MAAP
Mapping AMR & AMU Partnership

Annual Report

# National Situation of Antimicrobial Resistance and Consumption Analysis from 2016-2018


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

**Year:** 2022

Zimbabwe (2016-2018)

ZIMBABWE

Fleming Fund Regional Grant (Round 1)

**Mapping Antimicrobial Resistance and Antimicrobial Use Partnership**

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

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

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# Abbreviations

| | |
|---|---|
| AMC | Antimicrobial Consumption |
| AMR | Antimicrobial Resistance |
| AMRCC | Antimicrobial Resistance Coordinating Committee |
| AMU | Antimicrobial Use |
| ASLM | African Society for Laboratory Medicine |
| ASP | Antimicrobial Stewardship Programme |
| AST | Antibiotic Susceptibility Testing |
| ATC | Anatomical Therapeutic Chemical |
| AWaRe | Access, Watch and Reserve |
| CDDEP | Center for Disease Dynamics, Economics and Policy |
| CI | Confidence Interval |
| CLSI | Clinical and Laboratory Standards Institute |
| CMS | Central Medical Store |
| CSF | Cerebrospinal Fluid |
| DDD | Defined Daily Dose |
| DID | DDD per 1,000 inhabitants per day |
| DRI | Drug Resistance Index |
| ECSA-HC | East, Central and Southern Africa Health Community |
| EML | Essential Medicines List |
| EDLIZ | Essential Medicines List for Zimbabwe |
| EQA | External Quality Assessment |
| EUCAST | European Committee on Antibiotic Susceptibility Testing |
| FDC | Fixed-Dose Combinations |
| GAP | Global Action Plan |
| GDP | Gross Domestic Product |
| GLASS | Global Antimicrobial Resistance Surveillance System |
| HIS | Hospital Information System |
| InSTEDD | Innovative Support to Emergencies, Diseases and Disasters |
| KIIs | Key Informant Interviews |
| LIS | Laboratory Information System |
| LMIC | Low- and Middle-Income Country |
| LQMS | Laboratory Quality Management System |
| MAAP | Mapping Antimicrobial resistance and Antimicrobial use Partnership |
| MCAZ | Medicines Control Authority of Zimbabwe |
| MoH | Ministry of Health |
| MoHCC | Ministry of Health and Child Care |
| MRSA | Methicillin-resistant Staphylococcus aureus |
| NatPharm | National Pharmaceutical Company |
| NCD | Non-Communicable Disease(s) |
| OR | Odds Ratio |
| QA | Quality Assessment |
| QC | Quality Control |
| QMS | Quality Management System |
| RSN | ResistanceMap Surveillance Network |
| SLIPTA | Stepwise Laboratory Improvement Process Towards Accreditation |
| SLMTA | Strengthening Laboratory Management Towards Accreditation |
| SOP | Standard Operating Procedure |
| SSTI | Skin and Soft Tissue Infections |
| 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, the availability of 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 Zimbabwe from 2016-2018.

Zimbabwe had approximately 1 630 laboratories in the national laboratory network during the study period, of which 23 were reported to have bacteriology testing capacity. Based on self-reported information, the functioning and quality compliance practices in 22 laboratories were assessed to understand laboratory preparedness for AMR surveillance. The AMR rates presented in this report are based on an analysis of antimicrobial susceptibility results 0f 14 887 positive cultures obtained from 14 laboratories. There were high rates of third-generation cephalosporin-resistant Enterobacterales (41-54%), methicillin-resistant Staphylococcus aureus (MRSA) (35-50%) and fluoroquinolone-resistant Salmonella species (38-41%). There was no association between the available patient variables and AMR. All results should be interpreted with caution because the participating laboratories were at different levels of service and had variable testing capacities.

AMC is measured as the quantity of antimicrobials sold or dispensed, whereas AMU reviews whether antimicrobials are used appropriately based on additional data such as clinical indicators. Only AMC data were retrievable at the selected sentinel pharmacies. AMU data were not obtained due to the lack of unique patient identifiers and tracking systems across hospital departments. National AMC data for 2016 was not available at the time of MAAP data collection due to limitations in the data formats and completeness of the datasets. The average national total AMC level in Zimbabwe between 2017-2018 was 32.1 defined daily doses (DDD) per 1 000 inhabitants per day (DID), ranging from 25.5 in 2017 to 38.7 in 2018.

