antibiotics in each category. Such a consumption pattern may be sub-optimal as evolutionary pressures 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 the consumption of antibiotics within each WHO AWaRe category.
- MAAP recommends an urgent review be conducted by the Ministry of Health (MoH) and the AMRCC to assess the availability of 'Reserve' category antibiotics in the country. This may subsequently lead to a 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 the 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 Southeast Asia) and aimed to expand the volume of available data on AMR and AMU.

Problem Statement

The quantum and quality of surveillance data are suboptimal in LMICs where AMR rates are typically lacking.[2] This hinders the assessment of the current treatment efficacy and an understanding of the drivers of resistance. It also 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.) that have 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 policies and stewardship activities.

MAAP

Against this background, the Regional Grant Round 1 aimed to increase the volume of data available to improve the spatiotemporal mapping of AMR and AMU across countries in each region and establish baselines. The programme was implemented by the 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, the West African Health Organisation and the East Central and Southern Africa Health Community (ECSA-HC). The technical partners were the Center for Disease Dynamics, Economics and Policy (CDDEP), IQVIA, and Innovative Support to Emergencies, Diseases and Disasters (InSTEDD). ASLM oversaw consortium activities and ensured the fulfilment of ethical considerations and the 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 between 2016 and 2018 in each country, and to understand the regional landscape. MAAP's primary focus was to determine the levels of resistance among the WHO-listed bacterial priority pathogens 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 and 2018. Based on feasibility, MAAP set out to collect information on AMC instead of AMU.

The results of this analysis will contribute to the determination of baselines and trends for AMR and AMC. The findings will also help identify AMR drivers and 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 (Burkina Faso, Ghana, Nigeria, Senegal, Sierra Leone), East (Kenya, Tanzania, Uganda), Central (Cameroon, Gabon) and Southern Africa (Eswatini, Malawi, Zambia, Zimbabwe) were included in MAAP activities.

Aim

To determine the spatiotemporal baselines and trends of AMR and AMC in Sierra Leone using available historical data

Specific Objectives

- To assess the sources and quality of historical AMR data generated routinely by the national laboratory network of Sierra Leone, including the public and private human healthcare sector
- To collect, digitise and analyse retrospective data from selected facilities using standardised electronic tools and to describe the completeness and validity of AMR data in selected facilities
- To estimate the country-level AMR prevalence and trends for WHO priority pathogens and other clinically important and frequently isolated pathogens as well as to enable spatiotemporal mapping of AMR and AMU data across countries
- To describe the in-country antimicrobial flow and highlight the status of the in-country AMC and AMU surveillance system
- To quantify and evaluate the trends of AMC and AMU at the 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 quality standards for 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 and other clinically important and frequently isolated pathogens
- A semi-quantitative analysis of the status of in-country AMC and AMU surveillance
- Total consumption of antimicrobials (DDD) in addition to AMC and AMU trends over time at the national and pharmacy levels
- Country-level DRI
- Association between patient factors and AMR

The results are intended to serve as a baseline for prospective AMR, AMC and AMU surveillance, as well as to highlight 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), the MAAP consortium (for the African region) and the CAPTURA ('Capturing Data on AMR Patterns and Trends in Use in Regions of Asia') consortium (for the Asian 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 of 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 ministries of health, AMR coordinating committees, health facilities, laboratories and pharmacies. This was followed by site selection and data collection in each country. Data analysis was done by the technical partners, and the final results were shared through dissemination meetings (Figure 1).

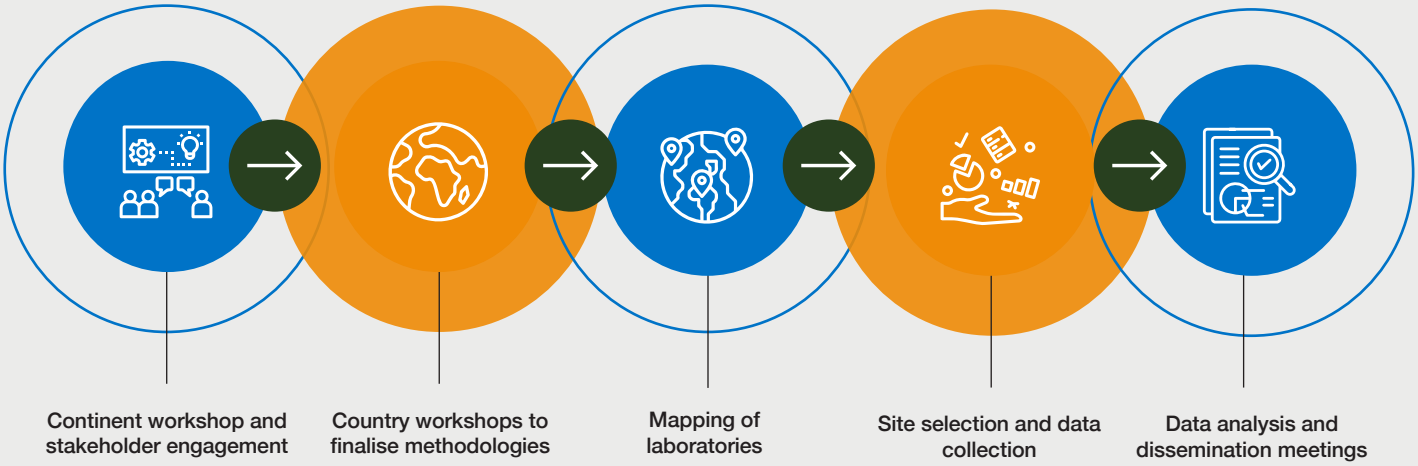


Figure 1: Key engagements and activities

Ethical issues and data sharing agreements

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

Country Profile

Health and demographic profile

As of 2020, Sierra Leone was estimated to have a population of 7.9 million inhabitants and a life expectancy of 55 years. The country has a high infectious disease burden, with a TB incidence of 298 per 100 000 people and an HIV prevalence of 1.5%. The country has a physicians density of 0.07 per 1 000 inhabitants and a nurses density of 0.75 per 1 000 inhabitants. With a universal health coverage index of 39, Sierra Leone appears to have a below-average coverage of essential services (Table 1).

Table 1: Health and demographic profile of Sierra Leone

	Sierra Leone		Comparator values (most recent year)*		
	Year	Value	India	Argentina	United States
Population	2020	7 976 985	1 380 004 390	45 376 763	329 484 123
Life expectancy during the study period, total (years)	2019	55	70	77	79
Universal health coverage service index (0-100)	2019	39	61	67	83
GDP per capita (current US$)	2020	509.38	1 927.7	8 579.0	63 593.4
Immunisation, DPT (% of children ages 12-23 months)	2019	95	91.0	86.0	94.0
Incidence of tuberculosis (per 100 000 people)	2020	298	188.0	31.0	2.4
Prevalence of HIV, total (% of population ages 15-49)#	2020	1.5	0.2*	0.4 2020	0.4 2019
Primary education (%)#	2020	87.19	94.6	98.6	100
Physicians density (physicians per 1 000)#	2018	0.07	0.93	4.0	2.6
Nurses density (nurses and midwives per 1 000)#	2018	0.75	2.39	2.60	15.69

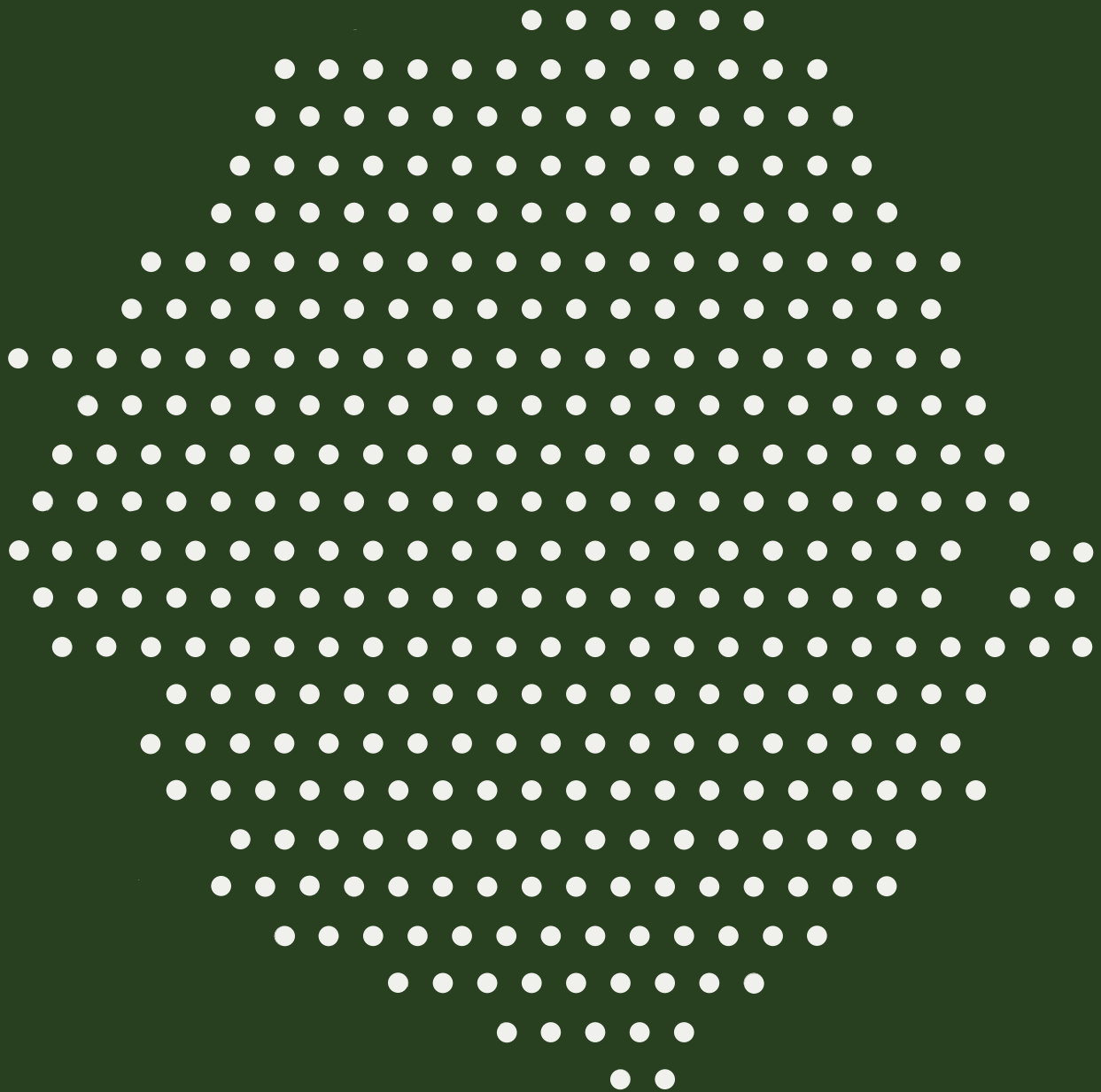
Sourced from World Bank[4,5,6] and *National AIDS Control Organisation[7]
Data for some country parameters may not necessarily be of the same year (but sourced from the most recently available information between 2017-2020).

Policy frameworks

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

Sierra Leone is currently not enrolled in GLASS. Recognising the urgency for combating AMR in the country, Sierra Leone put in place an inter-sectoral AMR Working Group in 2017 that developed a National Strategic Plan on AMR (2016-2020)[10] based on the objectives of the GAP-AMR and the Food and Agricultural Organisation Action Plan on AMR. This plan has a multidimensional and all-inclusive strategy based on the One Health approach that aims to consolidate all efforts in the fight against AMR in the country.

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 Sierra Leone, 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 AMR data collection. Ultimately, only those laboratories most likely to guarantee the highest level of data quality were selected. Country-specific circumstances as well as 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 questionnaire was administered to the identified laboratories to obtain site-specific details and assess the laboratories on five aspects: status of commodities and equipment, quality management systems (QMS), personnel and training, specimen management, and laboratory information systems (AMR Appendix 2). Based on self-reported information on the above parameters, each laboratory was assigned a readiness score for AMR surveillance (AMR Appendix 3). The scoring scheme was standardised across all participating countries. The final selection of laboratories for data collection was made by the MoH and was not necessarily based on laboratory rankings.

Results

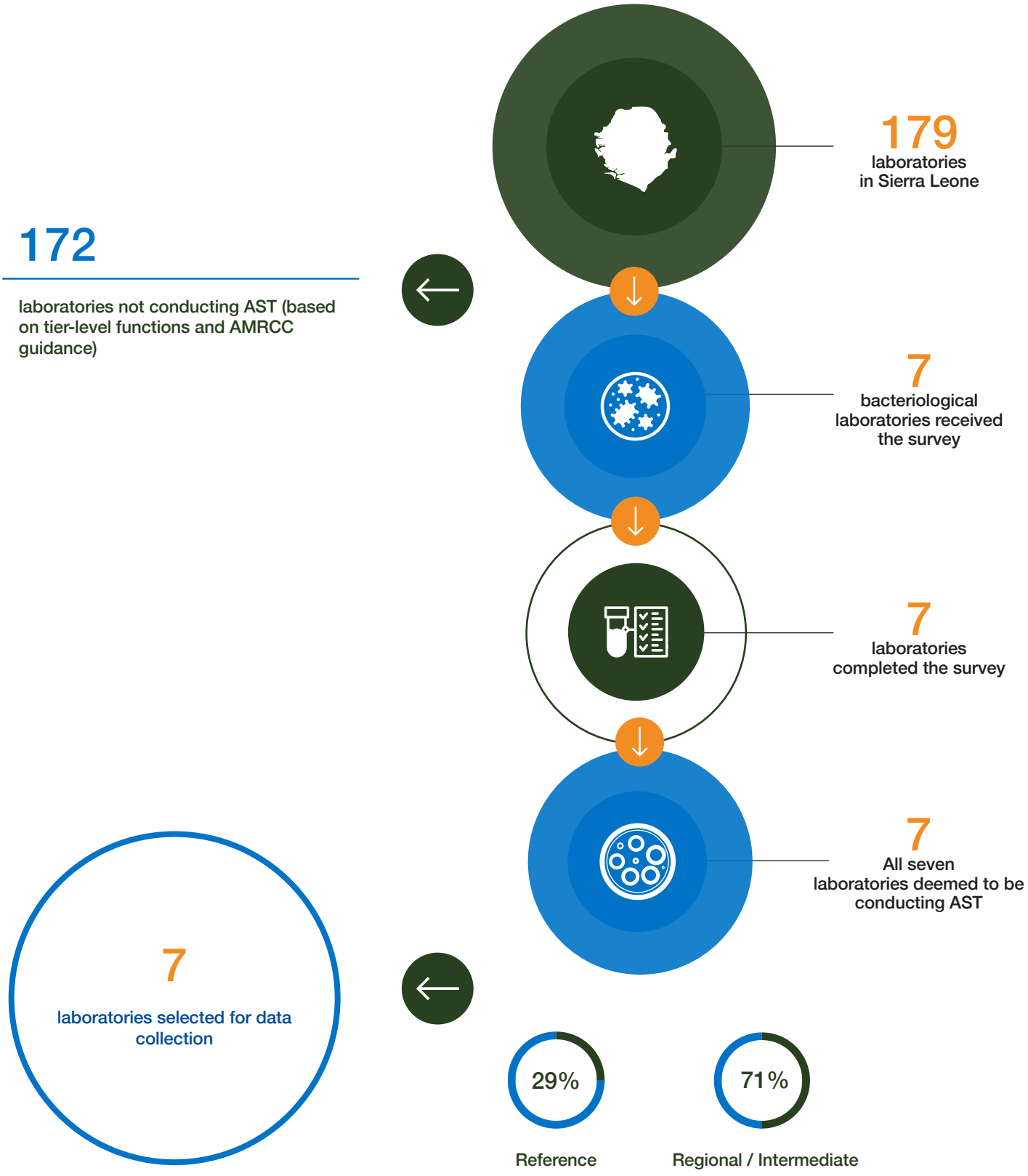
Mapping and selection of laboratories

During the initial stages of in-country work in Sierra Leone, 179 laboratories were mapped to the national laboratory network. An eligibility questionnaire was sent to seven laboratories identified as having bacteriology testing capacity. Of the seven laboratories, the majority were affiliated with the government (Table 2, Supplementary Table 1). The laboratory readiness scores of the surveyed laboratories varied widely (range: 28.9-92.1%). All seven laboratories were selected for data collection (Figure 2).

Table 2: Laboratory readiness scores of surveyed laboratories in Sierra Leone

Surveyed laboratories*	Laboratory readiness score (%)	Level of service	Affiliation
Selected			
National TB Reference Laboratory Lakka	92.1	Reference	Government
Kenema Government Hospital Clinical Referral Laboratory	81.6	Regional/Intermediate	Government
ODCH/PCMH Laboratory	68.4	Regional/Intermediate	Government
Ramsy Medical Laboratory	60.5	Regional/Intermediate	Private
34 Military Hospital Laboratory	60.5	Regional/Intermediate	Government
Bo Government Hospital Regional Laboratory	52.6	Regional/Intermediate	Government
Connaught Laboratory	28.9	Reference	Government

** Laboratory names are abbreviated. The laboratories are listed in order of decreasing laboratory readiness scores*



Abbreviations: AST=antibiotic susceptibility testing; AMRCC=antimicrobial resistance coordinating committee

Figure 2: Selection of laboratories in Sierra Leone

Surveillance preparedness of surveyed laboratories

Based on the self-reported information from the seven laboratories, we assessed their laboratory functions and quality compliance practices to understand their preparedness for AMR surveillance. Six laboratories had implemented a QMS and had at least one qualified microbiologist on board. Three laboratories were accredited and two used automated methods for pathogen identification (Figure 3, Supplementary Table 2). Since these findings may affect the quality of laboratory data, the AMR rates presented in this report should be interpreted with caution.

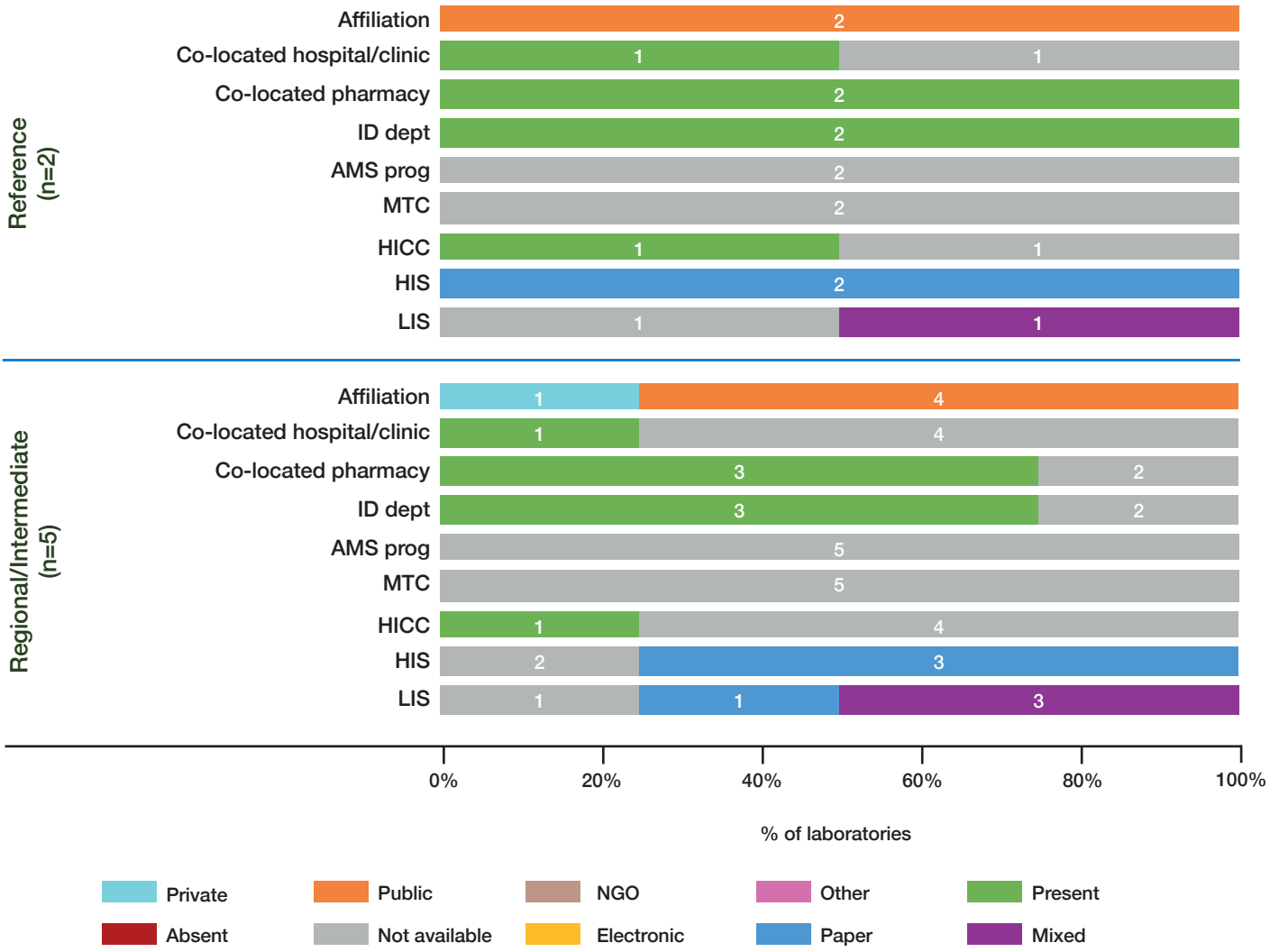
	Parameters			N (%)
Commodity and equipment status	Regular power supply and functional back up			6 (85.7)
	Continuous water supply)			5 (71.4)
	Certified and functional biosafety cabinets			4 (57.1)
	Automated methods for pathogen identification			2 (28.6)
	Automated methods for AST			1 (14.3)
	Methods for testing AMR mechanisms			3 (42.9)
QMS implementation	Reported QMS Implementation			6 (85.7)
		Types of QMS	LQMS	1 (16.7)
			SLIPTA	2 (33.3)
			SLMTA	0
			Mentoring	
			Combination‡	1(16.7)
			Others	2 (33.3)
	Quality Certification			3 (42.9)
		Types of Quality certification	SLIPTA	2 (66.7)
			Col. of Am. Path	0
			Others	1 (33.3)
	Accreditation			3 (42.9)
	Participation in proficiency testing			5 (71.4)
	Utilisation of reference strains			6 (85.7)
	Reported consistent maintenance of QC records			6 (85.7)
	Designated focal quality person			7 (100.0)
	Reported compliance to standard operating procedures			7 (100.0)
	Reported compliance to AST standards			4 (57.1)
Personnel and training status	Presence of at least one qualified microbiologist			6 (85.7)
	Presence of an experienced laboratory scientist/technologist			7 (100.0)
	Up-to-date and complete records on staff training and competence			5 (71.4)
Specimen Management status	Reported compliance to SOPs on specimen collection and testing			7 (100.0)
	Reported compliance to SOPs on specimen rejection			6 (85.7)
	Average number of specimens processed for AST in 2018			6 (85.7)
LIS and Linkage to Clinical Data	Assigned specimen (laboratory) identification number			7 (100.0)
	Availability of system/database to store patient data			5 (71.4)
		Database format	Paper-based	1 (20)
			Electronic	0
			Mixed	2 (40)
			Other	2 (40)
	Captured patients' records on test request forms			6 (85.7)
			Retrievable	4 (66.7)

‡ Combination refers to more than one option presented in the questionnaire (laboratory quality management system, stepwise laboratory improvement process towards accreditation, strengthening laboratory management towards accreditation, and mentoring).
Abbreviations: AMR=antimicrobial resistance; AST=antibiotic susceptibility testing; LIS=laboratory information system; LQMS=laboratory quality management system; QC=quality control; QMS=quality management system; SLIPTA=Stepwise Laboratory Improvement Process Towards Accreditation; SLMTA=Strengthening Laboratory Management Towards Accreditation; SOP=standard operating procedure

Figure 3: Laboratory preparedness for AMR surveillance

Profile of Selected Laboratories

Out of the seven selected laboratories, five were co-located with clinical facilities. Information on the presence of infectious disease departments, ASPs, medical therapeutic committees and hospital infection control committees was largely unavailable. Most of the laboratories had mixed (paper and electronic) information systems while most of the hospitals had paper-based information systems (Figure 4).



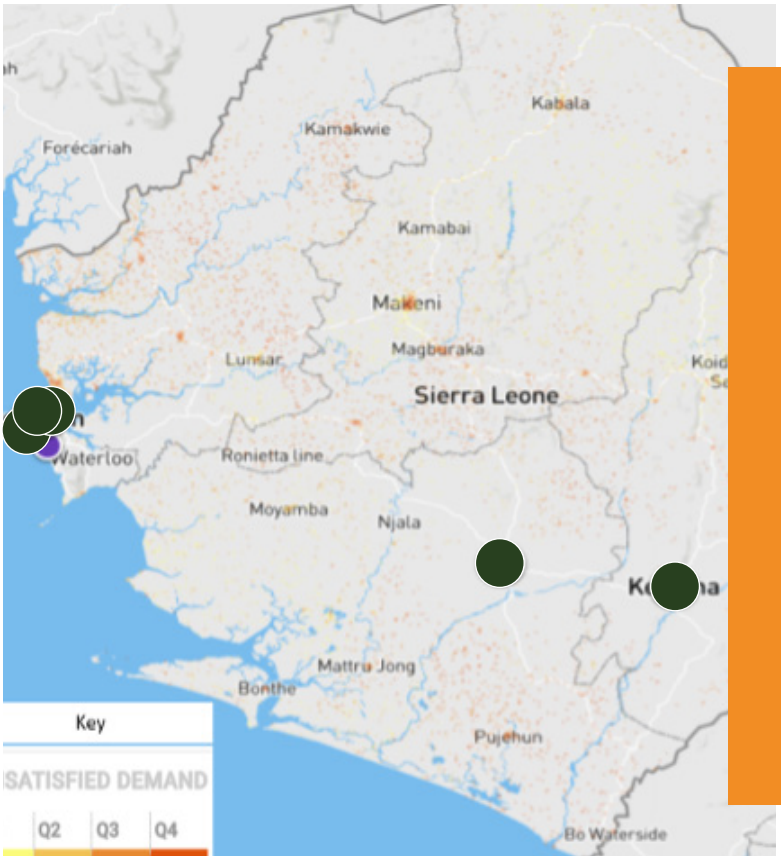
Abbreviations: AMS prog=antimicrobial stewardship programme; HICC=hospital infection control committee; HIS=hospital information system; ID dept=infectious diseases department; LIS=laboratory information system; MTC=medical therapeutics committee

Figure 4: Profile of selected laboratories

Population coverage of laboratories

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

As of 2020, Sierra Leone had an estimated population of 7.977 million.