Based on the World Health Organisation (WHO) Anatomical Therapeutic Chemical (ATC) classification of antimicrobials, combinations of sulfonamides and trimethoprim, including derivatives were the most consumed antimicrobial class in Zimbabwe (range 36.7% to 44.4%). This was followed by penicillins with extended spectrum (range 15.4% to 18.9%) and second-generation cephalosporins (range 2.2% to 14.0%). The top five most consumed antimicrobials were sulfamethoxazole/trimethoprim, amoxicillin, cefuroxime, doxycycline and ciprofloxacin. Together, these antimicrobials accounted for 82.0% 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, 75.9% of the antimicrobials consumed in Zimbabwe were in the 'Access' category, 24.1% were in the 'Watch' category and <0.1% were in the 'Reserve' category. Between 2017-2018, the use of 'Access' category antibiotics exceeded the WHO minimum recommended consumption threshold of 60%.

Drug resistance index (DRI) is a simple metric based on aggregate rates of resistance and measured on a scale of 0-100, where 0 indicates 'fully susceptible' and 100 indicates 'fully resistant'. The DRI estimate was high (66.6%; 95% confidence interval [CI]: 52.6-80.6%), implying low antibiotic effectiveness, which is a threat to effective infectious disease management and calls for urgent policy intervention.

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

- To strengthen the delivery of services by the laboratories, we recommend that all laboratories are mapped across a range of indicators, including population coverage, infectious disease burden, testing capabilities and quality compliance. This would inform decision makers on unmet needs and decide a way forward for 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 point-prevalence surveys on a larger scale 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 2016-2018 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 Zimbabwe using available historical data

## Specific Objectives

- To assess the sources and quality of historical AMR data generated routinely by the national laboratory network of Zimbabwe, 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).

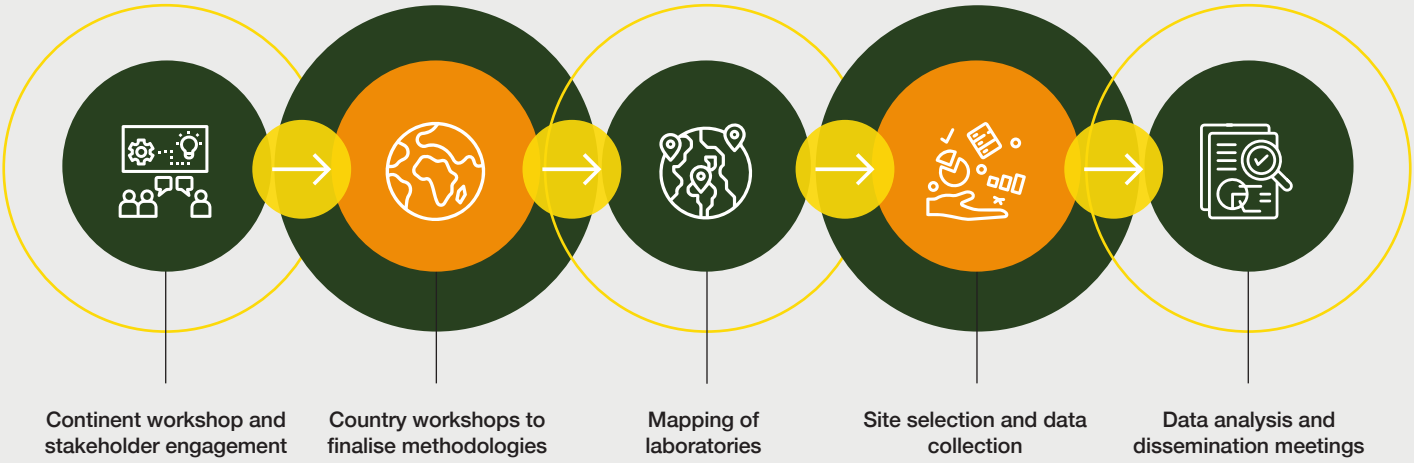



*Figure 1: Key engagements and activities*

## 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, Zimbabwe was estimated to have a population of 14.9 million inhabitants and a life expectancy of 62 years. The country has a high infectious disease burden, with a TB incidence of 193 per 100 000 and an HIV prevalence of 11.9%. The country has a physicians density of 0.21 per 1 000 inhabitants and a nurses density of 1.93 per 1 000 inhabitants. With a universal health coverage index of 55, Zimbabwe appears to have an above-average coverage of essential services (Table 1).

*Table 1: Health and demographic profile of Zimbabwe*

| | Zimbabwe | | Comparator values (most recent year)* | | |
|---|---|---|---|---|---|
| | Year | Value | India | Argentina | United States |
| Population | 2020 | 14 862 927 | 1 380 004 390 | 45 376 763 | 329 484 123 |
| Life expectancy during the study period, total (years) | 2019 | 62 | 70 | 77 | 79 |
| Universal health coverage service index (0-100) | 2019 | 55 | 61 | 67 | 83 |
| GDP per capita (current US$) | 2020 | 1 214.51 | 1 927.7 | 8 579.0 | 63 593.4 |
| Immunisation, DPT (% of children ages 12-23 months) | 2019 | 90 | 91.0 | 86.0 | 94.0 |
| Incidence of tuberculosis (per 100 000 people) | 2020 | 193 | 188.0 | 31.0 | 2.4 |
| Prevalence of HIV, total (% of population ages 15-49)# | 2020 | 11.9 | 0.2* | 0.4<br>2020 | 0.4<br>2019 |
| Primary education (%)# | 2019 | 90.02 | 94.6 | 98.6 | 100 |
| Physicians density (physicians per 1 000)# | 2018 | 0.21 | 0.93 | 4.0 | 2.6 |
| Nurses density (nurses and midwives per 1 000)# | 2018 | 1.935 | 2.39 | 2.60 | 15.69 |

Sourced from World Bank4,5 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)
Abbreviations: GDP=gross domestic product

## Policy frameworks

In May 2015, the World Health Assembly approved the Global Action Plan on Antimicrobial Resistance.[8] Later that year, the WHO launched the Global Antimicrobial Resistance Surveillance System (GLASS)[9] to support the implementation of the Global Action Plan on Antimicrobial Resistance and strengthen AMR surveillance and research. 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.

Zimbabwe enrolled in GLASS in November 2016 and has been providing information on the national surveillance to GLASS in all three data calls, the last being in 2019.[10-12] Zimbabwe launched its One Health Antimicrobial Resistance National Action Plan in 2017, with objectives aligned to the WHO Global Action Plan.