Population coverage of laboratory services is defined as the catchment population living within one-hour travel (by car or foot) from the testing laboratory. It is represented in grey on the map. The analysis assumes that the laboratory has sufficient testing capacity to serve the entire population within the catchment area. By definition, the population outside the catchment area of the facilities represents the overall unmet need. For ease of use, the unit of unmet need is represented on the map as 'pixels', i.e., the lowest base unit of a raster image. 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 people living in the 'pixel'. The ranking is then divided into quartiles made of equal population fractions (from Q1 [lowest population density] to Q4 [highest density]), with each fraction corresponding to a different colour (from yellow [Q1] to dark red [Q4]). Therefore, the colours on the map correspond to the level of unmet need (people not within the reach of a facility) relative to the whole population.

Supplementary Figure 1: Population coverage of AST laboratories in Sierra Leone

In Sierra Leone, 29% of the catchment population live within one hour of the seven participating AMR surveillance sites. Hence, 71% of the population is not covered at all by the existing facilities. To increase the population coverage, new capacity should be introduced (either by upgrading an existing laboratory to start providing services or by constructing a new laboratory) in regions in dark red (Q4), 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 patients' culture (laboratory) results, clinical information and antimicrobial usage (AMR Appendix 4). For all positive blood and cerebrospinal fluid (CSF) cultures, information on the patient's demographics, clinical profile and antimicrobial usage was also collected from clinics and hospitals. However, this was possible only where patient records could be tracked between the laboratories and hospitals (Figure 5). Additionally, data on AMC were collected at the facility and national levels.

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 WHONET[14] and the specially developed MAAP tool for the secure transfer of collected data.

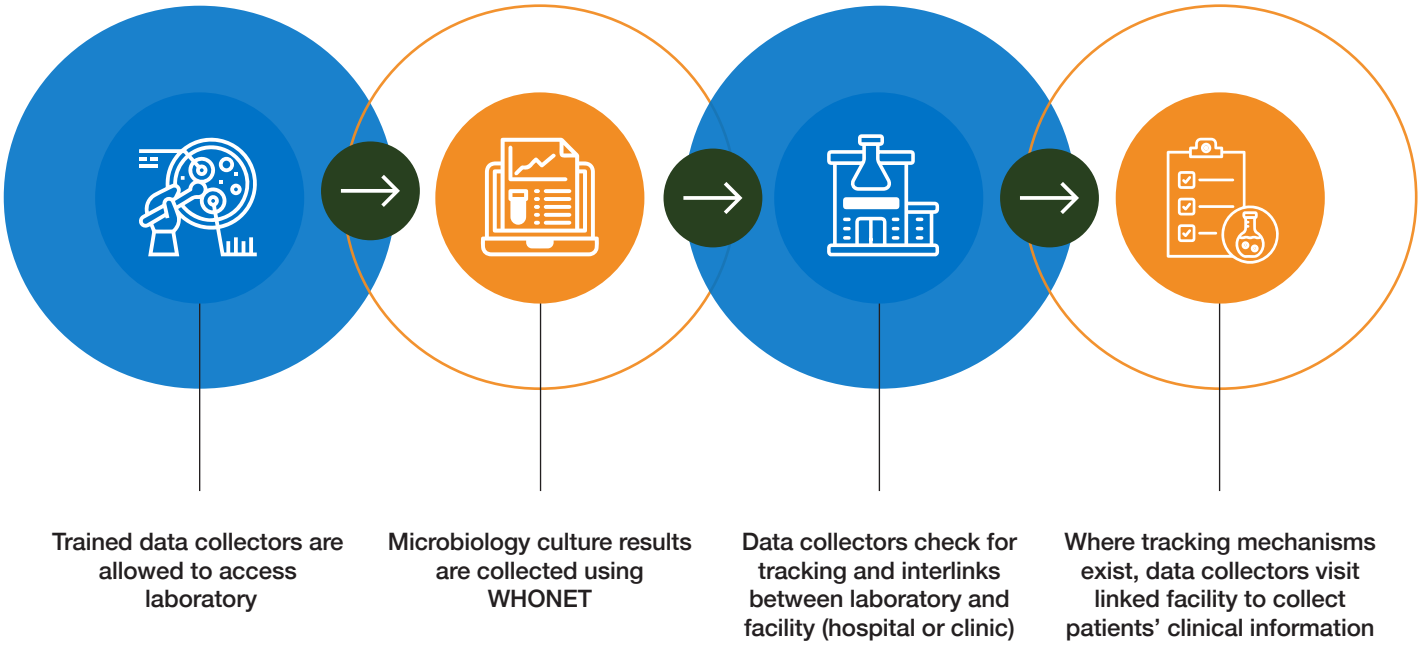


Figure 5: Steps for AMR data collection

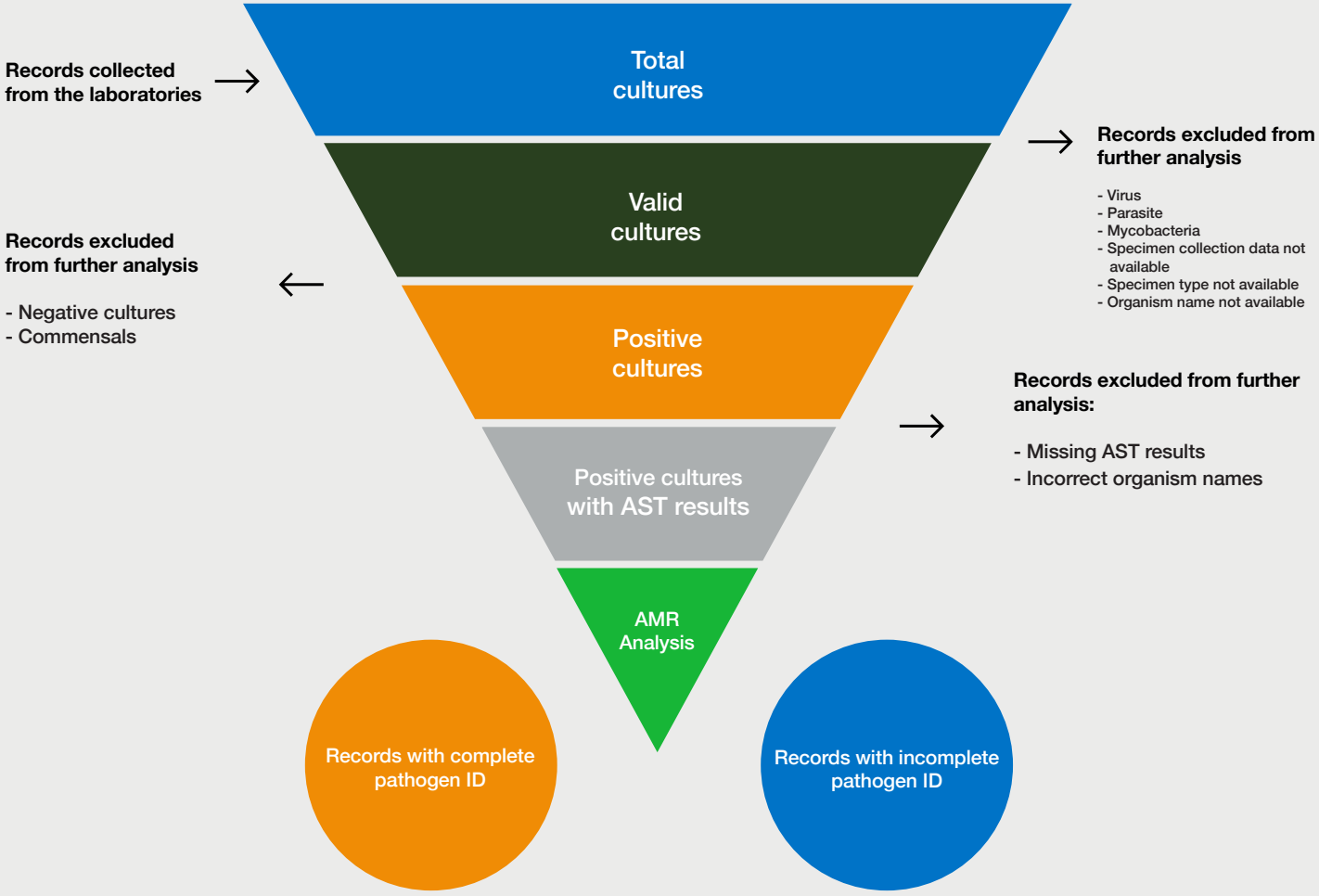
Historical data were collected for the period between 1 January 2016 and 31 December 2018. The AMR data were initially captured using WHONET, a free Windows-based database software developed for the management and analysis of microbiology laboratory data. The software allowed data entry of clinical and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

Figure 6: Data collection at a Sierra Leonean 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 the subset of total cultures that had complete information on 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; reporting at a species level indicated complete pathogen identification. Data were stratified for each laboratory and assessed over the entire study period.



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

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 assessed for each study year.
- **Inappropriate testing:** Positive cultures with AST results were assessed for compliance with AST standards. However, a comprehensive assessment of the validity of AST results was beyond the scope of the study. Data were pooled across laboratories and assessed for each study year. The conventional AST standards are those provided by the Clinical and Laboratory Standards Institute (CLSI), the European Committee on Antimicrobial Susceptibility Testing (EUCAST) and the Comité de l'antibiogramme de la Société Française de Microbiologie-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 devices and antimicrobial use. Data were quantified for each laboratory and assessed over the entire study period.
- **Specimen characteristics:** Positive cultures with AST results were summarised based on information on specimen types. Data were pooled across all laboratories and assessed for each study year.
- **Quality of data:** We used the level of pathogen identification as a parameter to evaluate the data quality from each laboratory seeing as a complete identification of pathogens is key in AMR surveillance and speaks to the quality of the laboratory's testing practices. Scoring was based on quartiles of the proportion of completely identified pathogens. Laboratories that identified >75% of pathogens identified to the species level were awarded the highest score (4), while those that identified less than 25% received the lowest score (1) (Table 3). First, the scoring was performed per year (i.e., 2016–2018), and then the average was assigned as the laboratory data quality score for each laboratory.

Table 3: Data scoring scheme

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

Seeing as we pooled all the data to obtain AMR rates at a national level, we computed a single metric to estimate the overall quality of data received from the 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.

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 laboratories and *i* represents individual laboratories.

Results

Retrospective data from 2016–2018 were collected from seven laboratories and their corresponding facilities in Sierra Leone.

1. Quantum of cultures and level of pathogen identification

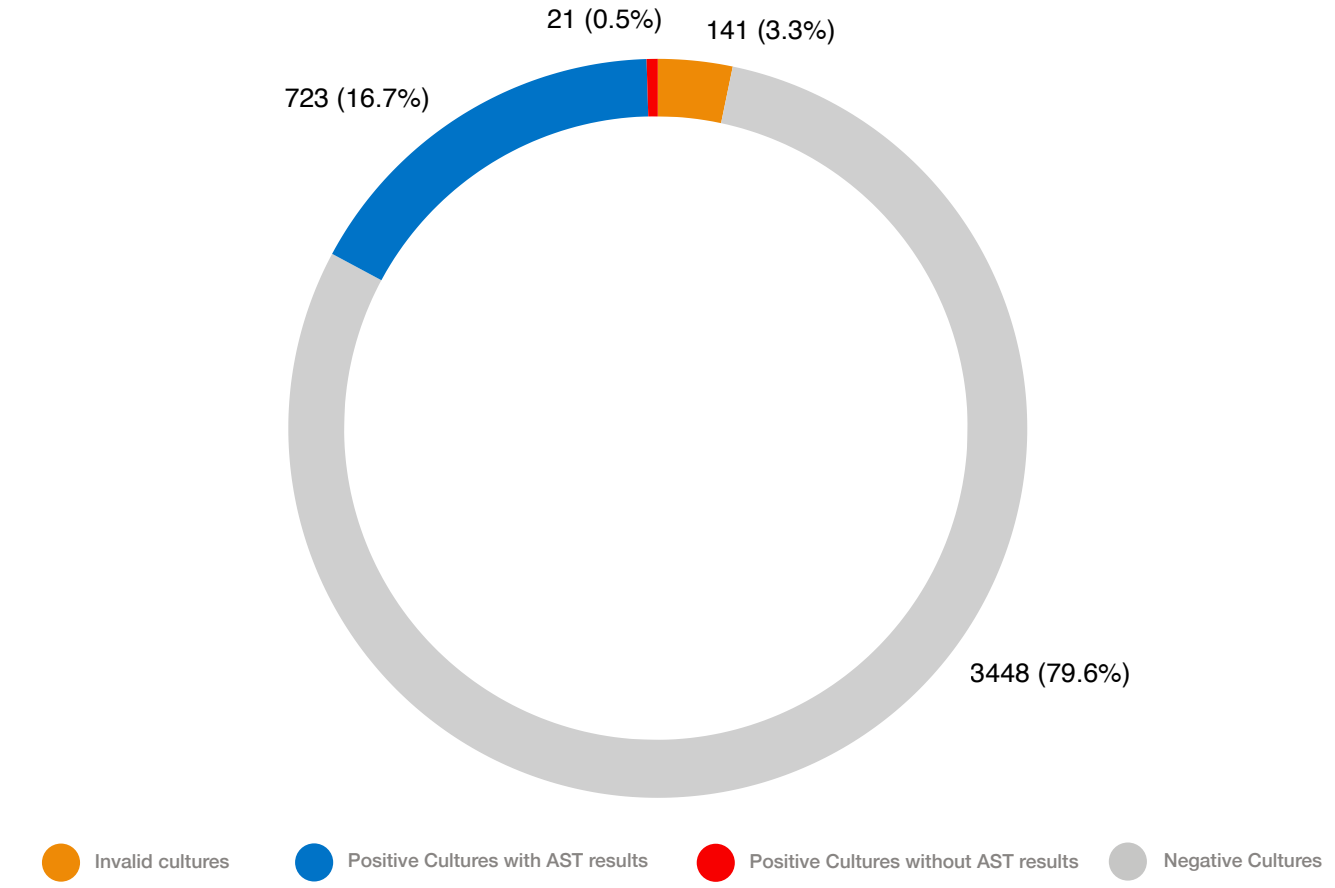
Data were retrieved for 4 333 total cultures, of which 4 192 were valid and 744 were positive. Of the positive cultures, AST results were available for 723 positive cultures, with the maximum (n=539) coming from Ramsy and the least (n=6) from Bo (Figures 8 and 9). Not all pathogens were identified completely (i.e., at the species level). Military had the highest proportion (61.1%) of completely identified isolates, while Bo (33.3%) had the lowest (Table 5).

Table 5: Summary of data retrieved from selected facilities in Sierra Leone, 2016-2018

Variable (Columns) / Laboratory (Rows)	Total cultures N = 4 333	Valid cultures N = 4 192	Positive cultures N = 744	Positive cultures with AST results N = 723	Incomplete identity* N = 546	Complete identity* N = 177
Lakka	198	86 (43.4)	-	-	-	-
Kenema	92	92.0 (100.0)	38 (41.3)	38 (100.0)	21 (55.3)	17 (44.7)
ODCH	99	89.0 (89.9)	31 (34.8)	31 (100.0)	14 (45.2)	17 (54.8)
Military	197	196.0 (99.5)	96 (49.0)	95 (99.0)	37 (38.9)	58 (61.1)
Ramsy	3659	3 643.0 (99.6)	559 (15.3)	539 (96.4)	463 (85.9)	76 (14.1)
Bo	41	41.0 (100.0)	6 (14.6)	6 (100.0)	4 (66.7)	2 (33.3)
Connaught	47	45.0 (95.7)	14 (31.1)	14 (100.0)	7 (50.0)	7 (50.0)

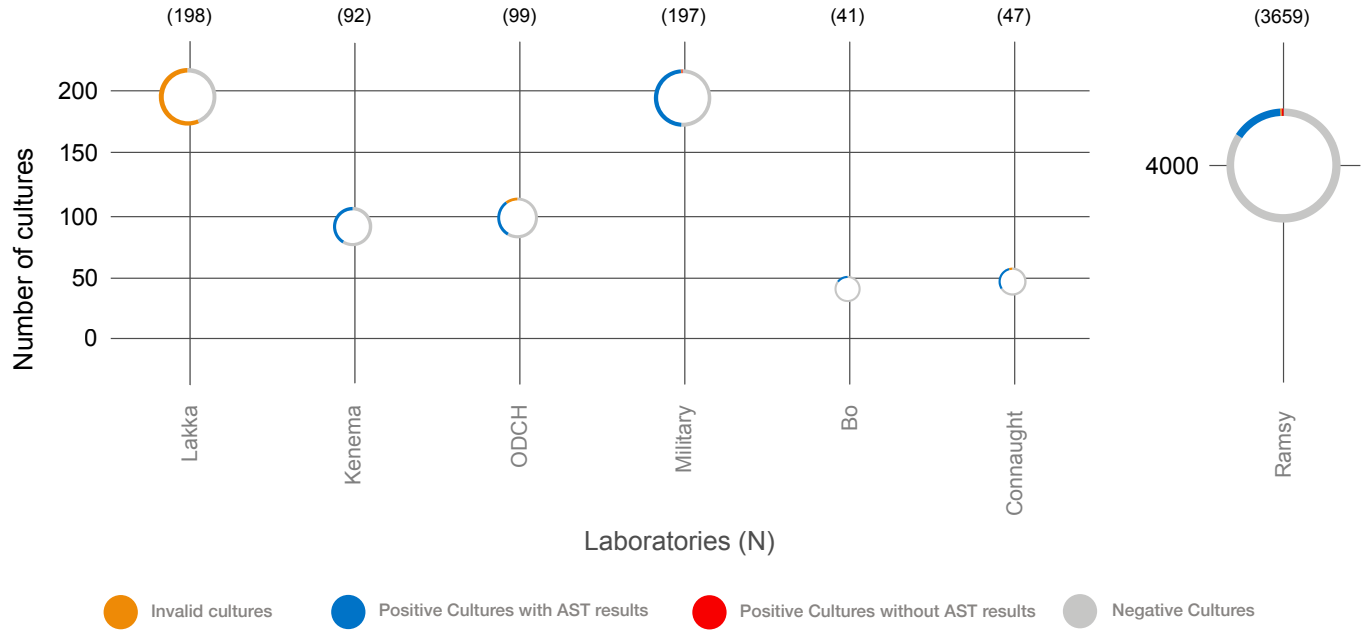
* Subsets of the category 'Positive cultures with AST results' where 'incomplete' includes cultures with only Gram- or genus-level identification and 'complete' includes cultures with species-level identification; — information not available

Abbreviations: AST=antibiotic susceptibility testing



Abbreviations: AST=antibiotic susceptibility testing

Figure 8: Quantum of cultures across all selected laboratories in Sierra Leone, 2016-2018



Abbreviations: AST=antibiotic susceptibility testing

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

2. Culture characteristics

Bacterial pathogens (720) were more commonly reported than fungal pathogens. Information on age was missing for 87.3% of cultures, but where available, the data showed a median age of 25 years (range: 0–90 years). Female patients (483) contributed more to the quantum of positive cultures with AST results. More data came from 2017 (344) than from other years (Table 6, Supplementary Table 3).

Table 6: Characteristics of positive cultures with antimicrobial susceptibility testing results in selected laboratories in Sierra Leone, 2016-2018

Characteristics	Positive cultures with AST results n=723 n (%)
Gender	
Male	240 (33.2)
Female	483 (66.8)
Age, years	
Less than 1	1 (0.1)
1 to 17	23 (3.2)
18 to 49	53 (7.3)
50 to 65	6 (0.8)
Above 65	9 (1.2)
Unknown age	631 (87.3)
Years	
2016	109 (15.1)
2017	344 (47.6)
2018	270 (37.3)
Pathogen	
Bacteria	720 (99.6)
Fungi	3 (0.4)

3. Inappropriate testing

The selected laboratories reported complying with the CLSI standards for AST testing. However, during the review of AST results, the following instances of inappropriate testing were noted:

- The activity of fluconazole was tested against bacterial isolates (Supplementary Figure 2a)
- The activity of cloxacillin was tested against S. aureus isolates (Supplementary Figure 2b)
- AST was performed when pathogens were identified based on their Gram reactions

4. Clinical information

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

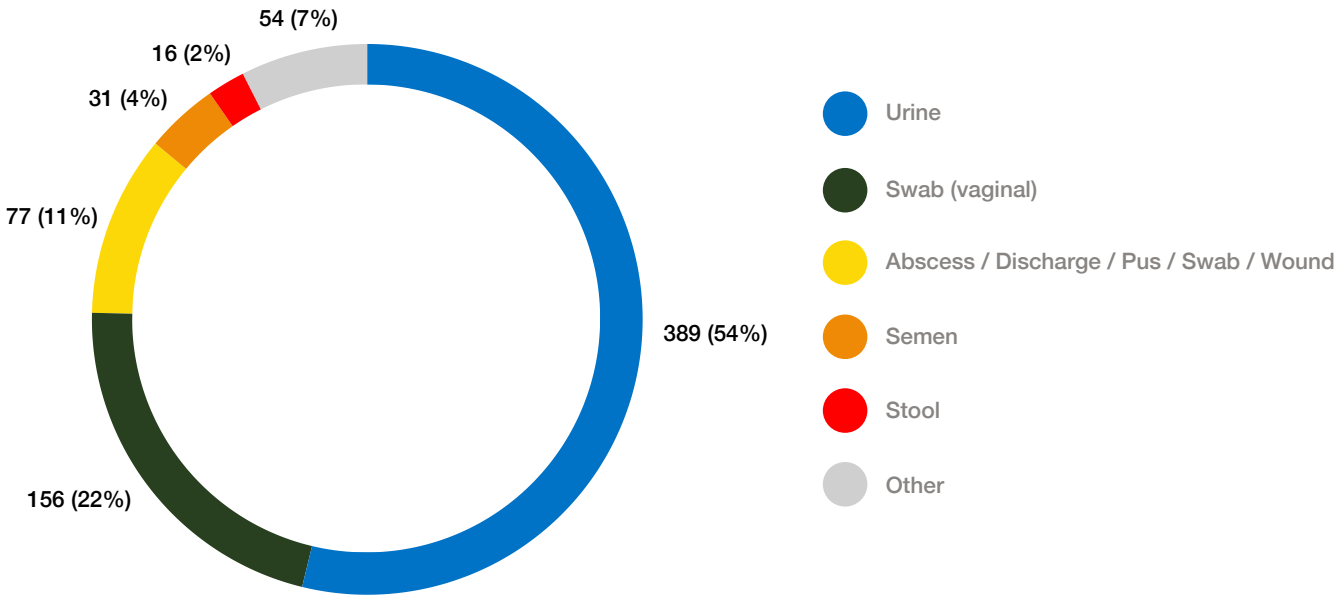
Table 7: Clinical information of patients in selected facilities in Sierra Leone, 2016-2018

Laboratory	Positive cultures with AST results N=723	Diagnosis data	Infection origin data*	Indwelling device data	AMU data
Lakka Lab	-	-	-	-	-
Military Lab	95	-	-	-	-
Kenema Lab	38	-	-	-	-
ODCH Lab	31	-	-	-	-
Bo Lab	6	-	-	-	-
Ramsy Lab	539	-	-	-	-
Connaught Lab	14	-	-	-	-

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

5. Specimen characteristics

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



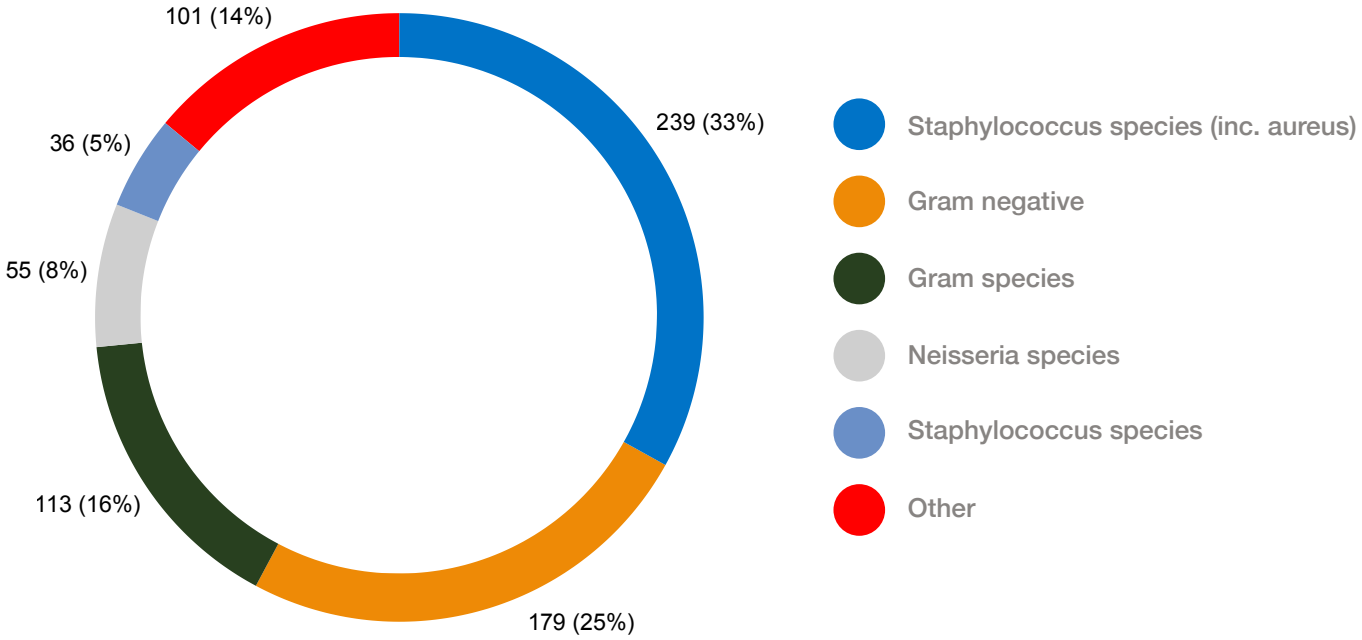
* Others include all other specimens excluding the top 5 mentioned here

Figure 10: Specimen distribution of positive cultures at selected facilities in Sierra Leone, 2016-2018

6. Identified pathogens

Staphylococcus species (33%) made up a substantial proportion of the positive cultures. In addition, many pathogens were reported solely based on Gram staining results (Figure 11).

In 2016, of the 109 positive cultures with AST results, Staphylococcus species (69%) were the most reported. In 2017, out of 344 cultures, 32% were Staphylococcus species. In 2018, information was available for 270 cultures, of which 19% were Staphylococcus species (Supplementary Table 5)



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

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

7. Quality of data

The country data quality score of the 4 192 valid culture records obtained from the 16 laboratories in Sierra Leone was 1.4, corresponding to a 'poor' rating 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 and to enable spatiotemporal mapping of AMR data across countries.

Methodology

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

Estimation of AMR rates

In this report, the AMR rate is the extent to which a pathogen is resistant to a particular antimicrobial agent or class, determined by the proportion of non-susceptible isolates (i.e., either intermediate or resistant) over a 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 pathogens[15] 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:

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

Removal of duplicate records

Before AMR rates were calculated, duplicate AST results were removed such that only the results of the first pathogen isolated from each 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.[16,17] The removal of duplicates 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 the AMR rates were calculated as the proportion of non-susceptible isolates.

AMR estimates statistics

Confidence intervals (CIs) at a 95% level of confidence were calculated to quantify the uncertainty in the estimated resistance rates. Typically, CIs for AST data have been constructed using the Wilson score method, which is a binomial calculation that assumes that all samples are independent.[18] However, there may be 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.[19]

The 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. Validation of the AST results was beyond the scope of the study, so data were taken at face value for the 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 and secure portal (CDDEP's ResistanceMap Surveillance Network [RSN]) for countries and laboratories to permit the analysis of their data at the patient level. RSN provides a simple approach to analysing AMR data. The 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 time or as line graphs showing changes over time (by month or year). Following the completion of the study, RSN will be made available for at least one year to each participating country for at least one year.

Data were also uploaded to CDDEP's ResistanceMap platform, a publicly available repository of aggregated country-level data.[20] The spatiotemporal analysis of the combined AMR and AMC-AMU datasets was built on the ResistanceMap framework. Current capabilities include the visualisation of maps, trendline 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 non-susceptible isolates over each one-year interval. The available data were insufficient to generate AMR rates and trends (Table 8). Statistics for vancomycin-resistant and intermediate Staphylococcus species and Staphylococcus aureus were also not included.

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

Pathogen	Antibiotic, class	2016				2017				2018			
		N	n (%)	95% CI	Labs* (range)	N	n (%)	95% CI	Labs* (range)	N	n (%)	95% CI	Labs* (range)
A. baumannii	Carbapenems	-	-	-	-	-	-	-	-	-	-	-	-
P. aeruginosa	Carbapenems	-	-	-	-	-	-	-	-	1	-	-	1 (1)
Enterobacter ales	Carbapenems	-	-	-	-	-	-	-	-	7	1	-	1 (7)
Enterobacter ales	Cephalosporins (3rd generation)	-	-	-	-	3	2	-	1 (3)	22	15	-	5 (1 - 9)
E. faecium	Vancomycin	-	-	-	-	-	-	-	-	-	-	-	-
H. influenzae	Ampicillin	-	-	-	-	-	-	-	-	-	-	-	-
H. pylori	Clarithromycin	-	-	-	-	-	-	-	-	-	-	-	-
N. gonorrhoeae	Cephalosporins (3rd generation)	-	-	-	-	1	-	-	1 (1)	1	-	-	1 (1)
N. gonorrhoeae	Fluoroquinolones	5	-	-	2 (1 - 4)	17	10	-	1(17)	1	-	-	1 (1)
Campylobacter species	Fluoroquinolones	-	-	-	-	-	-	-	-	-	-	-	-
Salmonella species	Fluoroquinolones	-	-	-	-	-	-	-	-	1	-	-	1 (1)
Shigella species	Fluoroquinolones	-	-	-	-	-	-	-	-	2	2	-	1 (2)
S. aureus	Methicillin	26	20	-	2 (2 - 24)	5	2	-	2 (2 - 3)	8	7	-	3 (2 - 3)
S. pneumoniae	Beta-lactam combinations	1	1	-	1 (1)	5	3	-	1 (5)	1	1	-	1 (1)
S. pneumoniae	Penicillins	-	-	-	-	1	1	-	1 (1)	-	-	-	-

N = number of tested isolates; n = number of non-susceptible isolates; n% and 95%CI are shown only if there are >30 isolates per year; — information not available; * contributing laboratories and range of tested isolates; for pathogens with the suffix 'species', all isolates of the same genus are grouped as one entity

(ii) AMR rates for other pathogens of clinical importance

AST data from blood and CSF isolates were insufficient for further analysis (Table 9).

Table 9: AMR rate estimates for other clinically important pathogens in Sierra Leone, 2016-2018*

		2016				2017				2018			
Pathogen	Antibiotic, class	N	n (%)	95% CI	Labs# (range)	N	n (%)	95% CI	Labs# (range)	N	n (%)	95% CI	Labs# (range)
Acinetobacter species	Carbapenems	-	-	-	-	-	-	-	-	-	-	-	-
Acinetobacter species	Lipopeptides	-	-	-	-	-	-	-	-	-	-	-	-
Enterococcus species	Aminoglycosides (high level)	-	-	-	-	-	-	-	-	-	-	-	-
Enterococcus species	Vancomycin	-	-	-	-	-	-	-	-	-	-	-	-
H. influenzae	Ampicillin	-	-	-	-	-	-	-	-	-	-	-	-
H. influenzae	3rd generation cephalosporins	-	-	-	-	-	-	-	-	-	-	-	-
Klebsiella species	Carbapenems	-	-	-	-	-	-	-	-	-	-	-	-
Klebsiella species	Cephalosporins (3rd generation)	-	-	-	-	-	-	-	-	-	-	-	-
N. meningitidis	Ampicillin	1	1	-	1 (1)	1	1	-	1 (1)	-	-	-	-
N. meningitidis	Cephalosporins (3rd generation)	-	-	-	-	-	-	-	-	-	-	-	-
Pseudomonas species	Carbapenems	-	-	-	-	-	-	-	-	-	-	-	-
Pseudomonas species	Lipopeptides	-	-	-	-	-	-	-	-	-	-	-	-
Salmonella species	Fluoroquinolones	-	-	-	-	-	-	-	-	-	-	-	-
Salmonella species	Macrolides	-	-	-	-	-	-	-	-	-	-	-	-
Salmonella species	3rd generation cephalosporins	-	-	-	-	-	-	-	-	-	-	-	-
Staphylococcus aureus	Methicillin	-	-	-	-	-	-	-	-	-	-	-	-
Staphylococcus species (Excluding aureus)	Methicillin	-	-	-	-	-	-	-	-	-	-	-	-
S. pneumoniae	Penicillins	-	-	-	-	1	1	-	1 (1)	-	-	-	-
S. pneumoniae	Beta-lactam combinations	-	-	-	-	-	-	-	-	-	-	-	-
S. pneumoniae	Macrolides	-	-	-	-	1	1	-	1 (1)	-	-	-	-
S. pneumoniae	Vancomycin	-	-	-	-	-	-	-	-	-	-	-	-

* Isolates were from blood and cerebrospinal fluid; N = number of tested isolates; n = number of non-susceptible isolates; 95% CI are shown only if there are >30 isolates per year; # contributing laboratories and range of tested isolates; — information not available; for pathogens with the suffix 'species', all isolates of the same genus are grouped as one entity

(iii) AMR rates for highly resistant pathogens

Data were insufficient to estimate AMR rates for highly resistant pathogens.

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, use of medical devices (catheter, central line, ventilator) and origin of infection (hospital- or community-acquired)
- Country-level factors: global health security index scores on AMR prevention, primary education, gross domestic product (GDP) per capita, density of physicians and nurses, disease prevalence and antibiotic consumption in DID (the country-level associations are presented separately at a regional or continental level)

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

Statistical analysis

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

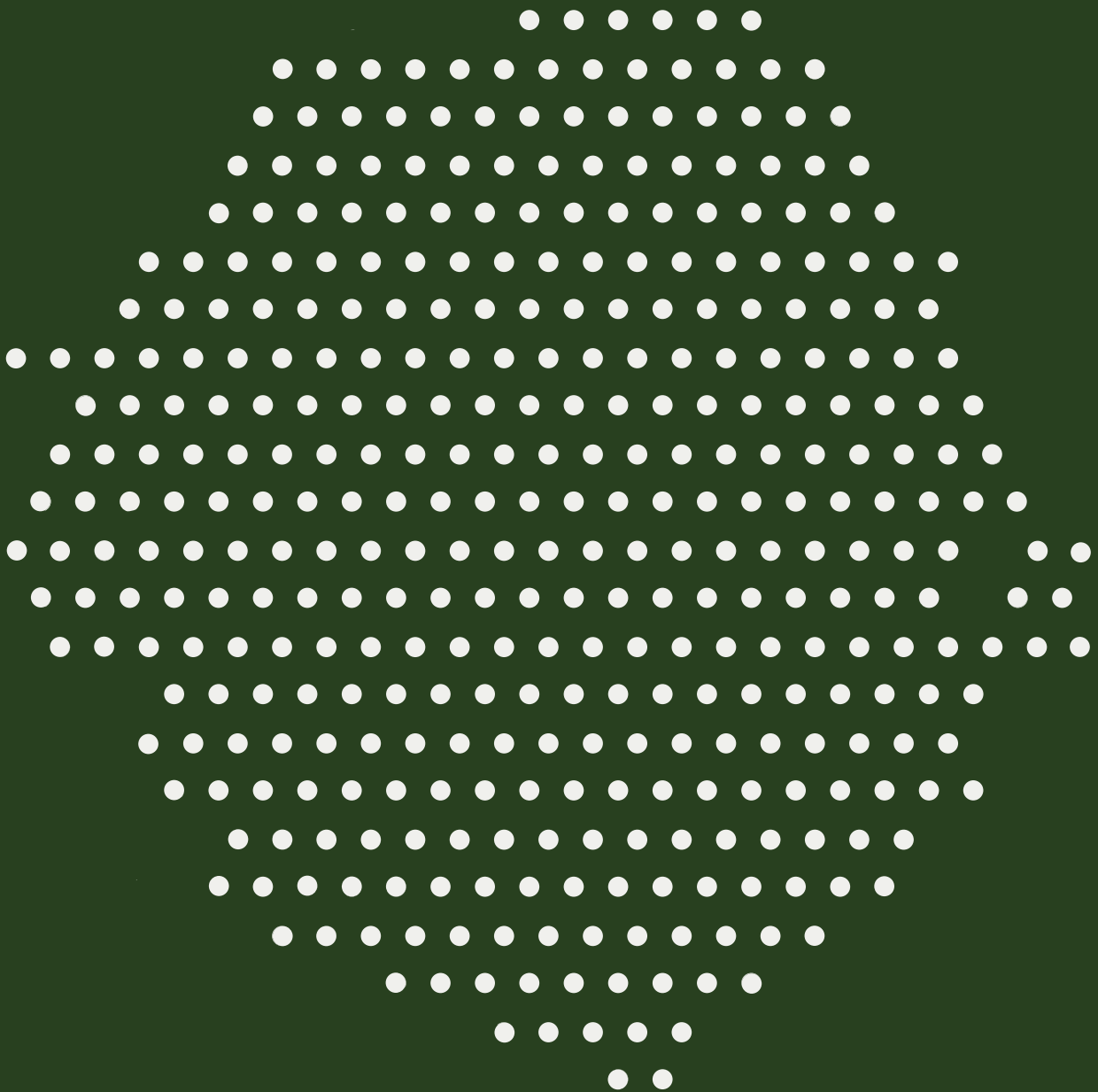
To explore the association between country factors (continuous variables) and AMR, a Pearson's correlation analysis was performed and reported at the continental level.

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

Results

The associations between AMR and patient-level factors were not assessed because of insufficient AMR data as well as a lack of information on patient-level factors. Owing to insufficient AMR data, country-level factors driving AMR were also not assessed.

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 antimicrobial usage exerts selective pressure by inhibiting the growth of some microorganisms, thus accelerating the development of AMR.[21,22] Therefore, monitoring how antimicrobials are utilised is a key step for stewardship programmes to stem AMR. The surveillance mechanisms recommended by the WHO include the monitoring of AMC and AMU. This is in line with MAAP's aims to expand the volume of AMR and AMC data presently available across Africa as well as Sierra Leone's National Strategic Plan for combating AMR.[10]

Definition of AMC and AMU

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

Link between the antimicrobial usage and AMR

The unwarranted use of antimicrobials contributes to the development of AMR and explains the link or association between AMU and AMR. This association implies that a reduction in the unnecessary consumption of antimicrobials could in turn affect resistance rates.[21] The inappropriate use of antimicrobials refers to the use of the wrong type of antimicrobial and/or at the wrong dose, frequency 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 due to improved access and increased economic strength within some of these countries. However, AMR can also develop because of a lack of access to antimicrobials, leading to the prolonged use of specific antimicrobials over a long time. The resulting selective pressure favours the proliferation of microbes that are resistant to these predominantly used antimicrobials. This is often the picture in LMIC settings where inequities in access to antimicrobials persist.[24]

This complicated picture demonstrates the need for the research and development of new agents that counteract emerging AMR, as well as the need to ensure that the available antimicrobials are accessible and used appropriately. To obtain a comprehensive picture of the link between AMU or AMC and AMR in Sierra Leone, it is important to identify prevalent gaps and areas needing targeted intervention to improve AMC and AMU surveillance and encourage the rational use of antimicrobials. In this regard, one of MAAP's key objectives was to evaluate the ability to conduct AMC and AMU surveillance (data collection and analysis) in Sierra Leone as this would equip the country with valuable information to support the appropriate use of antimicrobials. The objective was to identify gaps that may exist in setting up a comprehensive surveillance system and provide the country with the needed information to support the setup of such a monitoring system.

AMC and AMU surveillance impact

To ensure the successful treatment of infectious diseases in patients, optimising antimicrobial usage is one of the strategic objectives of the WHO GAP-AMR.[8] For the successful implementation of this objective, there is a need to understand the pattern of AMU and the quantities of antimicrobials consumed in each country. At present, there are only a few published reports on AMC or AMU surveillance in Africa.[25-29] Obtaining AMC or AMU data provides local information on the various problems that exist with AMU and allows the monitoring of the accessibility of antimicrobials. Further, obtaining AMC or AMU data permits a continuous local assessment of correlations between antimicrobial usage and emerging local AMR, thus allowing the design of proper mitigation policies and activities using relevant data. In addition, local surveillance data can better inform ASPs. Therefore, MAAP set out to analyse AMC and AMU trends at selected facilities and the national level to better inform the design of future stewardship programmes, policies and regulations, which will optimise the use of antimicrobials in Sierra Leone. In addition, this will provide the country with a reference point to measure the impact and success of these implemented interventions.

The aim of this work

1. Describe the in-country antimicrobial flow and highlight the status of the AMC and AMU surveillance system in Sierra Leone

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

Section II: AMC or AMU surveillance status

Objective

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

Methodology

Data sources

The national AMC data for Sierra Leone was obtained from the Pharmacy Board of Sierra Leone (PBSL) as they were the sole entity involved in approving and regulating all medicine importations into the country. The data were obtained using structured key informant interviews (KIIs) (AMC Appendix 1). It should be noted that the data from the PBSL would reflect import cycles rather than consumption patterns. Regarding AMC data coverage, the importation manifests from the PBSL, for a specified period, can be assumed to represent 100% coverage of the total antimicrobials consumed in Sierra Leone. However, it is important to note that importation data serve only as an indicator of the total AMC in Sierra Leone. In using this proxy data, we assumed that all medicines imported were consumed locally before their expiry, and thus did not account for possible losses or re-exportation.

Under the guidance of Sierra Leone's AMRCC, MAAP aimed to recruit and obtain data from thrice as many pharmacies as the seven selected AST laboratories (i.e., a total of 28 pharmacies) (see AMC Appendix 2 for the tool used). Further AMC data were to be collected from community pharmacies (n=14) that were nominated by the co-located pharmacies. The selection was based on their proximity to the AST laboratories and/or whether these community pharmacies served as the preferred sources of patient medicines or as a backup prescription fulfilment source in case of stock-outs in the main hospital pharmacy. Furthermore, the availability of retrospective data from 2016-2018 and willingness to share the data were key criteria considered during the selection.

In addition to AMC data, AMU data were to be obtained from the seven hospital-based pharmacies and this was to be provided from the prescription or patient medical records at each facility. To clarify, community pharmacies, which are also known as retail pharmacies, are licensed commercial pharmaceutical stores that provide medicinal products (prescription-only and over-the-counter medicines) to a specific community group or region. Hospital pharmacies, on the other hand, are pharmacies located within hospitals and provide medicinal products to inpatients and outpatients who visit the hospital.

Data collection scope

MAAP purposively selected to collect data on J01 (antibiotics for systemic use) consumption trends. J01 medicines are one of the WHO core monitoring anatomical therapeutic chemical (ATC) medicine categories for AMC surveillance. In addition, as per the country's request, selected P01AB (nitroimidazole derivates) and/or selected J02 (antimycotics for systemic use) were also included in the scope for AMC data collection (see AMC Appendix 3 for the full list of selected antimicrobials in Sierra Leone). P01AB and J02 ATC antimicrobials are part of the WHO core and optional monitored medicine classes respectively for AMC surveillance (World Health Organisation, 2016). AMC data on these medicine categories were collected from January 2016 to December 2018.

Data collection

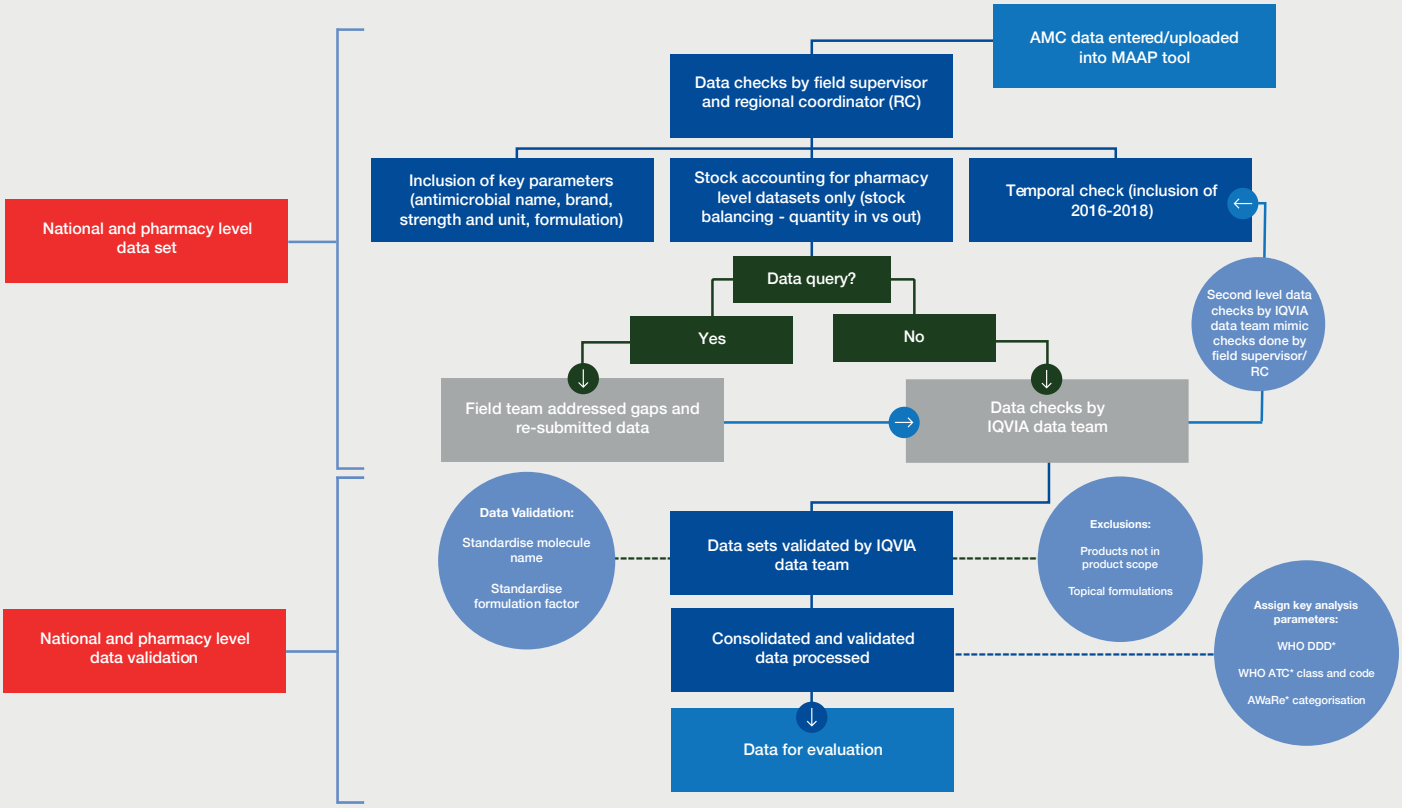
Import manifests for the data collection period (2016-2018) were requested from the PBSL. However, antimicrobial import datasets for the year 2016 were unavailable from the PBSL. From these importation manifests, data were first manually entered into a Microsoft Excel™ sheet before being transferred to or directly entered into the MAAP tool. The MAAP tool captured all medicines by their standard molecule name and/or product brand, pack size, strength and formulation (e.g., tablets, capsules, suspensions or syrups). AMC Appendix 4 captures the full list of data variables collected to tally national- and pharmacy-level AMC.

Pharmacy-level data were collected using the same procedures and tools used for the collection of national-level data (AMC Appendix 5). Pharmacy-level data were successfully collected in 14 of the targeted pharmacies. The remaining seven targeted community pharmacies were unwilling to share their AMC data and were therefore excluded from the data collection.

To assess the appropriateness of consumed antimicrobials, MAAP also planned to collect AMU data in pharmacies that were co-located with AST laboratories in the same facilities offering clinical services. Data to be captured included patient characteristics and medical conditions for which each antimicrobial was prescribed. MAAP also aimed to determine the appropriateness of each prescription in relation to national guidelines (by assessing whether any relevant laboratory testing and clinical assessments were conducted prior to prescription and assessing the strength, frequency and duration of the prescription).

Data cleaning and validation

Prior to analysis, the collected AMC data were subjected to a series of data validation checks to ensure accuracy and consistency (Figure 12). Here, the pharmacy-and national-level AMC data were subjected to secondary and tertiary checks by field supervisors, regional coordinators and the IQVIA data team.



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

Figure 12: Flow chart of the data checks and validation processes conducted for national- and pharmacy-level AMC data collected in Sierra Leone

Results

Flow of antimicrobials in the country

To characterise the pathways through which antimicrobials get to patients in the country, a total of five KIIs were conducted with stakeholders in the national AMRCC, the PBSL, the private for-profit sector (community pharmacies) and the private non-profit sector (non-governmental organisations). In Sierra Leone, all medicines, including antimicrobials, are imported into the country, and the PBSL is the sole entity involved in approving and regulating all medicine importations into the country. All importers must first obtain an import permit before medicines are allowed into the country. No local medicine manufacturers or central medical stores (CMSs) were present in the country during the reviewed period (2016-2018). After importation, private for-profit wholesalers and private not-for-profit distributors then pass the antimicrobials to the community pharmacies, private (both for-profit and non-profit) facilities and public facilities, who eventually issue antimicrobials to the patients (Figure 13).