# 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 Zimbabwe, 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

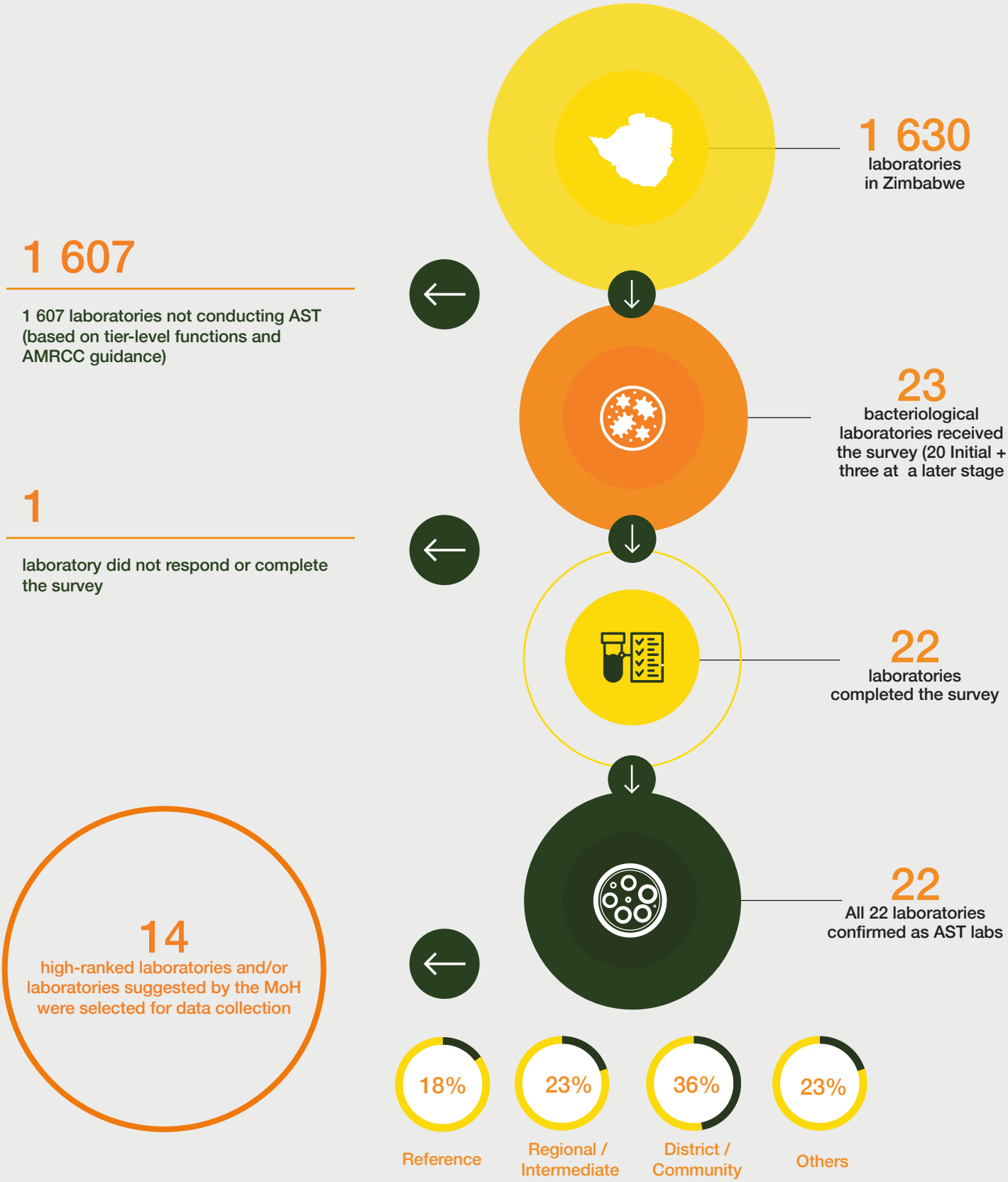
### Mapping and selection of laboratories

During the initial stages of in-country work in Zimbabwe, 1 630 laboratories were mapped to the national laboratory network. An eligibility questionnaire was sent to 23 laboratories identified as having bacteriology testing capacity. Of the 22 laboratories that responded to the questionnaire and had AST capacity, the majority were affiliated with the government (Table 2, Supplementary Table 1). The laboratory readiness scores of the surveyed laboratories varied widely (range: 36.8%-89.5%). Fourteen of the 22 laboratories were selected for data collection (Figure 2).