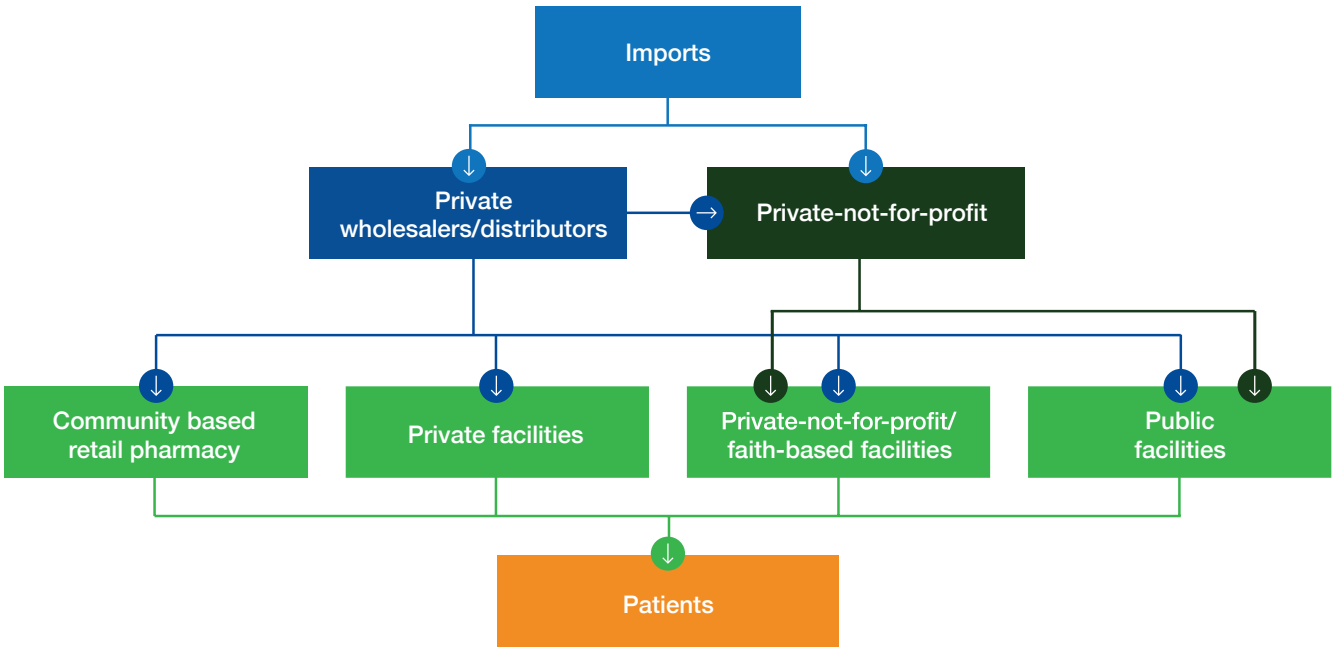


Figure 13: The flow of antimicrobials to patients in Sierra Leone

Regulation of antimicrobials consumption

Antimicrobials for human consumption are regulated under the Pharmacy Drug Act, 2001. This law stipulates that antimicrobials can only be dispensed based on a valid prescription and sales are to be recorded in an antimicrobial register.[11] However, due to poor enforcement, low motivation, and inadequate punitive actions, it is possible to obtain antimicrobials without a prescription from the various healthcare delivery points across the country.[12] Furthermore, while pharmacists are the only authorised healthcare workers allowed to dispense antimicrobials to patients, persons who are not pharmacists (e.g., medicine vendors) also tend to dispense antimicrobials, particularly in the suburban and rural areas.[13] To address these and other issues, and seeing as the overuse and misuse of antimicrobials contributes significantly to the emergence of AMR, the country developed a National Strategic Plan (2018 – 2022)[10] for combating AMR.

Availability of data for AMU surveillance

Attempts were made to obtain AMU data from the participating pharmacies that were co-located with AST laboratories in facilities offering clinical services (n=7). Unfortunately, no AMU data were obtained during the MAAP data collection exercise because the participating pharmacies used stock issuance record cards that do not track which patient specifically received what medicines. MAAP was thus unable to retrieve the necessary AMU variables (i.e., patient characteristics, the indication for which the antimicrobial was prescribed, and the appropriateness of the prescription in relation to national guidelines) from the selected health facilities in Sierra Leone.

Availability of data for AMC surveillance

National-level data

Data collectors were able to access national AMC data from the PBSL for the years 2017 and 2018. The paper records of the 2016 data were either damaged or missing. Therefore, this report presents only national-level AMC datasets for 2017-2018. Furthermore, it was not feasible to gain insights into the consumption trends across different health sectors (i.e., private versus public) as the PBSL datasets did not provide information on the end destination of imported medicines. Lastly, since the PBSL is the sole data source of medicines imported into the country and all importation manifests were availed to data collectors and captured during data entry, it was reasonable to assume that the 2017 and 2018 AMC data collected and presented in this report represented 100% coverage of all antimicrobials consumed in Sierra Leone. The PBSL data included all the variables required to conduct AMC analysis, namely the transaction date, antibiotic name, pack size, strength and formulation (e.g., tablets, capsules, suspensions, syrups or injections).

Facility-level data

Out of the 32 targeted community pharmacies and hospital pharmacies co-located in the same facility with AST laboratories, data were successfully collected in seven community pharmacies and seven AST hospital pharmacies. All the seven participating pharmacies that were co-located with AST laboratories were in public government hospitals (six were secondary care hospitals and one was a tertiary care hospital) (Table 10). The remaining seven recruited pharmacies were stand-alone community-based retail pharmacies. As the total number of hospital or community pharmacies in Sierra Leone was unknown, the representativeness of the facility-level data could not be assessed.

In the case of pharmacy-level data, the necessary variables were available in the stock cards or electronic records of 14 pharmacies where the data were collected. However, there were instances in each of the visited facilities where the strength or pack size information for a few line items/transactions was missing from the stock cards. These information gaps were filled by revisiting the facilities and gathering information from the facility staff or through secondary desk research using the available product details. MAAP was able to collect data across the three years in six of the seven hospital pharmacies and six of the seven community pharmacies. Only two participating pharmacies (one hospital pharmacy and one community pharmacy) did not have archived data for the 2016-2017 period in their systems.

Furthermore, due to the lack of any national AMC surveillance system, none of the recruited pharmacies actively reported AMC data regionally or centrally.

Table 10: Characteristics of the recruited community pharmacies and the recruited hospital pharmacies co-located with antimicrobial susceptibility testing (AST) laboratories in Sierra Leone

	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)	Military Hospital	Secondary care	Public	Freetown	Manual	No	No
	Kenema Hospital	Secondary care	Public	Kenema	Manual	No	No
	ODCH Hospital	Secondary care	Public	Freetown	Manual	No	No
	Bo Hospital	Secondary care	Public	Bo	Manual	No	No
	Lakka Hospital	Secondary care	Public	Freetown	Manual	No	No
	Connaught Hospital	Tertiary care	Public	Freetown	Manual	No	No
	PCM Hospital	Secondary care	Public	Freetown	Manual	No	No
Community pharmacies ~	Bodicare Community Pharmacy	Dispensing	Private	Freetown	Manual	N/A	No
	East Side Community Pharmacy	Dispensing	Private	Freetown	Manual	N/A	No
	Eastern Community Pharmacy	Dispensing	Private	Bo	Manual	N/A	No
	Misuydeh Jagisa Community Pharmacy	Dispensing	Private	Bo	Manual	N/A	No
	Pottal Community Pharmacy	Dispensing	Private	Freetown	Manual	N/A	No
	Sarafina Community Pharmacy	Dispensing	Private	Freetown	Manual	N/A	No
	Uma-K Community Pharmacy	Dispensing	Private	Freetown	Manual	N/A	No

*For the review period, i.e., 2016-2018

† Refers to the ability of the 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 (patients referred from peripheral health units) and inpatient services, i.e., admission facilities, diagnostic services and management of accidents and emergencies. Tertiary care services are delivered at government regional-level hospitals and at some private hospitals that are involved in specialist surgeries such as internal medicine, obstetrics and gynaecology and paediatrics[34,35]

~ Hospital pharmacies refer to pharmacies located within a hospital for the provision of medicinal products to inpatients and outpatients that visit the hospital. Community pharmacies or retail pharmacies refer to commercial pharmaceutical stores that provide medicinal products (prescription-only and over-the-counter medicines) to a specific community group or region

Abbreviations: AMC=antimicrobial consumption; AST=antimicrobial susceptibility

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

Objective

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

Methodology

Statistical analysis

Data analysis for MAAP was conducted according to the WHO's protocol for conducting AMC analysis using the DDD-ATC-AWaRe methodology (Figure 14, AMC Appendix 6).[30,31] Each of these WHO methodologies as well as the additional analyses conducted are briefly described below. 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 and related metrics are used to analyse AMC. The DDD metric helps in standardising the different doses (in milligrams) of different antibiotics used in managing infections to allow easy comparisons. It is also recommended to use drug utilisation figures such as DDD along with a relevant denominator for the health context such as numbers of DDDs per 1 000 inhabitants per day, DDD per inhabitant per year or DDDs per 100 bed days. Studying DDDs or associated metrics over time helps to understand the consumption pattern or determine if any national- or facility-level interventions have led to a change (+/-) in consumption patterns over the study period or a pre-defined base period.

Using the WHO 2020 DDD guide, the total consumed milligrams per antimicrobial were divided against the standard DDD value issued by the WHO to obtain total DDDs.[32] Total DDDs were then adjusted for the country's population size in the year of data collection (2016-2018) and presented as DDDs per 1 000 inhabitants per day (DID). Pharmacy-level AMC data were to be adjusted as per the number of inpatients and presented as DDDs per 100 patient beds per day. However, the use of the WHO DDD per 100 patient bed days per day presented limitations at the point of analysis as, for most of the hospital facilities, information on patient bed days and patient days was not easily accessible. Secondly, this metric would not allow a comparison of 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 comparisons of AMC between hospital and community pharmacies. All calculations were done in Microsoft Excel™ software.

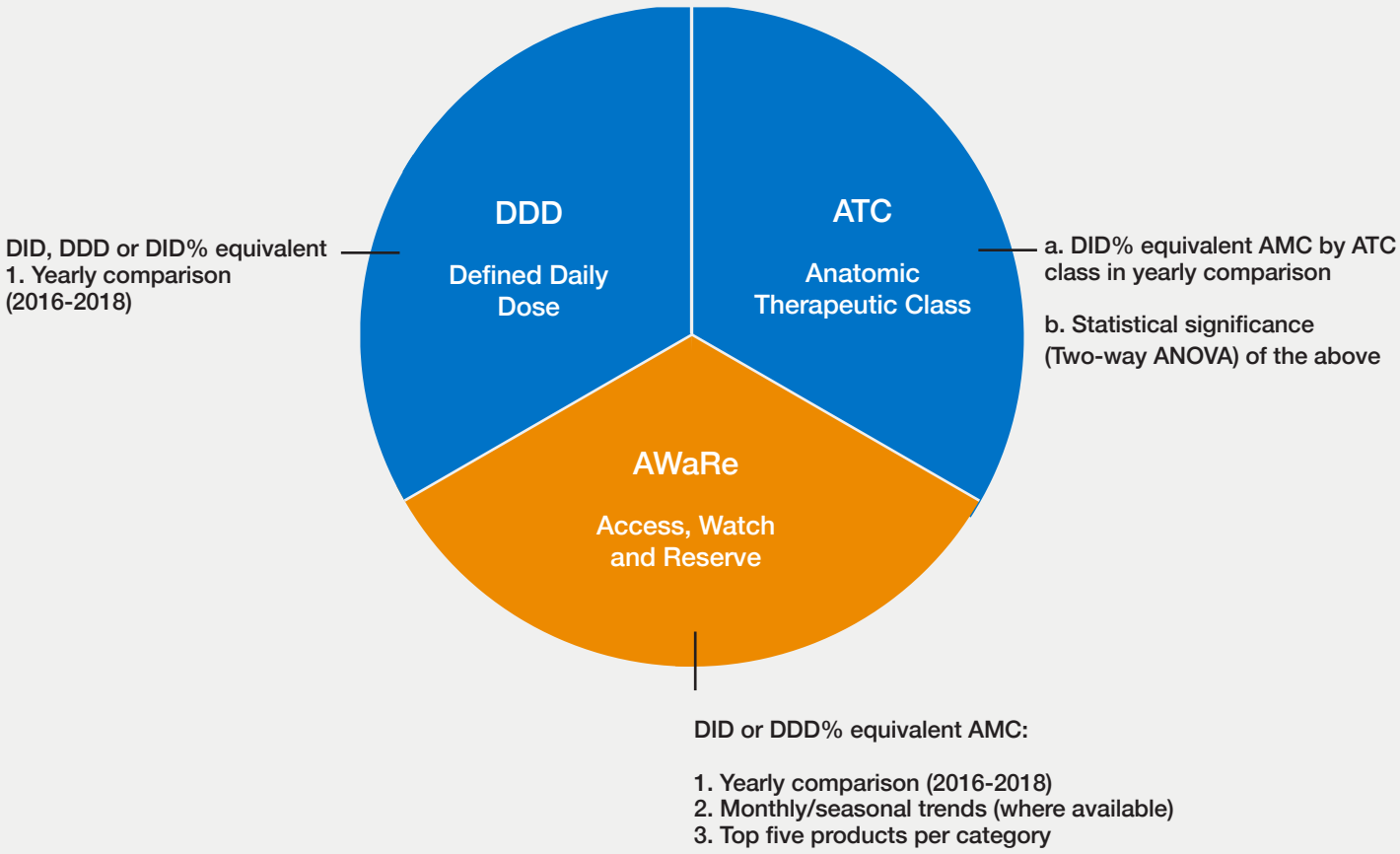
ii. Anatomic Therapeutic Chemical (ATC) Classification

Using the standard list of antimicrobial names, data collected were coded in the Microsoft Excel™ analysis database in accordance with the 2020 WHO ATC codes and then analysed to characterise the macro (above-molecule) AMC trends. In addition, statistical testing (two-way analysis of variance [ANOVA]) was also conducted to determine whether there were year-on-year differences within each ATC group.

iii. WHO Access, Watch and Reserve (AWaRe)

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

We stratified the total DDDs per antibiotic molecule into 'Access', 'Watch' and 'Reserve' categories in accordance with the 2019 WHO AWaRe list33 using Microsoft Excel™. The total DDDs in each WHO AWaRe category were then analysed to determine the proportion of antimicrobials consumed per category over time (yearly and monthly), where possible. The WHO recommends that at least 60% of a country's total AMC should come from the 'Access' category of antibiotics. In addition, we identified the top five antibiotics consumed in each WHO AWaRe category.



Abbreviations: AMC=antimicrobial consumption; ANOVA=analysis of variance; ATC=Anatomic Therapeutic Chemical, DID=defined daily dose per 1 000 inhabitants per day

Figure 14: Methods and indicators used for the analysis of the data collected in Sierra Leone. Defined daily dose (DDD) indicators utilised for volumetric standardisation were sourced from WHOCC 2020. The ATC classification utilised to categorise the antibiotics according to the organ or system in which they act, and their therapeutic, pharmacological and chemical properties was sourced from the WHOCCC ATC database. The 'Access', 'Watch' and 'Reserve' categorisation was sourced from the 2019 WHO AWaRe classification

iv. Review of Essential Medicines List (EML)

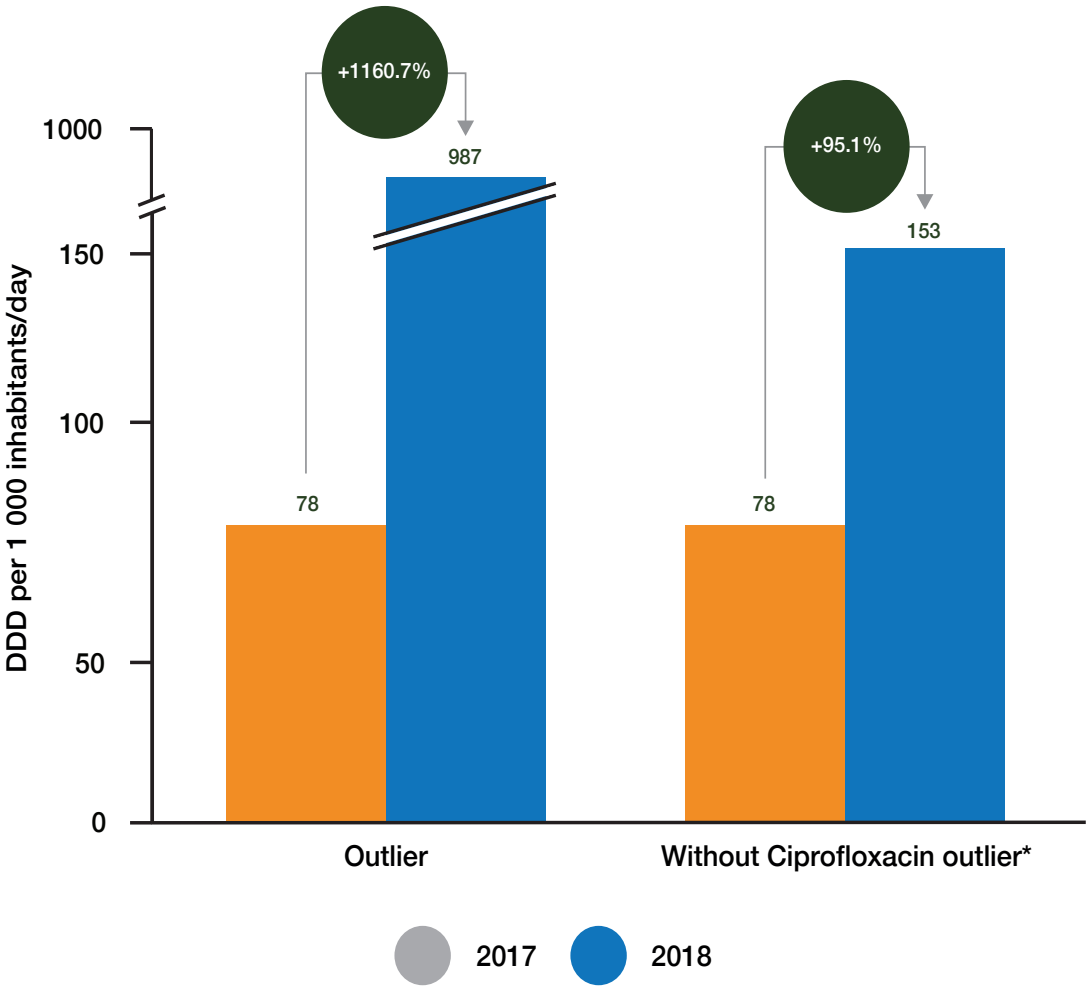
According to the WHO, essential medicines are those that satisfy the priority healthcare needs of a population. They are selected with due regard to disease prevalence and public health relevance, evidence of efficacy and safety and comparative cost-effectiveness. They are intended to always be available 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 to the antimicrobials listed in the national EML and against the documented antimicrobials from the retrieved national- and pharmacy-level data. The comparison was conducted using the WHO-defined AWaRe categories.

Results

National AMC datasets analysed by DDD per year

The total in-country AMC was 78 DID in 2017 and 987 DID in 2018. There was a notable (1 160.7%; 909 DID) increase in AMC between 2017 and 2018. This disparity was largely attributable to the increased consumption of ciprofloxacin (i.e., an increase from 7.4 DID in 2017 to 836.4 DID in 2018). This outlier change in year-on-year AMC was confirmed and replicated through a fresh re-collection of national AMC data but was also pencilled as possible inaccurate data by the country's AMRCC.[25] This ciprofloxacin data outlier rendered subsequent analysis of consumption trends difficult. Therefore, the data were analysed with and without ciprofloxacin data for July and August 2018 to reveal seminal data trends within other antimicrobials (Figure 15). The ciprofloxacin data outlier was excluded from subsequent analyses of the AMC data.

The average total in-country AMC between 2017 and 2018 was 115.5 DID. Despite the removal of the outlier, there was still a notable increase in AMC (95.1%; 75 DID) between 2017-2018.



Abbreviations: DDD=defined daily dose

*Figure 15: Variation in the national-level total defined daily dose per 1 000 inhabitants per day between 2017 and 2018 in Sierra Leone. *The data are presented with (left) and without (right) ciprofloxacin consumption data from July and August 2018*

National AMC analysed by ATC classification

Penicillins with extended spectrum (J01CA) were the most frequently consumed ATC class across both years (68.9% in 2017 and 38.9% in 2018), with amoxicillin being the most consumed antibiotic within this class (Figure 16). Tetracyclines (J01AA) and combinations of sulfonamides and trimethoprim including derivatives (J01EE) were the second and third leading antimicrobial classes, with tetracycline and the combination of sulfamethoxazole/trimethoprim being the most consumed antimicrobials within these ATC classes, respectively. Between 2017 and 2018, there were no prominent changes in the consumption of all antimicrobial ATC classes. The five most consumed antimicrobials were amoxicillin, tetracycline, sulfamethoxazole/trimethoprim, ampicillin/cloxacillin and ampicillin. Together, they accounted for 78% of the total consumption. Detailed breakdowns of the national AMC by antimicrobial molecule and by ATC class are presented in AMC Appendix 7 and AMC Appendix 8.

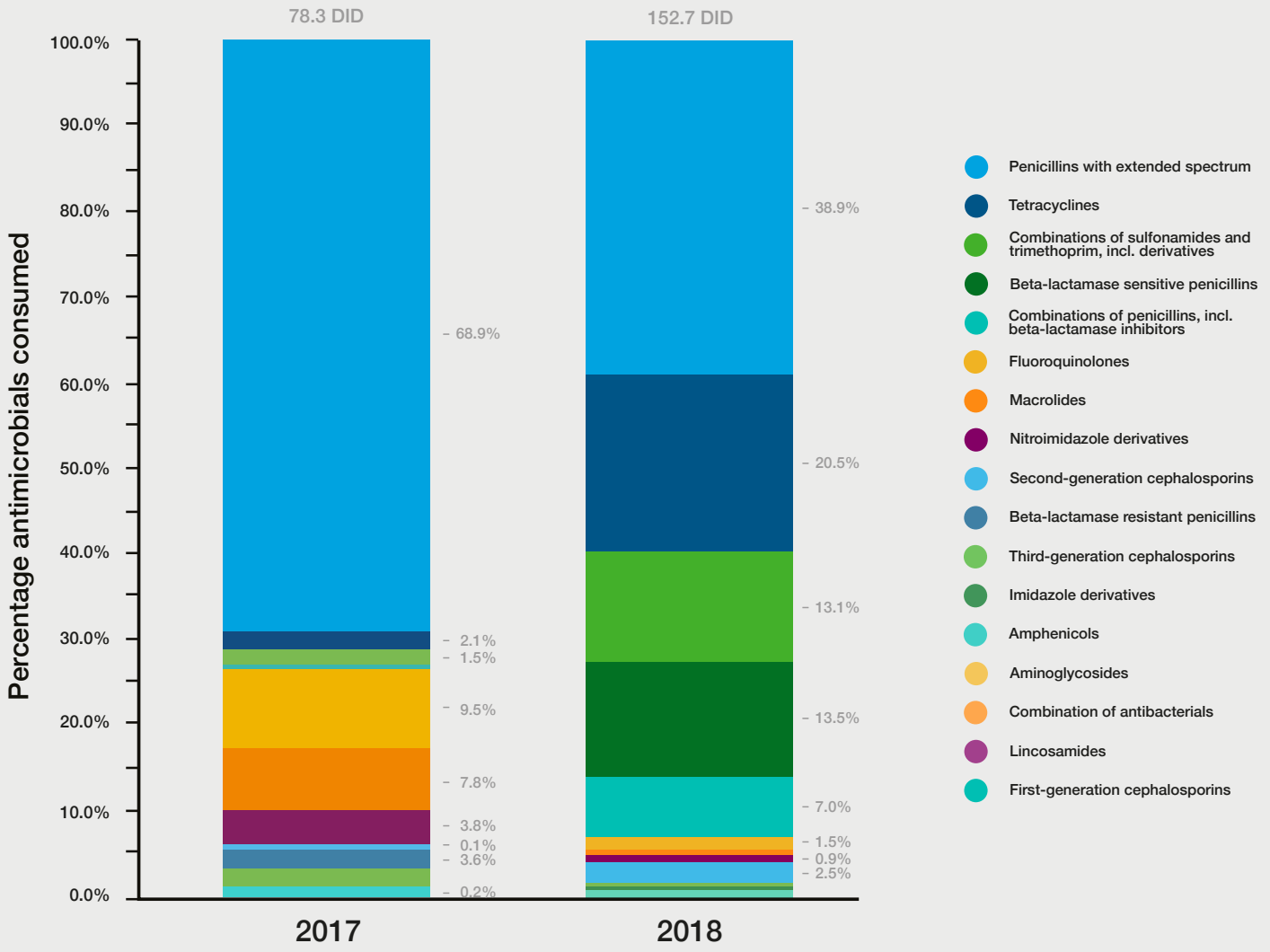


Figure 16: National-level antimicrobial consumption (AMC) in Sierra Leone between 2017 and 2018. The bars show the percentage of antimicrobials consumed broken down by Anatomic Therapeutic Chemical (ATC) classes. The annual national-level total defined daily dose per 1 000 inhabitants per day (DID) is shown at the top of each bar. The 'Penicillins with extended spectrum' class of molecules were the highest consumed antimicrobials in 2017 and 2018. No statistically significant changes were noted. See AMC Appendix 8 for a more detailed breakdown of AMC by ATC classes

National-and pharmacy-level AMC analysed by WHO AWaRe categorisation

Across the two years reviewed, 89.7% of all antibiotics consumed were in the 'Access' category, 10.3% were in the 'Watch' category and none (0.0%) were in the 'Reserve' category. The percentage consumption share of 'Watch' antibiotics reduced from 19.4% in 2017 to 5.3% in 2018 whereas the consumption share of 'Access' category antibiotics increased from 80.6% in 2017 to 94.7% in 2018 (Figure 17). On average and within each year analysed, the consumption of 'Access' category antibiotics in Sierra Leone exceeded the 60% minimum consumption threshold set by the WHO. There were no stocks of 'Reserve' group antibiotics supplied in Sierra Leone during the reviewed period. Some antimicrobials (4.7% of total AMC; 5.5 DID) that are not categorised within the WHO AWaRe list of 2019 were omitted from this analysis.

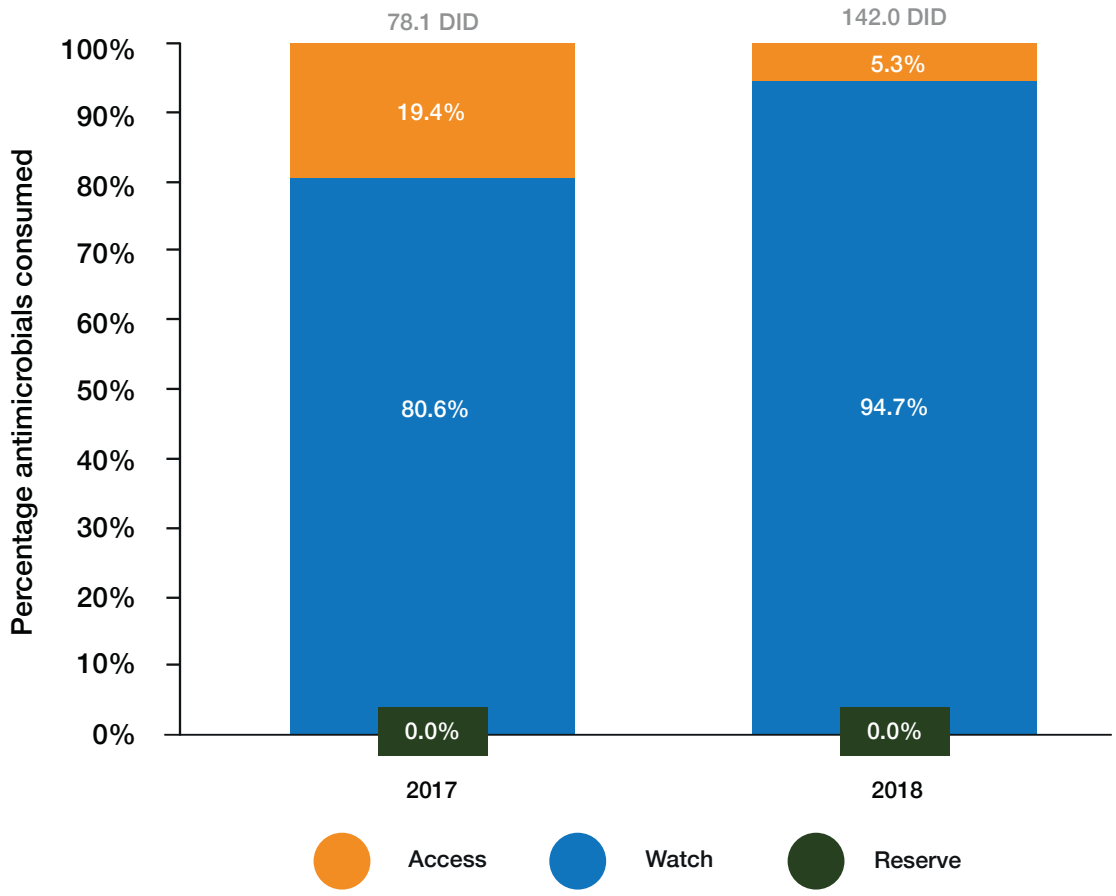
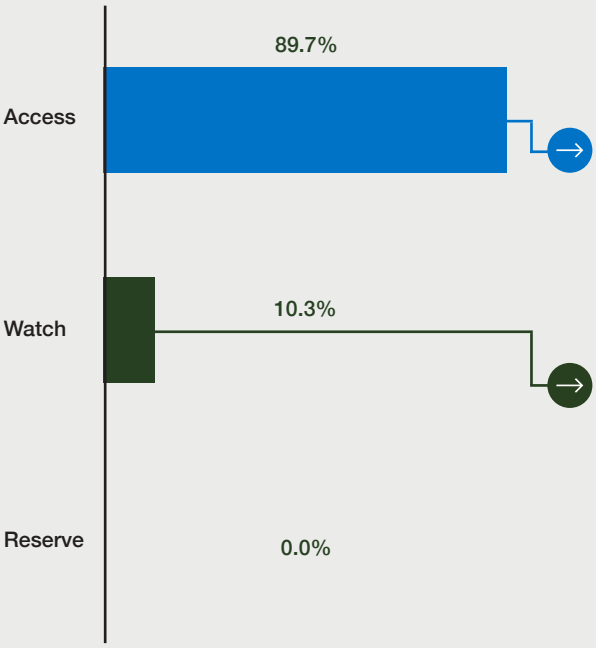


Figure 17: Antimicrobial consumption in Sierra Leone between 2017 and 2018. The bars show the percentage of antibiotics consumed broken down by WHO AWaRe categories. The annual total defined daily dose per 1 000 inhabitants per day (DID) is shown at the top of each bar.

Further analysis was done to identify the most frequently consumed antibiotics nationally within each WHO AWaRe category. In the 'Access' category, the top five most consumed antimicrobials accounted for 88% of all AMC within this group (Figure 18). In the 'Watch' category, the top five most consumed antimicrobials accounted for 99% of all AMC within this group. There was no consumption of 'Reserve' category antibiotics for the reviewed period (2017-2018).



Molecule Name	% Total	Mean DDD/1000 inhabitants/ day
Amoxicillin	52.4%	51.8
Tetracycline	15.9%	15.7
Sulfamethoazole/Trimethoprim	10.7%	10.6
Ampicillin	5.0%	5.0
Procaine Benzylpenicillin	4.7%	4.6

Molecule Name	% Total	Mean DDD/1000 inhabitants/ day
Ciprofloxacin	42.8%	4.9
Erythromycin	29.6%	3.4
Cefuroxime	17.2%	2.0
Cefixime	7.2%	0.8
Ceftriaxone	2.2%	0.2

Abbreviations: DDD=defined daily dose

Figure 18: Breakdown of antibiotics consumed at the national level in Sierra Leone by WHO AWaRe ('Access', 'Watch' and 'Reserve' categories, 2017–2018. The inset tables show the top five most consumed antibiotics in each category. No consumption of 'Reserve' category antibiotics was recorded

Within the WHO AWaRe database, there exists a list of 'antibiotics not recommended' as they consist of FDCs of multiple broad-spectrum antibiotics whose use is neither evidence-based nor recommended in high-quality international guidelines. These antibiotics are represented as 'uncategorised' by MAAP. We analysed the national AMC data to determine if these antibiotics were consumed in the country. Three of these FDCs (ampicillin/cloxacillin, ciprofloxacin/tinidazole and cefuroxime/clavulanic acid) were consumed during the period reviewed, representing 4.7% of the total national AMC. Of these three combinations, ampicillin/cloxacillin was the most frequently consumed (accounting for 97.6% of the consumption from the total consumption of the mentioned FDC antibiotics, with a mean DID of 5.3). This FDC was also found to be the fourth most frequently consumed antimicrobial in the national dataset analysed.

Aggregated pharmacy-level data from the 14 participating pharmacies were analysed by the pharmacy type (hospital-based or community-based) and proportional consumption of WHO AWaRe antibiotic categories. Community pharmacies consumed 20% more 'Watch' category antibiotics compared to hospital pharmacies (Table 11). Conversely, while hospital-based pharmacies (68.9% consumption) exceeded the WHO threshold of 60% consumption of antibiotics in the 'Access' category, community pharmacies (48.4% consumption) did not. Within the hospital-based pharmacies, the tertiary care facilities consumed over 10% more 'Watch' category antibiotics compared to the secondary care facilities. There was no recorded consumption of 'Reserve' category antibiotics in any of the participating pharmacies.

Table 11: Antimicrobial consumption broken down by WHO AWaRe ('Access', 'Watch' and 'Reserve') categories at the hospital and community pharmacies in Sierra Leone between 2016-2018

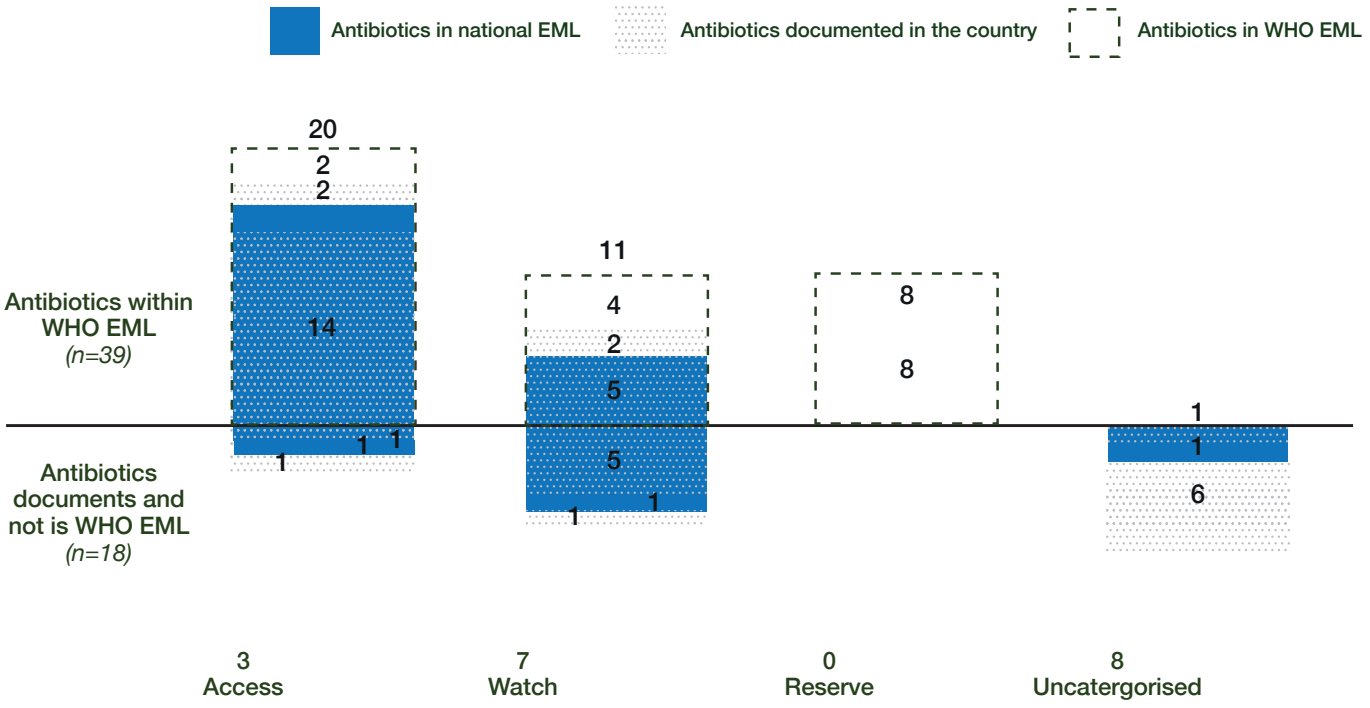
	AWaRe Categorisation	
	Access	Watch
Pharmacy Type	Percentage share	(Absolute DDD)
Community pharmacies (7/14)	48.4% (126 715)	51.6% (135 037)
Hospital pharmacies (7/14)	68.9% (2.0 million)	31.1% (904 485)
Secondary care facilities (6/7)	69.4% (1.9 million)	30.6% (856 967)
Tertiary care facilities (1/7)	55.7% (59 623)	44.4% (47 517)
Grand Total	67.2% (2.1 million)	32.8% (1.0 million)

Abbreviations: AWaRe=Access, Watch and Reserve; DDD=defined daily dose

Comparison of the WHO EML and Eswatini EML with documented antibiotics by WHO AwaRe categorisation

The WHO EML includes 39 antibiotics across the AWaRe categories. A total of 57 antimicrobials were documented during national- and pharmacy-level data collection. Figure 19 shows, for each AWaRe category, the number of antibiotics in the WHO EML and the Sierra Leone national EML, thereby indicating if the antibiotic was documented during data collection.

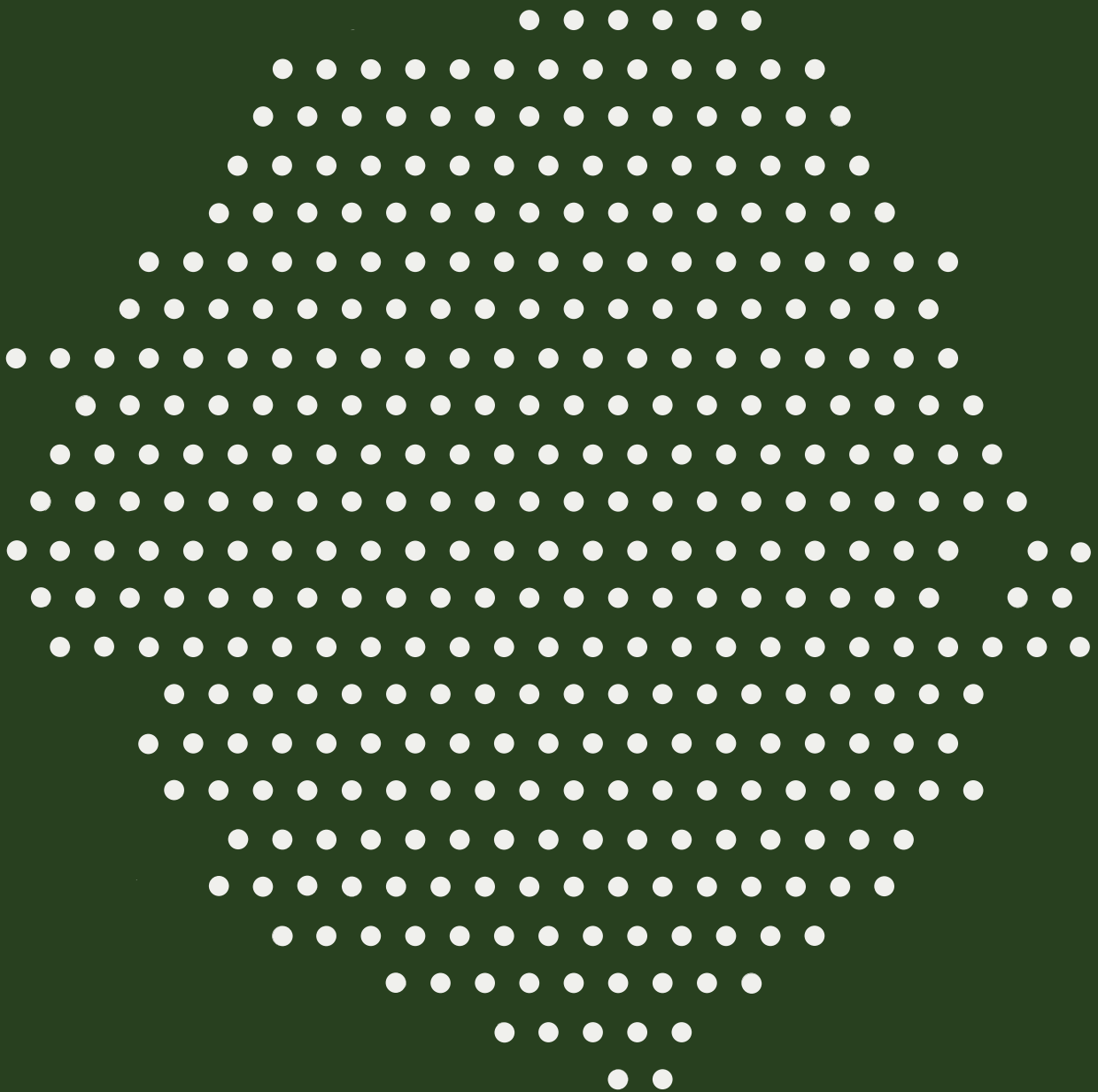
It was found that two antibiotics in the 'Access' category and two in the 'Watch' category are listed in the WHO EML and were documented during data collection but are not part of the national EML. In addition, there were two 'Access', four 'Watch' and eight 'Reserve' category antibiotics that are part of the WHO EML but are not listed in the national EML and were not documented during data collection. Interestingly, there were two 'Access' category antibiotics that are listed in both the WHO EML and the national EML but were not documented during data collection. Some uncategorised antimicrobials as well as antimicrobials in the three AWaRe categories that are not listed in the WHO EML or national EML were documented during data collection. The detailed breakdown of antimicrobials documented and their inclusion in the WHO EML and national EML is provided in AMC Appendix 9.



Abbreviations: WHO=World Health Organisation; EML=Emergency Medicines List

Figure 19: AWaRe analysis of documented antibiotics in national- and pharmacy-level data in Sierra Leone (2016 to 2018) compared to the WHO EML and national EML definitions

Part C: Resistance and Consumption Interlinkages



Objective

To assess the relationship between AMC and AMU

Methodology

The DRI was estimated to convey aggregate rates of resistance as well as measurements of AMC (at a national level since AMU data were not available) across select pathogen-antimicrobial combinations (AMR Appendix 8). The pathogens considered were A. baumannii, E. coli, K. pneumoniae, P. aeruginosa, S. aureus, E. faecium and E. faecalis, while the antibiotics were aminoglycosides, broad-spectrum penicillins, carbapenems, cephalosporins, glycopeptides, narrow-spectrum penicillins and quinolones. The DRI estimates, which help communicate the effectiveness of antibiotic therapy to decision makers, were generated using a previously published methodology[36,37]. DRI values range from 0 (100% susceptibility) to 100 (100% resistance). Available AST results for at least 30 tested isolates and at least 15 of the 25 combinations were required 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, the correlation between AMC and AMR was determined. 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). A Pearson's correlation analysis was performed to determine the correlation between the two variables (AMR rate [%] and total DDD). Antibiotic classes contributing less than 0.05% to the total antibiotics consumed were excluded from the analysis.

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

Results

Drug Resistance Index

The DRI was not assessed owing to insufficient AMR data.

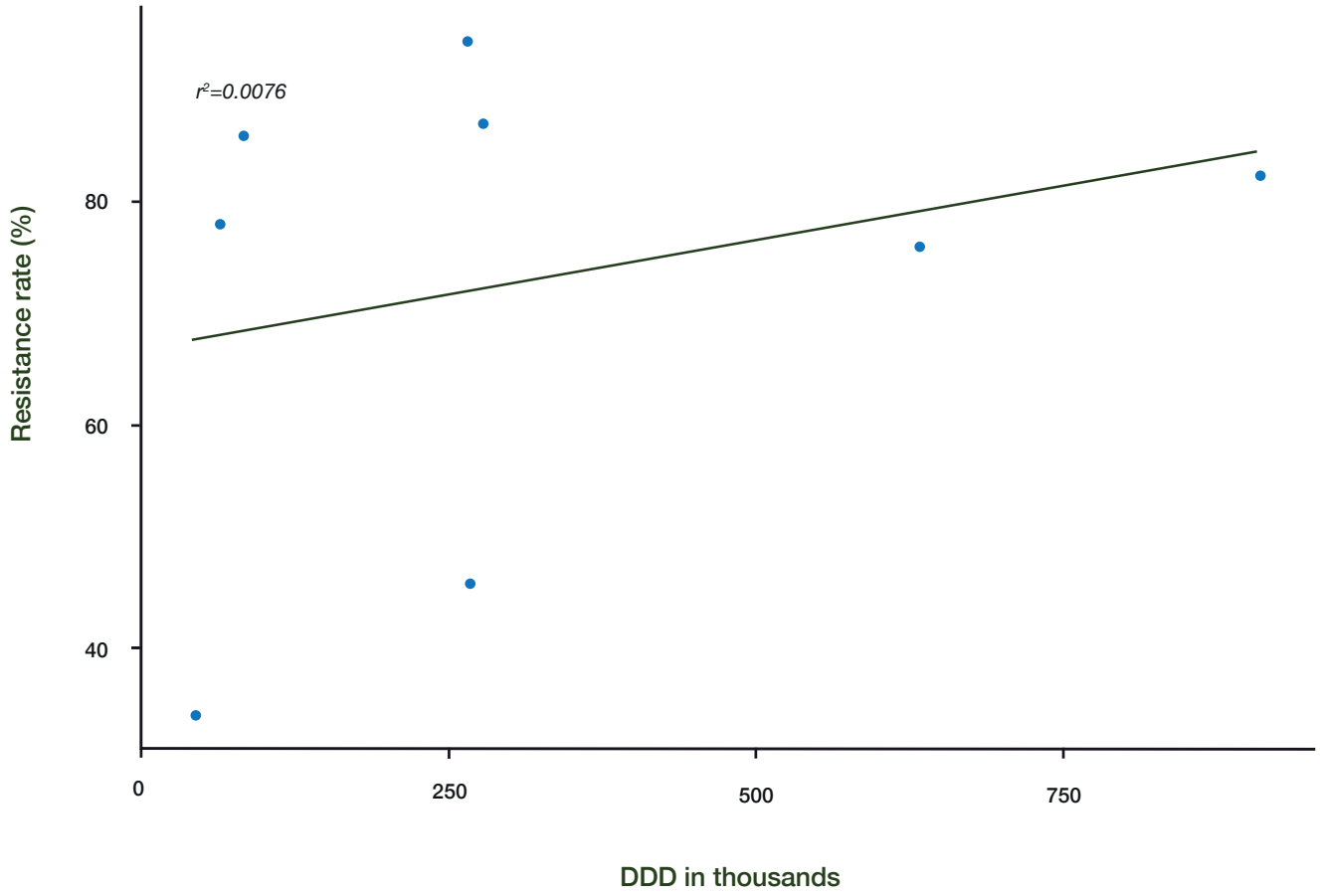
AMC and AMR correlation

The top three highly consumed antibiotic classes at the facility level were aminopenicillins, macrolides and folate pathway inhibitors. The AMR rates were highest for penicillins (94.3%), folate pathway inhibitors (87.1%) and tetracyclines (85.9%) (Table 12). Pearson's correlation analysis revealed a weak positive correlation (r^2=0.08) between AMR and AMC, implying that AMC is not a significant driver of AMR in Sierra Leone (Figure 20).

Table 12: AMC and AMR rates across antibiotic classes in Sierra Leone, 2016-2018

Antibiotic class	Year	Total DDD in thousands	Resistance rate (%)
Aminopenicillins	2016-2018	908.90	82.3
Macrolides	2016-2018	633.07	76.0
Folate pathway inhibitors	2016-2018	277.88	87.1
Fluoroquinolones	2016-2018	267.64	46.1
Penicillins	2016-2018	264.75	94.3
Tetracyclines	2016-2018	82.94	85.9
Methicillin	2016-2018	63.33	77.9
Aminoglycosides	2016-2018	42.38	33.9