*Table 2: Laboratory readiness scores*

| Surveyed laboratories* | Laboratory readiness score (%) | Level of service | Affiliation |
|---|---|---|---|
| **Selected** | | | |
| CIMAS MED Labs (CIMAS) | 73.7 | Other | Private |
| Parirenyatwa Group of Hospitals (Parirenyatwa) | 68.4 | Reference | Government |
| National Microbiology Reference Laboratory (NMRL) | 63.2 | Reference | Government |
| Gweru Provincial Hospital Laboratory (Gweru) | 63.2 | Regional/Intermediate | Government |
| Harare Central Hospital Laboratory (Harare) | 60.5 | Other | Government |
| Masvingo Provincial Hospital Laboratory (Masvingo) | 60.5 | Regional/Intermediate | Government |
| Beitbridge District Hospital Laboratory (Beitbridge) | 60.5 | District/Community | Government |
| Bindura Provincial Hospital (Bindura) | 55.3 | Regional/Intermediate | Government |
| Mutare Provincial Hospital Laboratory (Mutare) | 55.3 | Regional/Intermediate | Government |
| Kwekwe General Hospital Laboratory (Kwekwe) | 52.6 | District/Community | Government |
| United Bulawayo Hospital Laboratory (United Bulawayo) | 52.6 | N/A | Government |
| Chitungwiza Central Hospital (Chitungwiza) | 50 | Regional/Intermediate | Government |
| Beatrice Road Infectious Disease Hospital Laboratory (Beatrice) | 47.4 | Reference | Government |
| Mpilo Central Hospital/ Bulawayo Group Laboratory (Mpilo) | 42.1 | Reference | Government |
| **Not selected** | | | |
| Lancet Clinical Laboratories Zimbabwe | 89.5 | Other | Private |
| Premier Service Medical Investments/PSMI laboratories | 76.3 | Other | Private |
| Kadoma General Hospital | 68.4 | District/Community | Government |
| Chegutu District Hospital | 47.4 | District/Community | Government |
| Murambinda Mission Hospital | 42.1 | District/Community | Government |
| Rusape General Hospital Laboratory | 42.1 | District/Community | Government |
| Gokwe North District Laboratory | 42.1 | District/Community | Government |
| Chipinge District Hospital | 36.8 | District/Community | 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; MoH=Ministry of Health

*Figure 2: Selection of laboratories in Zimbabwe*

## Surveillance preparedness of surveyed laboratories

Based on the self-reported information from the 22 laboratories, we assessed their laboratory functions and quality compliance practices to understand their preparedness for AMR surveillance. Nineteen laboratories had implemented a QMS, and 13 laboratories had at least one qualified microbiologist on board. Four laboratories were accredited or 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.