Abbreviations: DDD=defined daily dose

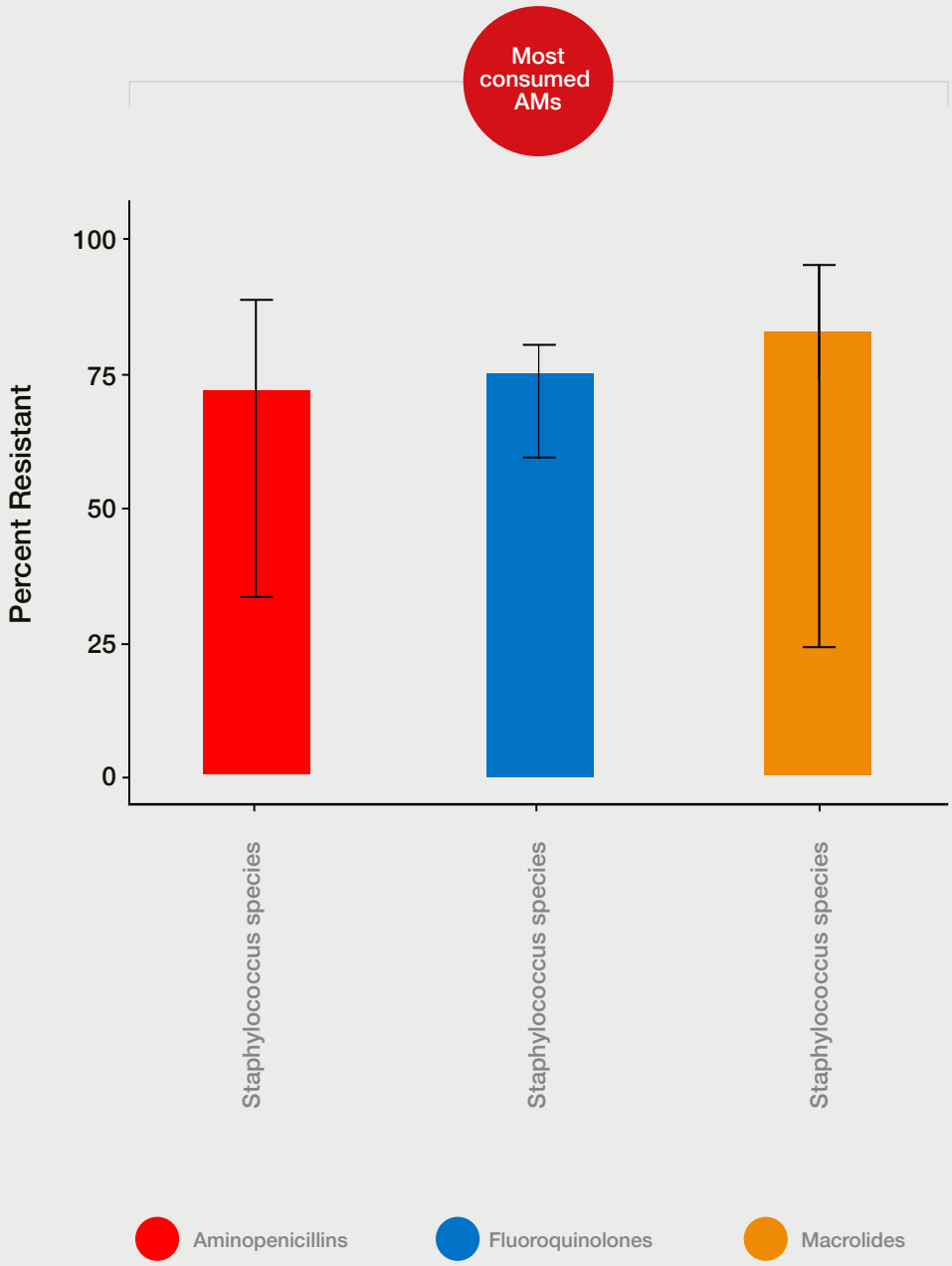


Abbreviations: DDD=defined daily dose

Figure 20: Correlation between AMR and AMC in Sierra Leone, 2016-2018

Resistance profiles of most and least consumed antimicrobial classes

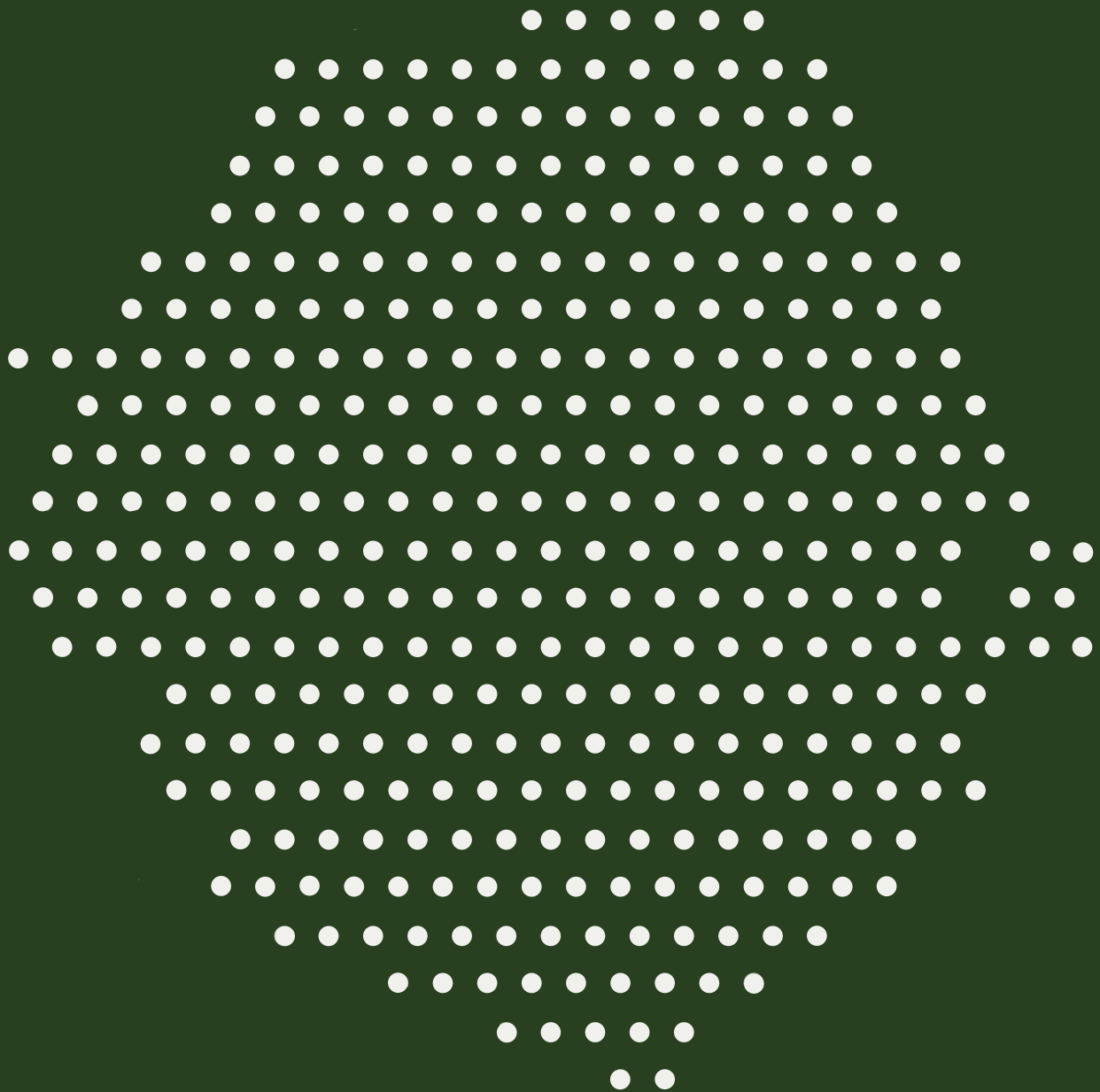
The most consumed antimicrobial classes across the study years were aminopenicillins, fluoroquinolones and macrolides. Data on the most consumed antimicrobial classes were only available for 2017. There were high rates (>75%) of macrolide-resistant Staphylococcus species (Figure 21). The Staphylococcus species also displayed high rates of resistance to fluoroquinolones and aminopenicillins. The least consumed antimicrobial classes across the study years were aminoglycosides, lincosamides and methicillin. However, AMR data were not available for the same.



Abbreviations: AMs= antimicrobials

Figure 21: Rates of resistance to the most consumed antimicrobial classes in Sierra Leone in 2017

Part D: Recommendations



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

Significance of AMR and DRI data including recommendations

Mitigation of AMR calls for a multipronged approach that involves 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 Sierra Leone.

Service delivery

The laboratory network in Sierra Leone was found to consist of 179 laboratories, of which only seven were identified as bacteriological laboratories with AST capabilities. While most of the surveyed laboratories reported implementing QMS, not all were certified or accredited. Considering the country's population of over 7.9 million people, the laboratories did not equitably cover the country's population. The testing load (quantum of cultures) at most participating laboratories was found to be low and suggested a lack of routine microbiology testing. There is thus the likelihood that the AMR rates were overestimated as most tests would have been conducted on special patient categories (cases of failed first-line therapy or patients admitted to intensive care).

To strengthen the delivery of services by the laboratories, we recommend that all laboratories get mapped across a range of indicators, including population coverage, infectious disease burden, testing capabilities and quality compliance. This would inform decision makers about unmet needs and help decide a way forward for the 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, all of them had an experienced laboratory scientist or technologist, 86% had at least one qualified microbiologist and 71% had up-to-date records on training and competence. For high-quality microbiology testing and reporting, it is essential to train staff on laboratory standards, identification of common pathogens and data management.[41] Capacity building of staff may be conducted by leveraging in-house expertise or may be outsourced to external organisations or tertiary facilities.

Information systems

The Regional Grant was a step towards the collection and digitisation of data. Most of the surveyed laboratories relied on a combination of electronic and paper-based records, and very few had linkages to patients' clinical records. In the current study, involving seven laboratories, susceptibility results could be collected for just 723 positive cultures.

To strengthen AMR surveillance, it is essential to curate the right data and generate evidence. We recommend data collection in 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 the management of infectious diseases should be based on the specific epidemiology of the patient setting, and resistance data should be shared with national and supra-national platforms. We also recommend establishing a system of assigning permanent identification numbers for tracking patients over time. This would help to collect data on patients' clinical profiles and antimicrobial histories, as well as the molecular profiles of the pathogens (where available), thus offering more context to the AMR epidemiology than stand-alone AST data.

Medicines and technologies

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

To strengthen AMR surveillance, it is imperative to generate reliable laboratory results using appropriate testing methods and authorised surrogates as well as to ensure uninterrupted availability of reagents, including antibiotics, for susceptibility testing. Improving supply chains for essential reagents should be prioritised, 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 community awareness of the importance of public health interventions (vaccinations, clean water, sanitation and hand hygiene) as well as compliance with physicians' advice. The strengthening of health and laboratory systems must be prioritised at the 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 Sierra Leone to optimise the observed AMC trends and facilitate future surveillance activities.

Feasibility of obtaining AMC and AMU data in Sierra Leone and recommendations

MAAP successfully collected and analysed national- and pharmacy-level AMC data in Sierra Leone. This indicates that conducting routine AMC surveillance is possible and that Sierra Leone can respond to the WHO's call to participate in GLASS, which now has an AMC reporting component. However, some AMC data were missing (e.g., the 2016 national AMC data), and the AMC data collected required extensive cleaning. Therefore, a comprehensive guiding policy for routine AMC surveillance is required in the country to guide, at the minimum, the reporting of AMC data variables and routine data cleaning practices. Generally, the closer the data source is to the end user, the more accurate the estimation of national AMC. Therefore, relevant regulatory authorities should identify and recruit medicine wholesalers or distributors or large-volume health facilities to serve as sub-national points for AMC surveillance. Such a decentralised approach would also offer the added benefit of allowing the examination of AMC trends within the private and public sectors as well as at the end-user institutions consuming the medicines (i.e., primary, secondary and tertiary levels).

Furthermore, the policy should outline the minimum duration for which records should be held to ensure that data are accessible during retrospective surveillance exercises. This could be done by establishing a clear retention and disposal schedule for essential medicine records. In addition, efforts should be made to address any lack of capacity, material resources, systems and infrastructure that may hinder the management of these records. Pharmacy-level AMC data from the hospitals were collected from manual records. To make future AMC surveillance activities more time- and cost-efficient, hospitals could consider switching to electronic systems and ensuring that such systems can transfer data across systems and/or produce user-friendly reports on AMC.

MAAP was unable to obtain AMU data in Sierra Leone, which would have helped to characterise antimicrobial prescriptions at the facility level, in line with the WHO's drug use research methodology.[42] This inability to collect AMU data from participating pharmacies that were co-located with AST laboratories was because the AMC data sources (i.e., stock record cards at the pharmacies) did not allow the back-tracing of individual patients to whom antimicrobials were dispensed as prescription chits were not archived. MAAP, in alignment with the WHO guide on facility AMU assessment, would recommend that future AMU surveillance attempts in the country be conducted through prospective AMU surveillance activities (e.g., point-prevalence surveys).[31] However, such an approach is time-consuming unlike retrospective data collection and often requires specialised data collection teams, making it expensive and difficult in resource-limited settings. Retrospective AMU data collection can, however, remain an option if facilities targeted for data collection are selected based on the existence of electronic patient records and the presence of cross-department unique patient identifiers.

Overview of AMC consumption trends and recommendations

The total AMC levels documented in this report provide a useful benchmark for comparing future in-country AMC levels following the implementation of in-country stewardship programmes. The observed AMC levels in Sierra Leone far exceed the levels described in a recent study in Sierra Leone[25] and in other African countries, including Burkina Faso, Cote d'Ivoire, Burundi[21] and Tanzania.[43] The AMC levels reported in the recently published Sierra Leone paper[25] were significantly lower, possibly due to the various assumptions the investigators made in the data collection methodology, particularly in relation to antimicrobial pack quantities. It is uncertain why the observed AMC levels in Sierra Leone were higher than those observed in the other countries, but methodological differences may have contributed to the differences. The disparities in AMC levels might also be due to relative differences in the burden of infectious diseases between the countries or limited availability of laboratory or point-of-care diagnostics at the health facility level. These factors may lead to presumptive treatment and unnecessary prescription of antimicrobials. The widespread availability of antimicrobials over the counter and unexplained use of some antimicrobials in the animal health sector[21] may be additional contributing factors. Nonetheless, given this relatively higher AMC trend in Sierra Leone, AMU point-prevalence surveys are recommended to better understand the in-country AMC levels. This will eventually guide future national action plans to optimise AMC if any overuse or misuse is detected.

An evaluation of the antibiotics consumed according to the WHO AWaRe categories showed that the proportion of narrow-spectrum 'Access' category antibiotics consumed in Sierra Leone well exceeded the WHO-recommended minimum consumption threshold.[33] We also observed a lower consumption rate of the broader-spectrum 'Watch' class antibiotics. This finding is quite commendable as it implies that any emerging AMR trends due to misuse or overuse will likely be restricted to narrow-spectrum antibiotics, thus sparing the lesser-used broader-spectrum antibiotics in the 'Watch' category. However, a closer examination revealed that the top five antibiotics consumed in the 'Access' and 'Watch' categories made up an overwhelming majority of all antibiotics consumed in the respective categories. Such a consumption pattern may be sub-optimal as evolutionary pressures driving resistance would be focused only on the narrow band of antibiotics consumed.[44] This narrow consumption of antibiotics within the 'Access' and 'Watch' categories of antibiotics can also make the country susceptible to stock-outs in the event of manufacturing and supply chain issues. Considering these observations, it is therefore recommended that the country's ASPs explore ways to ensure a wider spread in the consumption of antibiotics within each WHO AWaRe category and ensure the appropriate use of antimicrobials.

Ciprofloxacin, which is one of the antimicrobials in the fluoroquinolones (J01MA) ATC class, was the highest-consumed antibiotic in the 'Watch' category. The consumption of this antibiotic remained high despite the removal of the two outlier importation quantities from 2018. According to the AMRCC, ciprofloxacin is known to be a widely overused or misused over-the-counter medication in the treatment of suspected typhoid fever or sexually transmitted infections.[25] Therefore, AMU studies should be conducted to determine the appropriateness of consumption of this antibiotic. Such studies will highlight the instances and settings where inappropriate antimicrobial use exists, help direct the country's antimicrobial stewardship activities and provide essential information that can be used to review the country's national clinical treatment guidelines.

None of the seven 'Reserve' category antibiotics listed in the WHO EML was consumed in Sierra Leone during the period reviewed.[33] This was expected as there are no 'Reserve' antibiotics listed in Sierra Leone's EML.[45] This finding suggests that this lack of consumption is due to the chronic lack of access to this group of antibiotics in Sierra Leone in 2017 and 2018 rather than a regulation of their consumption or a lack of need for their use. The AMRCC needs to urgently review the country's EML and ensure the availability of 'Reserve' category antibiotics where necessary.

The WHO also provides guidance on antibiotics that are 'not recommended' for use in clinical practice due to their broad-spectrum activity and a lack of clinical evidence supporting their use.[33] Three of such FDCs 'not recommended' for use by the WHO were used in Sierra Leone during the period reviewed. These are ampicillin/cloxacillin, ciprofloxacin/tinidazole and cefuroxime/clavulanic acid, with ampicillin/cloxacillin being the most common combination used. The clinical utility of these FDCs is questionable as the two antibiotics in each combination have overlapping spectra of activity and indications that require treatment with both antibiotics are uncommon.[46] Therefore, the AMRCC needs to identify the reasons why these FDCs were prescribed and the exact locations where they are commonly prescribed or dispensed. To correct this prescribing practice, the AMRCC should also sensitise prescribers on more appropriate treatment options for the identified ailments.

Data generated from the AMC and AMU surveillance activities can provide unique insights for national stewardship programmes and for the formulation of policies to stem the emergence of AMR. Sierra Leone should be commended for exceeding the minimum threshold of consumption (>60%) of antibiotics in the WHO 'Access' category (narrow-spectrum and first-choice antibiotics). There is, however, an opportunity for more diversification as only five antibiotics made up 78% of the total antibiotics consumed in this category. Table 13 describes the next steps for AMC and AMU surveillance.

Table 13: Next steps for AMC and AMU surveillance in Sierra Leone

A.

Leadership and Governance

The country will need to develop an AMC surveillance policy that addresses how, when and by whom 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 and 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). This will also help to inform and/or assess future policy decisions by the national antimicrobial stewardship programme.
- Lessons learned from the ongoing Fleming Fund Country Grants and the MoH surveillance programmes could be considered in the development of the policy.

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

The national stewardship programmes should work to review the national treatment guidelines and EML to include the essential 'Reserve' category 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. Alternatively, as only a limited number of facilities have such systems in place, the country could aim to prospectively collect this data as guided by the WHO methodology for point-prevalence surveys.[31]

National stewardship programmes, led by the AMRCC, should conduct educational campaigns for healthcare practitioners to ensure that they are aware of the full spectrum of antimicrobials available in the country's EML as well as the need to stop the use of unapproved FDCs.

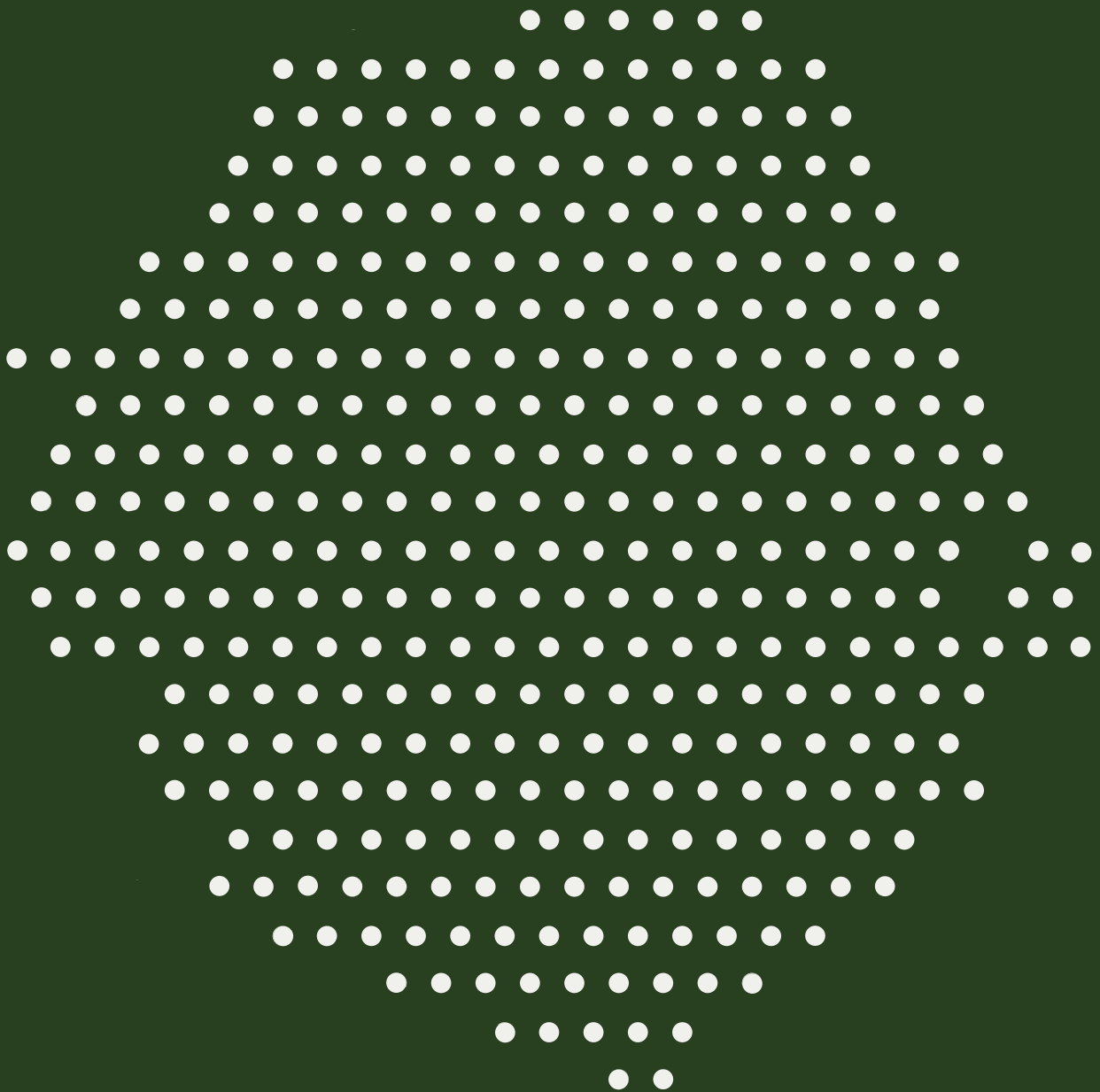
C.

Medical products and technologies

The national stewardship programmes should collaborate with pharmacists and medicine importers to increase the importation of more varieties of antibiotics (including 'Reserve' category antibiotics) as per the country's EML.

Abbreviations: AMC=antimicrobial consumption; AMRCC=antimicrobial resistance coordinating committee; AMU=antimicrobial use; EML=essential medicines list; FDC=fixed-dose combinations; GLASS=Global Antimicrobial Resistance Surveillance System; MAAP= Mapping Antimicrobial resistance and Antimicrobial use Partnership; MoH= Ministry of Health; PBSL= Pharmacy Board of Sierra Leone; WHO =World Health Organisation

Part E: Limitations



Since the participating laboratories were at different levels of service and had variable testing capacities, all results in this report should be interpreted with caution. The limitations of the current study are 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 the data to provide robust analyses of AMR and its clinical impact.

3. The seven 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 7.9 million). Furthermore, as routine testing does not appear to be the norm in most hospitals and laboratories (AST is mostly conducted in instances of failed therapy), the resistance rates in this study may have been overestimated.

4. Clinical data and antimicrobial usage information were not sufficient to allow robust analyses of AMR drivers.

5. National medicines importation data and purchasing records were used as an indicator of national AMC levels. In using this proxy data, we did not account for possible losses or re-exportation or re-sale of antimicrobials outside the country. We also assumed that all medicines imported were consumed locally before their expiry. Thus, the total AMC levels presented in this report might be an overestimation of the actual consumption levels.

6. A sample of 14 pharmacies, mostly from within the capital, Freetown, were purposively selected for AMC data collection. This sample size was a relatively small proportion of the total number of pharmacies in Sierra Leone. A more systematic sampling strategy that factors in the populations and geographical locations served will be required to draw more representative conclusions from pharmacy-level data.

7. MAAP was unable to obtain AMU data from the participating pharmacies co-located with AST laboratories and thus could not determine how and why antimicrobials were prescribed and dispensed (i.e., the appropriateness of prescriptions). This information is important to guide the country's stewardship programmes.

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Glossary

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

Antimicrobial consumption:
According to the WHO, antimicrobial consumption is defined as the 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 harder to treat and increasing the risk of disease spread, severe illness and death. As a result of drug resistance, antibiotics and other antimicrobial medicines become ineffective and infections become increasingly difficult or impossible to treat.

Antimicrobial resistance rate:
The extent to which a pathogen is resistant to a particular antimicrobial agent or class, determined by the proportion of isolates that are non-susceptible (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 extent to which a particular bacterium or fungus is sensitive to specific antibiotics.

Antimicrobial susceptibility testing standards:
These are standards to be followed by laboratories while performing AST. The standards are produced by several internationally recognised agencies such as the Clinical Laboratory Standards Institute, the 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. Firstly, each laboratory was assigned a data score based on their level of pathogen identification. Scoring was based on quartiles of the proportion of completely identified pathogens such that 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). Each laboratory was scored for each year reviewed, and then the average score was assigned as the laboratory data quality score. Secondly, the country data quality score was computed by weighting the laboratory data quality score with the quantum of valid cultures contributed by each laboratory. The maximum attainable country data quality score was 4.

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

GLASS:
According to the WHO, the 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:
The process of scoring the responses on the laboratory eligibility questionnaire to assess the laboratory's readiness or preparedness for AMR surveillance.

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

MAAP:
The Mapping Antimicrobial resistance and Antimicrobial use Partnership is a multi-organisational consortium of strategic and technical partners. It was set up to collect and analyse historical antimicrobial susceptibility and consumption or usage data collected between 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 the 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.

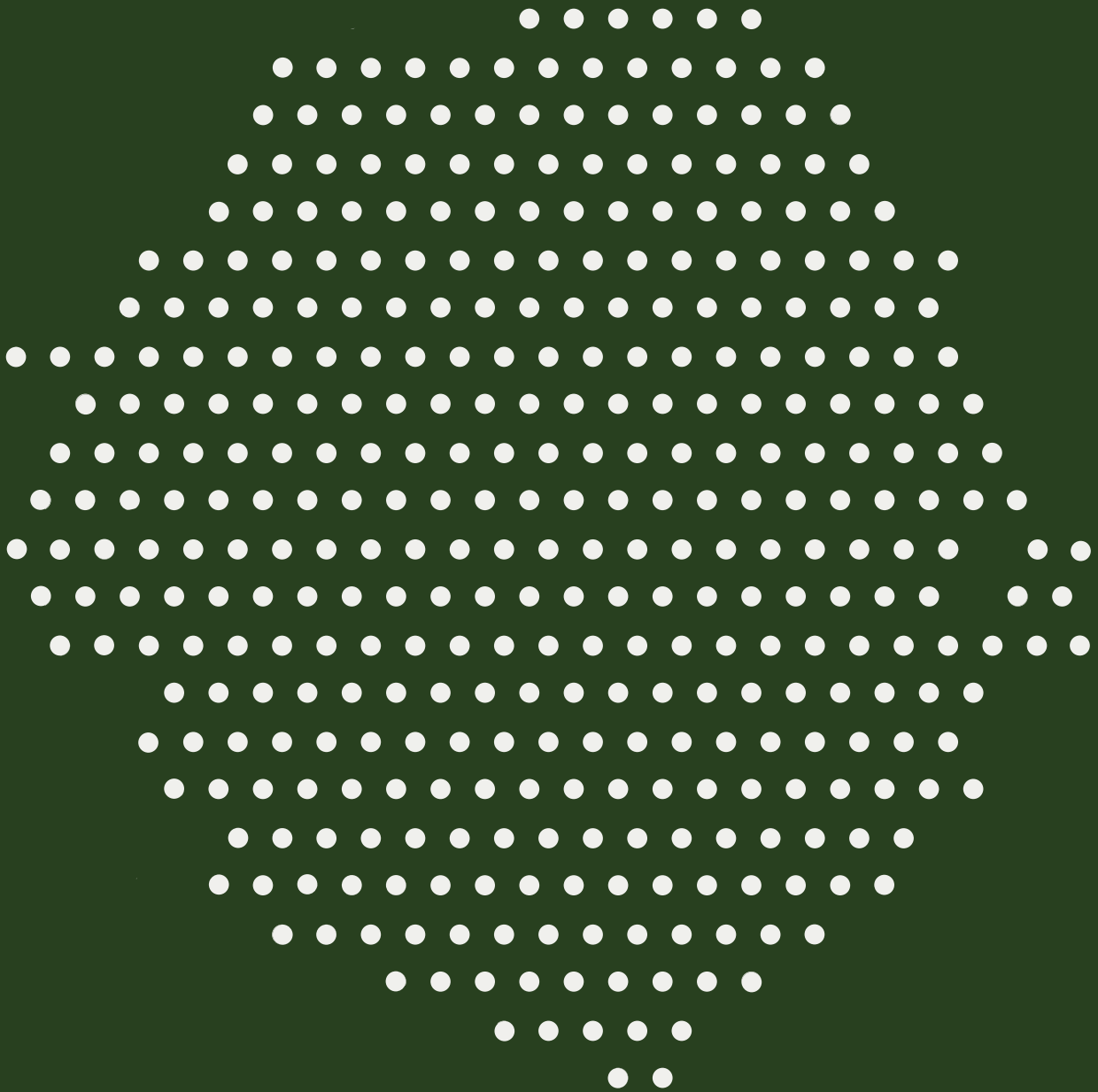
Quality Certification:
Certification is used for verifying that laboratory personnel have adequate credentials to practice certain disciplines, as well as for verifying that products meet certain requirements.

Quality Management Systems:
These are systematic and integrated sets of activities to establish and control the work processes (pre-analytical, analytical and post-analytical), manage resources, conduct evaluations and make continued improvements to ensure consistent quality results.

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

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

AMR Appendices and Supplementary Tables



Appendix 1: Data Sharing Agreement

Data-Sharing Agreement

Between

Ministry of Health of SIERRA LEONE

(The Provider)

And

The African Society for Laboratory Medicine (ASLM)

(Recipient)

1. Purpose of Agreement.

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

2. Description of Data.

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

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

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

3. Confidentiality, use and storage of data

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

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

Appendix 2: Laboratory Eligibility Questionnaire

Question	Response
Part 1: Site Information	
1.1 What is the name of the laboratory?	

1.2	Between 2016 and 2018, did the laboratory routinely conduct antimicrobial susceptibility testing?	Yes		No	
1.3	Is the laboratory willing to share 2016-2018 AST results with the MAAP consortium?	Yes		No	

1.4 What is the address of the laboratory?

1.5 What is the laboratory's level of service?

Reference- tier 3 or 4	Regional/Intermediate	District or community	Other

1.6 What is the laboratory's affiliation?

Government/Ministry of Health	Private	Non-government organisation	Other

1.7	Is the laboratory co-located in a clinical facility?	Yes		No	
1.8	Is a pharmacy co-located with the laboratory?	Yes		No	
1.9	Did the laboratory serve as a national AMR surveillance site at any time between 2016 and 2018?	Yes		No	
1.10	Is your country participating in the World Health Organisation's Global Antimicrobial Resistance Surveillance System (WHO GLASS)?	Yes		No	
Part 2: Commodity and Equipment					
2.1	Did the laboratory have regular power supply with functional back up, in place at any time between 2016-18?	Yes		No	
2.2	Did the laboratory have continuous water supply, in place at any time between 2016-18?	Yes		No	
2.3	Did the laboratory have certified and functional biosafety cabinet, in place at any time between 2016-18?	Yes		No	
2.4	Did the laboratory have automated methods for bacterial identification, in place at any time between 2016-18?	Yes		No	
2.5	Did the laboratory have automated methods for antimicrobial susceptibility testing, in place at any time between 2016-18?	Yes		No	
2.6	Did the laboratory test for mechanisms of antimicrobial resistance at any time between 2016-2018?	Yes		No	
Part 3. Quality Assurance (QA), Accreditation and Certification					
3.1A	Was the laboratory implementing quality management systems at any time between 2016-2018?	Yes		No	
3.1B	If you answered 'yes' to question 1A: What quality management tools did the laboratory utilize? (e.g., LQMS, SLIPTA, SLMTA, mentoring, others)				
3.2A	Did the laboratory receive a quality certification at any time between 2016-2018?	Yes		No	
3.2B	If you answered 'yes' to question 2A: What kind of quality certification did the laboratory receive? (e.g., SLIPTA, College of American pathologists)				
3.2C	If you answered 'yes' to question 2A: What was the laboratory's level of quality certification (e.g., star rating for SLIPTA certified laboratories)?				
3.3A	Was the laboratory accredited by a national or international body at any time between 2016-2018?	Yes		No	
3.3B	If you answered 'yes' to question 3A: What was the name of the accreditation body/bodies?				

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

Part 4. Personnel and Training

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

Part 5. Specimen Management

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

<200	200-1000	1000-3000	>3000

Part 6. Laboratory Information System and Linkage to Clinical Data

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

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

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

Appendix 3: Laboratory Readiness Assessment

The EQ questions were scored for laboratory readiness as follows:

Part 1: Site Information (Maximum score=0)

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

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

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

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

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

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

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

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

Part 5. Specimen Management (Maximum Score=3)

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

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

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

Appendix 4: Key AMR Variables

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

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

Appendix 5: WHO Priority Pathogens

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

**Previously known as Enterobacteriaceae.*

Appendix 6: Other clinically important pathogens

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

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

Appendix 7: Pathogen Phenotype Definitions

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

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

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

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

Appendix 8: Pathogens and antimicrobials for AMR drivers and DRI

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

AMR Supplementary Tables

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

Affiliation	All AST laboratories N = 7 n (%)	Reference N = 2 n (%)	Regional/ Intermediate N = 5 n (%)	District/ Community N = 0 n (%)	Unspecified N = 0 n (%)
Government	6 (85.71)	2 (100.0)	4 (80.0)	0	0
Private	1 (14.29)	0	1 (20.0)	0	0

Supplementary Table 2: Assessment of preparedness for AMR surveillance

Parameters	Surveyed laboratories N=7 n (%)
Commodity and equipment status	
Regular power supply and functional back up	6 (85.7)
Continuous water supply	5 (71.4)
Certified and functional biosafety cabinets	4 (57.1)
Automated methods for pathogen identification	2 (28.6)
Automated methods for antimicrobial susceptibility testing	1 (14.3)
Methods for testing antimicrobial resistance mechanisms	3 (42.9)
QMS implementation	
Reported QMS Implementation	**6 (85.7)**
• Reported QMS tool (n=6)	
• LQMS	**1 (16.7)**
• SLIPTA	**2 (33.3)**
• SLMTA	**0 (0)**
• Mentoring	**0 (0)**
• Combination‡	**1 (16.7)**
• Others	**2 (33.3)**
Quality Certification	**3 (4.29)**
• Reported certification type (n=3)	
• SLIPTA	**2 (66.7)**
• College of American Pathologists	**0 (0)**
• Others	**1 (33.3)**
Accreditation	3 (42.9)
Participation in proficiency testing	5 (71.4)
Utilization of reference strains	6 (85.7)
Reported consistent maintenance of QC records	6 (85.7)
Designated focal quality person	7 (100)
Reported compliance to standard operating procedures	7 (100)
Reported compliance to antimicrobial susceptibility testing standards	4 (57.1)
Personnel and training status	
Presence of at least one qualified microbiologist	6 (85.7)
Presence of an experienced laboratory scientist/technologist	7 (100)
Up-to-date and complete records on staff training and competence	5 (71.4)
Specimen Management status	
Reported compliance to standard operating procedures on specimen collection and testing	7 (100)
Reported compliance to standard operating procedures on specimen rejection	6 (85.7)
Availability on average number of specimens processed for culture and sensitivity in year 2018	6 (85.7)
Laboratory Information System and Linkage to Clinical Data	
Availability of system/database to store patient data	5 (71.4)
• System/database format (n=5)	
• Paper-based	1 (20.0)
• Electronic	0 (0)
• Mixed	4 (80.0)
Captured patients' demographics and clinical information on test request forms	6 (85.7)
• Retrievable test request forms (n=6)	4 (66.7)
Assigned specimen (laboratory) identification number	7 (100)

*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		587	2036	1580	122	344	288	109	344	270
Pathogen type	bacteria	-	-	-	111 (99.11)	344 (100.0)	286 (99.31)	108 (99.08)	344 (100.0)	268 (99.26)
	fungi	-	-	-	1 (0.89)	-	2 (0.69)	1 (0.92)	-	2 (0.74)
Age, years	Less than 1	-	3 (0.1)	7 (0.4)	-	-	1 (0.35)	-	-	1 (0.37)
	1 to 17	1 (0.2)	24 (1.2)	38 (2.4)	1 (0.89)	6 (1.74)	16 (5.56)	1 (0.92)	6 (1.74)	16 (5.93)
	18 to 49	27 (4.6)	68 (3.3)	102 (6.5)	10 (8.93)	9 (2.62)	34 (11.81)	10 (9.17)	9 (2.62)	34 (12.59)
	50 to 65	4 (0.7)	19 (0.9)	13 (0.8)	-	2 (0.58)	4 (1.39)	-	2 (0.58)	4 (1.48)
	Above 65	-	8 (0.4)	12 (0.8)	-	3 (0.87)	6 (2.08)	-	3 (0.87)	6 (2.22)
	Unknown Age	555 (94.5)	1911 (94.0)	1400 (89.1)	101 (90.18)	324 (94.19)	227 (78.82)	98 (89.91)	324 (94.19)	209 (77.41)
Gender	Male	290 (49.4)	1308 (64.3)	932 (59.3)	19 (16.96)	125 (36.34)	97 (33.68)	18 (16.51)	125 (36.34)	97 (35.93)
	Female	297 (50.6)	725 (35.7)	640 (40.7)	93 (83.04)	219 (63.66)	191 (66.32)	91 (83.49)	219 (63.66)	173 (64.07)
Laboratory	Lakka Lab	18 (3.1)	68 (3.3)	-	-	-	-	-	-	-
	Military Lab	170 (29.0)	2 (0.1)	24 (1.5)	70 (62.5)	2 (0.58)	24 (8.33)	69 (63.3)	2 (0.58)	24 (8.89)
	Kenema Lab	-	47 (2.3)	45 (2.9)	-	20 (5.81)	18 (6.25)	-	20 (5.81)	18 (6.67)
	ODCH Lab	-		89 (5.7)	-	-	31 (10.76)	-	-	31 (11.48)
	Bo Lab	-	8 (0.4)	33 (2.1)	-	-	6 (2.08)	-	-	6 (2.22)
	Ramsy Lab	399 (68.0)	1908 (93.9)	1336 (85.0)	42 (37.5)	322 (93.6)	195 (67.71)	40 (36.7)	322 (93.6)	177 (65.56)
	Connaught Lab	-	-	45 (2.9)	-	-	14 (4.86)	-	-	14 (5.19)

Supplementary Table 4: Specimen characteristics

Specimen Type	All years* N= 723 n (%)	2016 N = 109 n (%)	2017 N = 344 n (%)	2018 N = 270 n (%)
Urine	389 (53.8)	89 (81.7)	158 (45.9)	142 (52.6)
Swab (vaginal)	156 (21.6)	10 (9.2)	86 (25)	60 (22.2)
Abscess/Discharge/Pus/Swab/Wound	77 (10.7)	5 (4.6)	42 (12.2)	30 (11.1)
Semen	31 (4.3)	1 (0.9)	18 (5.2)	12 (4.4)
Stool	16 (2.2)	1 (0.9)	5 (1.5)	10 (3.7)
Others	54 (7.5)	3 (2.8)	35 (10.2)	16 (5.9)

**Indicates positive cultures with AST results*

Supplementary Table 5: Pathogen identification

Pathogen	All years* N=723 n(%)	2016 N=109 n(%)	2017 N=344 n(%)	2018 N=270 n(%)
Positive cultures with specific pathogen name	**177 (24.5)**	**53 (48.62)**	**63 (18.31)**	**61 (22.59)**
Candida albicans	1 (0.1)	1 (0.9)	-	-
Enterococcus faecalis	2 (0.3)	-	-	2 (0.7)
Escherichia coli	14 (1.9)	-	1 (0.3)	13 (4.8)
Neisseria gonorrhoeae	41 (5.7)	6 (5.5)	23 (6.7)	12 (4.4)
Neisseria meningitidis	2 (0.3)	-	-	2 (0.7)
Proteus vulgaris	1 (0.1)	-	-	1 (0.4)
Pseudomonas aeruginosa	5 (0.7)	-	3 (0.9)	2 (0.7)
Shigella dysenteriae	2 (0.3)	-	-	2 (0.7)
Staphylococcus aureus	67 (9.3)	32 (29.4)	19 (5.5)	16 (5.9)
Staphylococcus epidermidis	1 (0.1)	-	-	1 (0.4)
Staphylococcus saprophyticus	16 (2.2)	9 (8.3)	-	7 (2.6)
Streptococcus pneumoniae	20 (2.8)	1 (0.9)	17 (4.9)	2 (0.7)
Streptococcus pyogenes	1 (0.1)	1 (0.9)	-	-
Streptococcus viridans	4 (0.6)	3 (2.8)	-	1 (0.4)
Positive cultures with non-specific pathogen name	**546 (75.5)**	**56 (51.38)**	**281 (81.69)**	**209 (77.41)**
Acinetobacter Sp.	2 (0.3)	-	-	2 (0.7)
Anaerobes	2 (0.3)	-	1 (0.3)	1 (0.4)
Bacillus Sp.	28 (3.9)	-	28 (8.1)	-

Enterobacter Sp.	6 (0.8)	-	-	6 (2.2)
Enterococcus Sp.	3 (0.4)	-	1 (0.3)	2 (0.7)
Gram negative	179 (24.8)	13 (11.9)	79 (23)	87 (32.2)
Gram positive	113 (15.6)	6 (5.5)	48 (14)	59 (21.9)
Klebsiella Sp.	9 (1.2)	-	2 (0.6)	7 (2.6)
Neisseria Sp.	12 (1.7)	-	12 (3.5)	-
Proteus Sp.	2 (0.3)	-	-	2 (0.7)
Pseudallescheria Sp.	2 (0.3)	-	-	2 (0.7)
Pseudomonas Sp.	9 (0.3)	-	5 (1.5)	4 (1.5)
Salmonella Sp.	3 (0.4)	-	-	3 (1.1)
Staphylococcus Sp.	155 (21.4)	34 (31.2)	92 (26.7)	29 (10.7)
Streptobacillus Sp.	10 (1.4)	-	7 (2)	3 (1.1)
Streptococcus Sp.	11 (1.5)	3 (2.8)	6 (1.7)	2 (0.7)
Unspecified (Gram negative bacilli)	93 (12.9)	4 (3.7)	48 (14)	41 (15.2)
Unspecified (Gram negative bacteria)	1 (0.1)	-	-	1 (0.4)
Unspecified (Gram negative cocci)	46 (6.4)	7 (6.4)	16 (4.7)	23 (8.5)
Unspecified (Gram negative coccobacilli)	37 (5.1)	2 (1.8)	13 (3.8)	22 (8.1)
Unspecified (Gram positive bacilli)	27 (3.7)	-	24 (7)	3 (1.1)
Unspecified (Gram positive cocci)	77 (10.7)	6 (5.5)	19 (5.5)	52 (19.3)
Unspecified (Gram positive coccobacilli)	9 (1.2)	-	5 (1.5)	4 (1.5)
Unspecified (Gram variable coccobacilli)	2 (0.3)	-	2 (0.6)	-

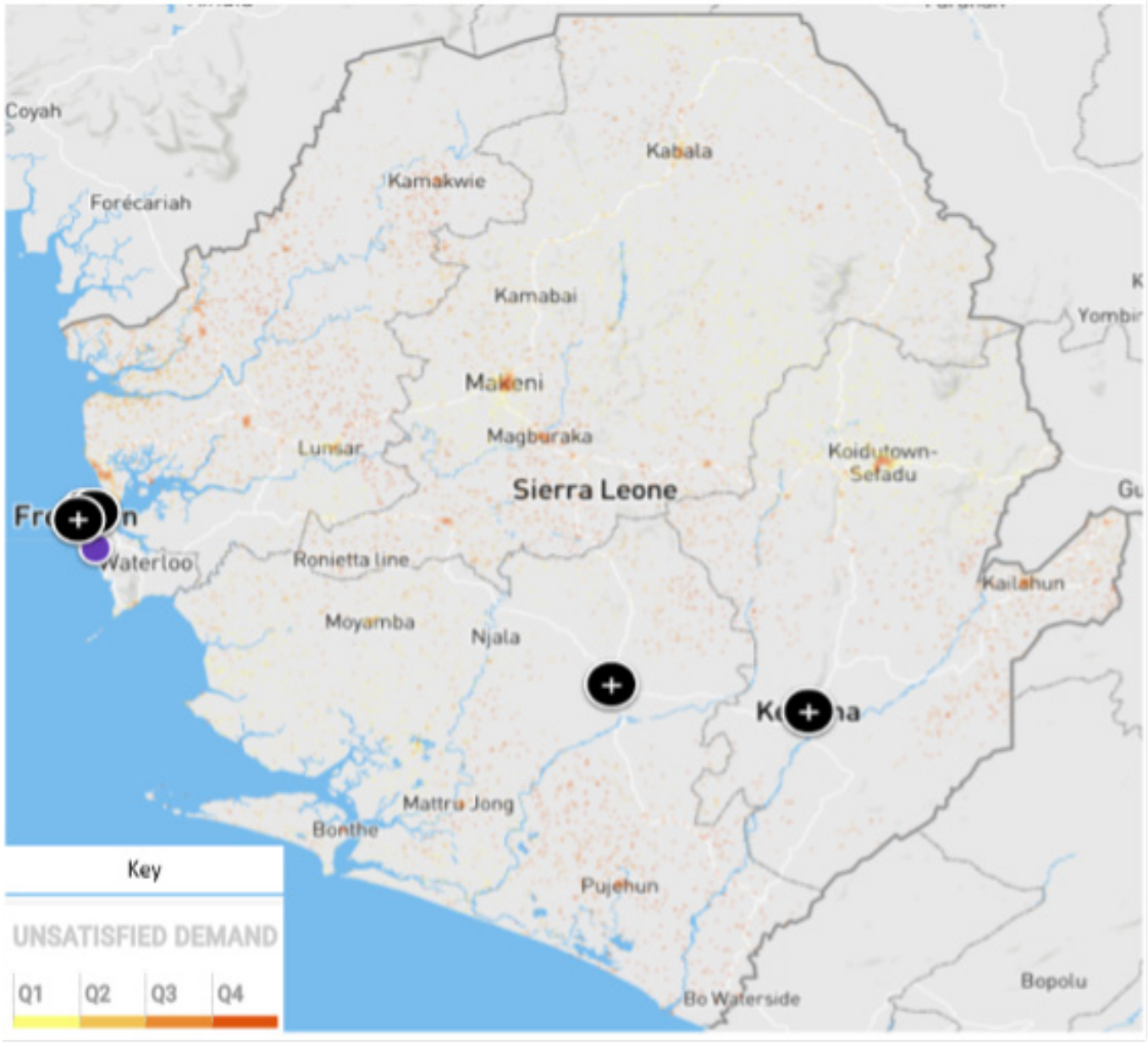
*Note: * indicates positive cultures with AST results; '-' means information was not available.*

Supplementary Table 6: Laboratory data scoring

Laboratory name	Laboratory data score (out of 4)			
	2016	2017	2018	Average
Kenema	-	3	2	2.5
ODCH	-	-	3	3
Military	3	2	3	2.7
Ramsy	2	1	1	1.3
Bo	-	-	2	2
Connaught	-	-	2	2

AMR Supplementary Figures

Supplementary Figure 1: Population coverage of laboratories



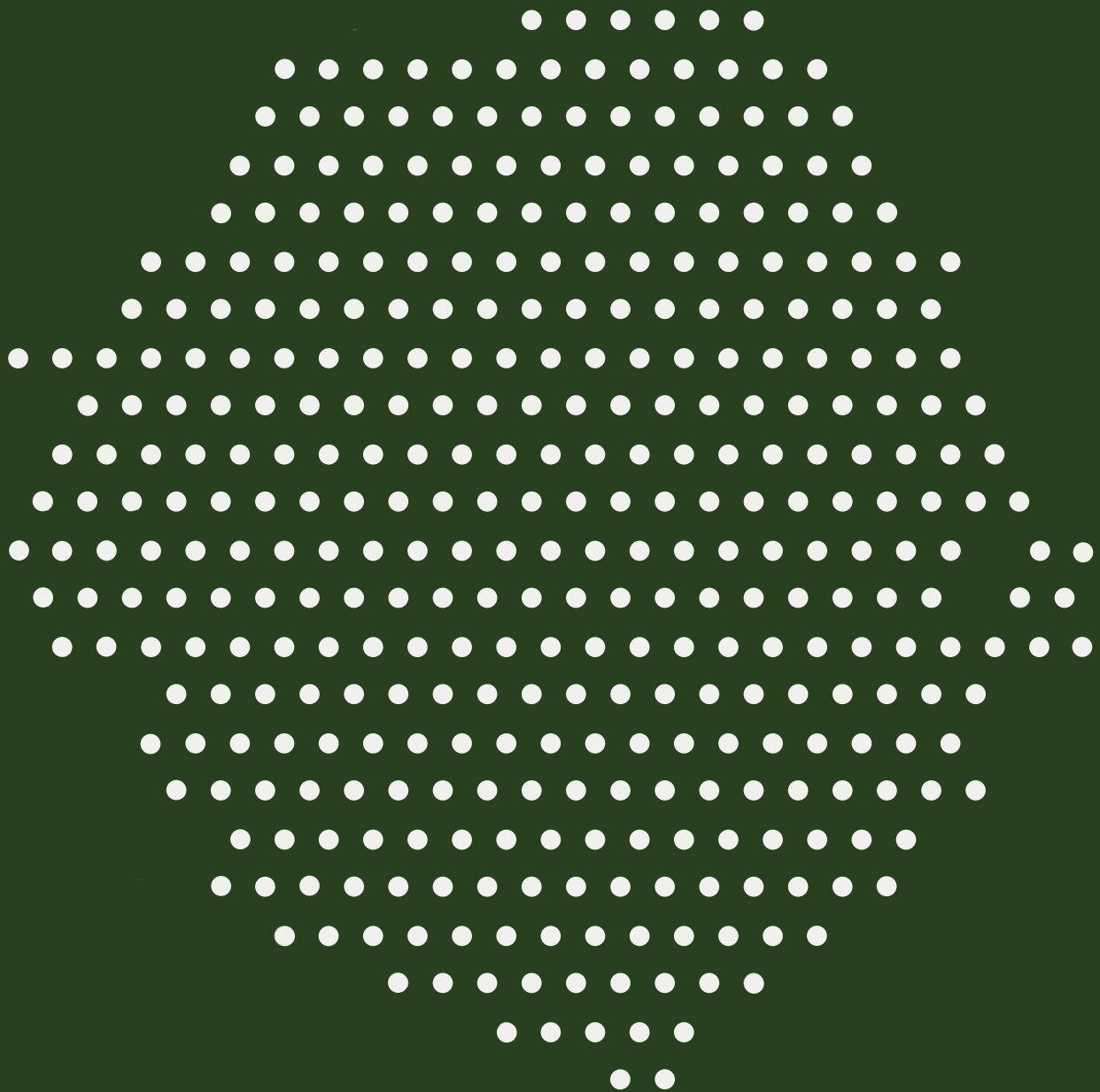
Supplementary Figure 2a: Inappropriate testing A

Organism Name	Antimicrobial Agent	Agent Code	Interpreted Results	Antimicrobial Susceptibility Method	Year
Neisseria gonorrhoeae	Fluconazole	FLU_ND25	R	Disk	2016
Staphylococcus sp.	Fluconazole	FLU_ND25	R	Disk	2016
Staphylococcus sp.	Fluconazole	FLU_ND25	R	Disk	2016
Staphylococcus aureus ss aureus	Fluconazole	FLU_ND25	R	Disk	2016
Staphylococcus aureus ss aureus	Fluconazole	FLU_ND25	R	Disk	2016
Staphylococcus	Fluconazole	FLU_ND25	I	Disk	2017
Staphylococcus sp.	Fluconazole	FLU_ND25	R	Disk	2018
Staphylococcus aureus ss aureus	Fluconazole	FLU_ND25	R	Disk	2018
Staphylococcus viridans	Fluconazole	FLU_ND25	R	Disk	2018
Staphylococcus aureus ss aureus	Fluconazole	FLU_ND25	S	Disk	2016
Staphylococcus	Fluconazole	FLU_ND25	S	Disk	2017
Staphylococcus	Fluconazole	FLU_ND25	S	Disk	2017

Supplementary Figure 2b: Inappropriate testing B

Organism Name	Antimicrobial Agent	Agent Code	Interpreted Results	Antimicrobial Susceptibility Method	Year
Staphylococcus aureus ss aureus	Cloxacillin	CLO_ND5	R	Disk	2016
Staphylococcus aureus ss aureus	Cloxacillin	CLO_ND5	R	Disk	2016
Staphylococcus aureus ss aureus	Cloxacillin	CLO_ND5	R	Disk	2016
Staphylococcus aureus ss aureus	Cloxacillin	CLO_ND5	R	Disk	2016
Staphylococcus aureus ss aureus	Cloxacillin	CLO_ND5	R	Disk	2016
Staphylococcus aureus ss aureus	Cloxacillin	CLO_ND5	R	Disk	2016
Staphylococcus aureus ss aureus	Cloxacillin	CLO_ND5	R	Disk	2016
Staphylococcus aureus ss aureus	Cloxacillin	CLO_ND5	R	Disk	2016
Staphylococcus aureus ss aureus	Cloxacillin	CLO_ND5	R	Disk	2016
Staphylococcus aureus ss aureus	Cloxacillin	CLO_ND5	R	Disk	2016
Staphylococcus aureus ss aureus	Cloxacillin	CLO_ND5	R	Disk	2016
Staphylococcus aureus ss aureus	Cloxacillin	CLO_ND5	R	Disk	2016
Staphylococcus aureus ss aureus	Cloxacillin	CLO_ND5	R	Disk	2016
Staphylococcus aureus ss aureus	Cloxacillin	CLO_ND5	R	Disk	2016
Staphylococcus aureus ss aureus	Cloxacillin	CLO_ND5	R	Disk	2016

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
Meticillin	J01CF03	U
Oxacillin	J01CF04	A
Flucloxacillin	J01CF05	A
Nafcillin	J01CF06	A
Sulbactam	J01CG01	U
Tazobactam	J01CG02	U
Ampicillin/Clavulanic Acid	J01CR01	A
Amoxicillin/Clavulanic Acid	J01CR02	A
Ticarcillin/Clavulanic Acid	J01CR03	W
Sultamicillin	J01CR04	A
Cefalexin	J01DB01	A
Cefaloridine	J01DB02	U
Cefalotin	J01DB03	A
Cefazolin	J01DB04	A
Cefadroxil	J01DB05	A
Cefazedone	J01DB06	A
Cefatrizine	J01DB07	A
Cefapirin	J01DB08	A
Cefradine	J01DB09	A
Cefacetrile	J01DB10	A
Cefroxadine	J01DB11	A
Ceftezole	J01DB12	A
Cefoxitin	J01DC01	W
Cefuroxime	J01DC02	W
Cefamandole	J01DC03	W
Cefaclor	J01DC04	W
Cefotetan	J01DC05	W
Cefonicid	J01DC06	W
Cefotiam	J01DC07	W
Loracarbef	J01DC08	U
Cefmetazole	J01DC09	W
Cefprozil	J01DC10	W
Ceforanide	J01DC11	W
Cefminox	J01DC12	W
Cefbuperazone	J01DC13	W

Flomoxef	J01DC14	W
Cefotaxime	J01DD01	W
Ceftazidime	J01DD02	W
Cefsulodin	J01DD03	U
Ceftriaxone	J01DD04	W
Cefmenoxime	J01DD05	W
Latamoxef	J01DD06	W
Ceftizoxime	J01DD07	W
Cefixime	J01DD08	W
Cefodizime	J01DD09	W
Cefetamet	J01DD10	W
Cefpiramide	J01DD11	W
Cefoperazone	J01DD12	W
Cefpodoxime	J01DD13	W
Ceftibuten	J01DD14	W
Cefdinir	J01DD15	W
Cefditoren	J01DD16	W
Cefcapene	J01DD17	W
Cefteram	J01DD18	W
Cefotaxime/Clavulanic Acid	J01DD51	W
Ceftazidime/Clavulanic Acid	J01DD52	W
Ceftazidime/Clavulanic Acid	J01DD52	W
Cefoperazone/Clavulanic Acid	J01DD62	W
Ceftriaxone/Clavulanic Acid	J01DD63	W
Cefpodoxime/Clavulanic Acid	J01DD64	W
Cefepime	J01DE01	W
Cefpirome	J01DE02	R
Cefozopran	J01DE03	R
Aztreonam	J01DF01	R
Carumonam	J01DF02	U
Meropenem	J01DH02	W
Ertapenem	J01DH03	W
Doripenem	J01DH04	W
Biapenem	J01DH05	W
Tebipenem Pivoxil	J01DH06	W
Imipenem/Cilastatin	J01DH51	W
Meropenem/Vaborbactam	J01DH52	R
Panipenem/Betamipron	J01DH55	U
Ceftobiprole Medocaril	J01DI01	R
Ceftaroline Fosamil	J01DI02	R
Faropenem	J01DI03	W

Ceftolozane/Tazobactam	J01DI54	U
Ceftolozane/Clavulanic Acid	J01DI54	R
Trimethoprim	J01EA01	A
Brodimoprim	J01EA02	U
Iclaprim	J01EA03	U
Sulfaisodimidine	J01EB01	U
Sulfamethizole	J01EB02	U
Sulfadimidine	J01EB03	U
Sulfapyridine	J01EB04	U
Sulfafurazole	J01EB05	U
Sulfanilamide	J01EB06	U
Sulfathiazole	J01EB07	U
Sulfathiourea	J01EB08	U
Sulfamethoxazole	J01EC01	U
Sulfadiazine	J01EC02	U
Sulfamoxole	J01EC03	U
Sulfadimethoxine	J01ED01	U
Sulfalene	J01ED02	U
Sulfametomidine	J01ED03	U
Sulfametoxydiazine	J01ED04	U
Sulfamethoxypyridazine	J01ED05	U
Sulfaperin	J01ED06	U
Sulfamerazine	J01ED07	U
Sulfaphenazole	J01ED08	U
Sulfamazone	J01ED09	U
Trimethoprim/Sulfamethoxazole	J01EE01	A
Sulfadiazine/Trimethoprim	J01EE02	A
Sulfametrole/Trimethoprim	J01EE03	A
Sulfamoxole/Trimethoprim	J01EE04	A
Sulfadimidine/Trimethoprim	J01EE05	U
Sulfadiazine/Tetroxoprim	J01EE06	U
Sulfamerazine/Trimethoprim	J01EE07	U
Erythromycin	J01FA01	W
Spiramycin	J01FA02	W
Midecamycin	J01FA03	W
Oleandomycin	J01FA05	W
Roxithromycin	J01FA06	W
Josamycin	J01FA07	W
Troleandomycin	J01FA08	U
Clarithromycin	J01FA09	W
Azithromycin	J01FA10	W

Miocamycin	J01FA11	U
Rokitamycin	J01FA12	U
Dirithromycin	J01FA13	W
Flurithromycin	J01FA14	U
Telithromycin	J01FA15	W
Solithromycin	J01FA16	U
Clindamycin	J01FF01	A
Lincomycin	J01FF02	W
Pristinamycin	J01FG01	W
Quinupristin/Dalfopristin	J01FG02	R
Streptomycin	J01GA01	A
Streptoduocin	J01GA02	U
Tobramycin	J01GB01	W
Gentamicin	J01GB03	A
Kanamycin	J01GB04	A
Neomycin	J01GB05	W
Amikacin	J01GB06	A
Netilmicin	J01GB07	W
Sisomicin	J01GB08	W
Dibekacin	J01GB09	W
Ribostamycin	J01GB10	W
Isepamicin	J01GB11	W
Arbekacin	J01GB12	W
Bekanamycin	J01GB13	U
Ofloxacin	J01MA01	W
Ciprofloxacin	J01MA02	W
Pefloxacin	J01MA03	W
Enoxacin	J01MA04	W
Temafloxacin	J01MA05	U
Norfloxacin	J01MA06	W
Lomefloxacin	J01MA07	W
Fleroxacin	J01MA08	W
Sparfloxacin	J01MA09	W
Rufloxacin	J01MA10	W
Grepafloxacin	J01MA11	U
Levofloxacin	J01MA12	W
Trovafloxacin	J01MA13	U
Moxifloxacin	J01MA14	W
Gemifloxacin	J01MA15	W
Gatifloxacin	J01MA16	W
Prulifloxacin	J01MA17	W

Pazufloxacin	J01MA18	W
Garenoxacin	J01MA19	W
Sitafloxacin	J01MA21	W
Tosufloxacin	J01MA22	W
Delafloxacin	J01MA23	W
Rosoxacin	J01MB01	U
Nalidixic acid	J01MB02	U
Piromidic Acid	J01MB03	U
Pipemidic Acid	J01MB04	U
Oxolinic Acid	J01MB05	U
Cinoxacin	J01MB06	U
Flumequine	J01MB07	W
Nemonoxacin	J01MB08	U
Cefuroxime/Metronidazole	J01RA03	U
Spiramycin/Metronidazole	J01RA04	W
Levofloxacin/Ornidazole	J01RA05	U
Cefepime/Amikacin	J01RA06	U
Azithromycin/Fluconazole/Secnidazole	J01RA07	U
Tetracycline/Oleandomycin	J01RA08	U
Ofloxacin/Ornidazole	J01RA09	U
Ciprofloxacin/Metronidazole	J01RA10	U
Ciprofloxacin/Tinidazole	J01RA11	U
Ciprofloxacin/Ornidazole	J01RA12	U
Norfloxacin/Tinidazole	J01RA13	U
Vancomycin	J01XA01	W
Teicoplanin	J01XA02	W
Telavancin	J01XA03	R
Dalbavancin	J01XA04	R
Oritavancin	J01XA05	R
Colistin	J01XB01	R
Polymyxin B	J01XB02	R
Fusidic Acid	J01XC01	W
Metronidazole	J01XD01	A
Tinidazole	J01XD02	U
Ornidazole	J01XD03	U
Nitrofurantoin	J01XE01	U
Nifurtoinol	J01XE02	U
Furazidin	J01XE03	U
Fosfomycin	J01XX01	R
Xibornol	J01XX02	U
Clofoctol	J01XX03	W

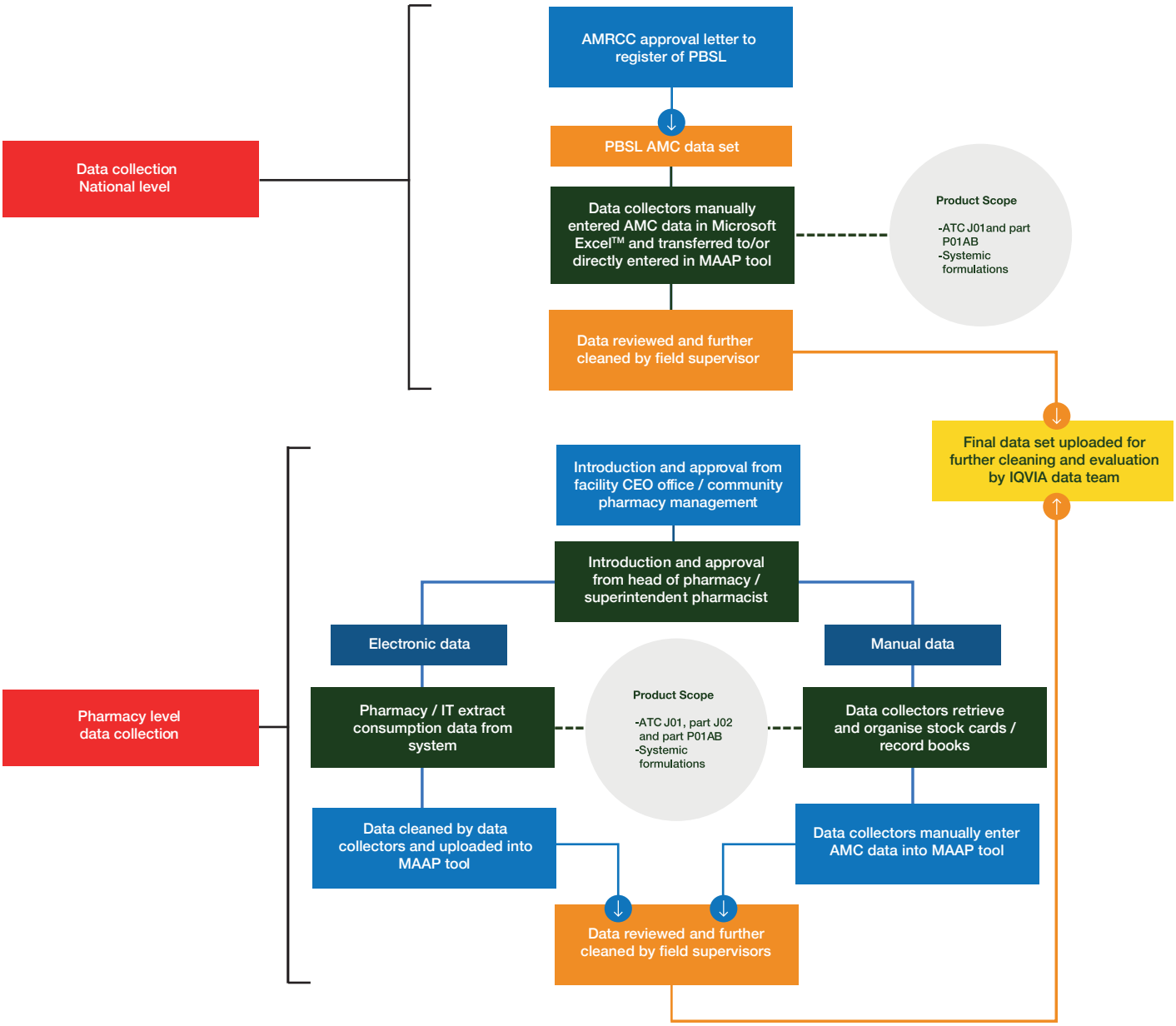
Spectinomycin	J01XX04	A
Linezolid	J01XX08	R
Daptomycin	J01XX09	R
Bacitracin	J01XX10	U
Tedizolid	J01XX11	R
Amphotericin B	J02AA01	N/A
Fluconazole	J02AC01	N/A
Itraconazole	J02AC02	N/A
Voriconazole	J02AC03	N/A
Posaconazole	J02AC04	N/A
Isavuconazole	J02AC05	N/A
Flucytosine	J02AX01	N/A
Caspofungin	J02AX04	N/A
Micafungin	J02AX05	N/A
Anidulafungin	J02AX06	N/A

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

Appendix 4: Key AMC specific variables

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

Appendix 5: Data collection process flowchart



**Pharmacy-level AMC data is a subset of the national-level AMC data; the two datasets were analysed and presented separately*

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 Sierra Leone 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 summarises how this calculation was done:

DDD/1000 Inhabitants/day =

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

*Sierra Leone population estimated for 2016-2018 obtained from: https://www.worldometers.info/world-population/sierra-leone-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 minimising the potential for resistance. The distribution of antibiotics in this group includes Beta (β)–lactam (52.63%), followed by aminoglycosides (15.78%), macrolides (5.26%), and tetracyclines (5.26%). '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 programmes and monitoring.

'Reserve' group antibiotics: 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; seven 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	Mean DDD/1000 inhabitant-days
			DDD/1000 inhabitant-days (%*)		
J01 Class		Total	75.32 (100)	151.32 (100)	113.32
1	Access	Amoxicillin	53.81 (71.4)	49.68 (32.8)	51.747
2	Access	Tetracycline	0.10 (0.1)	31.30 (20.7)	15.702
3	Access	Sulfamethoxazole/Trimethoprim	1.17 (1.6)	20.01 (13.2)	10.587
4	Uncategorised	Ampicillin/Cloxacillin	0.16 (0.2)	10.47 (6.9)	5.317
5	Access	Ampicillin	0.14 (0.2)	9.79 (6.5)	4.966
6	Watch	Ciprofloxacin	7.44 (9.9)	2.28 (1.5)	4.857
7	Access	Procaine benzylpenicillin	0.0008 (0)	9.22 (6.1)	4.611
8	Access	Phenoxymethylpenicillin	0.050 (0.1)	9.10 (6)	4.574
9	Watch	Erythromycin	5.60 (8)	0.72 (0.5)	3.358
10	Watch	Cefuroxime	0.094 (0.1)	3.80 (2.5)	1.946
11	Access	Cloxacillin	2.84 (3.8)	0.05 (0)	1.448
12	Watch	Cefixime	1.43 (1.9)	0.20 (0.1)	0.817
13	Access	Doxycycline	1.56 (2.1)	0.006 (0)	0.781
14	Access	Benzathine benzylpenicillin	0.01 (0)	1.51 (1)	0.763
15	Access	Benzylpenicillin	0.02 (0)	0.81 (0.5)	0.417
16	Access	Metronidazole	0.006 (0)	0.78 (0.5)	0.393
17	Access	Chloramphenicol	0.13 (0.2)	0.40 (0.3)	0.264
18	Watch	Ceftriaxone	0.10 (0.1)	0.38 (0.3)	0.244
19	Access	Gentamicin	0.048 (0.1)	0.26 (0.2)	0.156
20	Uncategorised	Ciprofloxacin/Tinidazole	0.037 (0)	0.22 (0.1)	0.127
21	Access	Amoxicillin/Clavulanic Acid	0.063 (0.1)	0.18 (0.1)	0.12
22	Watch	Azithromycin	0.073 (0.1)	0.13 (0.1)	0.099
23	Watch	Clarithromycin	0.016 (0)	0.0025 (0)	0.009
24	Uncategorised	Cefuroxime/Clavulanic Acid	0 (0)	0.011 (0)	0.005
25	Watch	Kanamycin	0.007 (0)	0 (0)	0.004
26	Watch	Ofloxacin	0.006 (0)	0 (0)	0.003
27	Access	Flucloxacillin	0 (0)	0.0025 (0)	0.001
28	Access	Clindamycin	0.0015 (0)	0.0004 (0)	0.001
29	Watch	Cefotaxime	0.0003 (0)	0.0005 (0)	0.00041
30	Access	Cefazolin	0 (0)	0.0003 (0)	0.00016
31	Access	Cefalexin	0 (0)	0.0001 (0)	0.00004
32	Watch	Levofloxacin	0 (0)	0.0001 (0)	0.000038
P01AB Class			2.96 (100)	1.39 (100)	2.18
1	Access	Metronidazole	2.96 (100)	1.39 (100)	2.18
2	Uncategorised	Tinidazole	0.0001 (0)	0.0002 (0)	0.00018

**Percentage is reflective of AMC of each molecule to total national AM*

Appendix 8: Breakdown of national AMC by ATC classes

ATC class	% consumption 2017	2018
Penicillins with extended spectrum	68.9%	38.9%
Tetracyclines	2.1%	20.5%
Beta-lactamase sensitive penicillins	0.1%	13.5%
Combinations of sulfonamides and trimethoprim, incl. Derivatives	1.5%	13.1%
Combinations of penicillins, incl. Beta-lactamase inhibitors	0.3%	7.0%
Second-generation cephalosporins	0.1%	2.5%
Fluoroquinolones	9.5%	1.5%
Nitroimidazole derivatives	3.8%	0.9%
Macrolides	7.8%	0.6%
Imidazole derivatives	0.0%	0.5%
Third-generation cephalosporins	2.0%	0.4%
Amphenicols	0.2%	0.3%
Aminoglycosides	0.1%	0.2%
Combinations of antibacterials	<0.1%	0.1%
Beta-lactamase resistant penicillins	3.6%	<0.1%
Lincosamides	<0.1%	<0.1%
First-generation cephalosporins	<0.1%	<0.1%

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

Standardised Molecule Name	WHO AWaRe Categorisation	WHO ATC Code	WHO EML	National EML	Documented Data
Linezolid	Reserve	J01XX08	Y	N	N
Amikacin	Access	J01GB06	Y	Y	N
Amoxicillin	Access	J01CA04	Y	Y	Y
Amoxicillin/Clavulanic Acid	Access	J01CR02	Y	Y	Y
Amoxicillin/Flucloxacillin		J01CR50	N	N	Y
Ampicillin	Access	J01CA01	Y	Y	Y
Ampicillin/Cloxacillin		J01CR50	N	N	Y
Azithromycin	Watch	J01FA10	Y	Y	Y
Benzathine benzylpenicillin	Access	J01CE08	Y	Y	Y
Benzylpenicillin	Access	J01CE01	Y	Y	Y
Cefalexin	Access	J01DB01	Y	N	Y
Cefalexin	Access	J01DB01	N	Y	N
Cefazolin	Access	J01DB04	Y	N	Y
Cefiderocol	Reserve	J01DI04	Y	N	N
Cefixime	Watch	J01DD08	Y	Y	Y
Cefotaxime	Watch	J01DD01	Y	N	Y
Ceftazidime	Watch	J01DD02	Y	N	N
Ceftazidime/avibactam	Reserve	J01DD52	Y	N	N
Ceftriaxone	Watch	J01DD04	Y	Y	Y
Cefuroxime	Watch	J01DC02	Y	Y	Y
Cefuroxime/Clavulanic Acid		J01DC--	N	N	Y
Chloramphenicol	Access	J01BA01	Y	Y	Y
Ciprofloxacin	Watch	J01MA02	Y	Y	Y
Ciprofloxacin/Tinidazole		J01RA11	N	N	Y
Clarithromycin	Watch	J01FA09	Y	N	Y
Clindamycin	Access	J01FF01	Y	Y	Y
Cloxacillin	Access	J01CF02	Y	Y	Y
Colistin	Reserve	J01XB01	Y	N	N

Doxycycline	Access	J01AA02	Y	Y	Y
Erythromycin	Watch	J01FA01	N	Y	Y
Flucloxacillin	Access	J01CF05	N	N	Y
Fosfomycin (IV)	Reserve	J01XX01	Y	N	N
Gentamicin	Access	J01GB03	Y	Y	Y
Kanamycin	Watch	J01GB04	N	Y	Y
Levofloxacin	Watch	J01MA12	N	Y	Y
Lincomycin	Watch	J01FF02	N	Y	N
Meropenem	Watch	J01DH02	Y	N	N
Meropenem/vaborbactam	Reserve	J01DH52	Y	N	N
Metronidazole	Access	P01AB01, J01XD01	Y	Y	Y
Nalidixic Acid		J01MB02	N	Y	N
Nitrofurantoin	Access	J01XE01	Y	N	N
Norfloxacin	Watch	J01MA06	N	N	Y
Ofloxacin	Watch	J01MA01	N	Y	Y
Phenoxymethylpenicillin	Access	J01CE02	Y	Y	Y
Piperacillin/tazobactam	Watch	J01CR05	Y	N	N
Plazomicin	Reserve	J01GB14	Y	N	N
Polymyxin-B	Reserve	J01XB02	Y	N	N
Procaine benzylpenicillin	Access	J01CE09	Y	Y	Y
Pyrimethamine/Sulfadoxine		P01BD51	N	Y	Y
Secnidazole		J01RA07	N	N	Y
Spectinomycin	Access	J01XX04	Y	Y	N
Streptomycin	Watch	J01GA01	N	Y	Y
Sulfamethoxazole/Trimethoprim	Access	J01EE01	Y	Y	Y
Tetracycline	Access	J01AA07	N	Y	Y
Tinidazole		P01AB02	N	N	Y
Trimethoprim	Access	J01EA01	Y	N	N
Vancomycin	Watch	J01XA01	Y	N	N

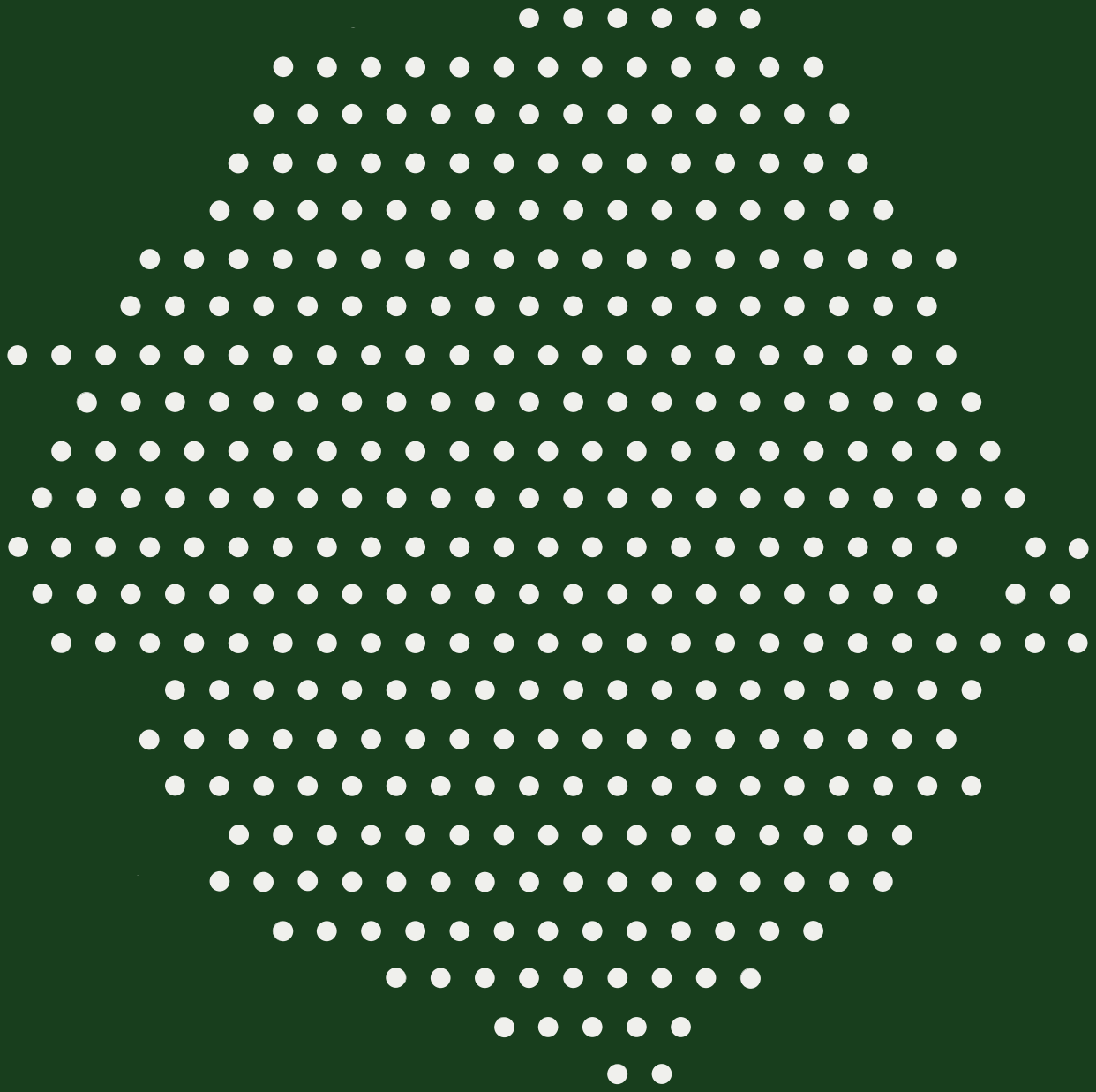
Appendix 10: AMC data collection and expired drug and losses tool

AMC Data Collection Tool

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

Expired Drug and Losses Tool

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



MAAP
Mapping AMR & AMU Partnership

The Fleming Fund
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