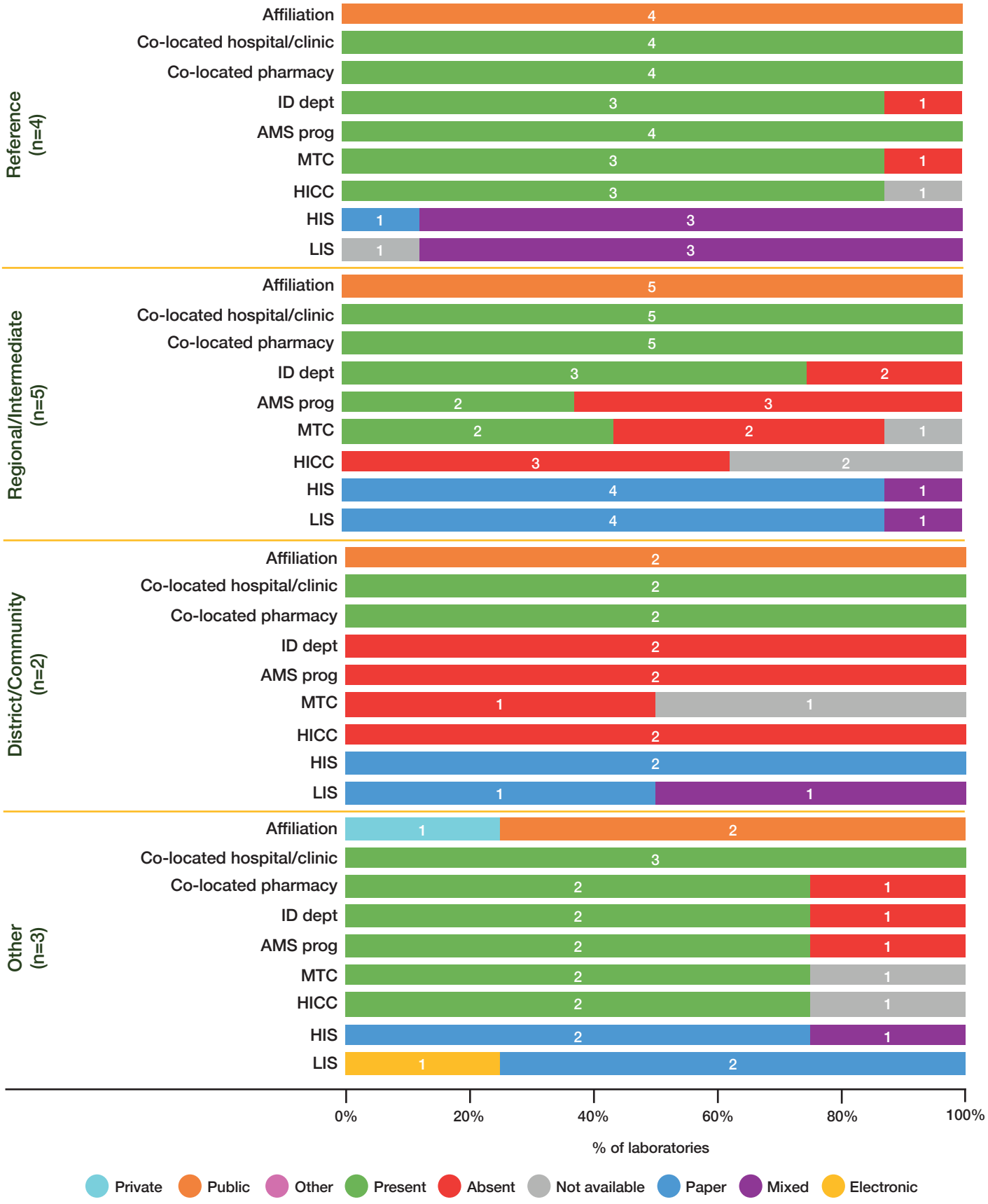
| | Parameters | | | N (%) |
|---|---|---|---|---|
| Commodity and equipment status | Regular power supply and functional back up | | | 17 (77.3) |
| | Continuous water supply) | | | 17 (77.3) |
| | Certified and functional biosafety cabinets | | | 16 (72.7) |
| | Automated methods for pathogen identification | | | 4 (18.2) |
| | Automated methods for AST | | | 4 (18.2) |
| | Methods for testing AMR mechanisms | | | 9 (40.9) |
| QMS implementation | Reported QMS Implementation | | | 19 (86.4) |
| | | Types of QMS | LQMS | - |
| | | | SLIPTA | - |
| | | | SLMTA | - |
| | | | Mentoring | - |
| | | | Combination‡ | - |
| | | | Others | - |
| | Quality Certification | | | 11 (50.0) |
| | | Types of Quality certification | SLIPTA | - |
| | | | Col. of Am. Path | - |
| | | | Others | - |
| | Accreditation | | | 4 (18.2) |
| | Participation in proficiency testing | | | 18 (81.8) |
| | Utilization of reference strains | | | 16 (72.7) |
| | Reported consistent maintenance of QC records | | | 21 (95.5) |
| | Designated focal quality person | | | 18 (81.8) |
| | Reported compliance to standard operating procedures | | | 21 (95.5) |
| | Reported compliance to AST standards | | | 12 (54.5) |
| Personnel and training status | Presence of at least one qualified microbiologist | | | 13 (59.1) |
| | Presence of an experienced laboratory scientist/technologist | | | 22 (100) |
| | Up-to-date and complete records on staff training and competence | | | 19 (86.4) |
| Specimen Management status | Reported compliance to SOPs on specimen collection and testing | | | 22 (100) |
| | Reported compliance to SOPs on specimen rejection | | | 22 (100) |
| | Average number of specimens processed for AST in 2018 | | | 21 (95.5) |
| LIS and Linkage to Clinical Data | Assigned specimen (laboratory) identification number | | | 22 (100) |
| | Availability of system/database to store patient data | | | 18 (81.1) |
| | | Database format | Paper-based | 10 (55.5) |
| | | | Electronic | 2 (11.1) |
| | | | Mixed | 6 (33.3) |
| | Captured patients' records on test request forms | | | 22 (100) |
| | | | Retrievable | 12 (54.5) |

‡ 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

All 14 selected laboratories were co-located with clinical facilities. Six clinical facilities lacked infectious disease departments and/or ASPs. Seven facilities had medical therapeutic committees and four had hospital infection control committees. Most laboratories and hospitals had paper-based information systems (Figure 4).



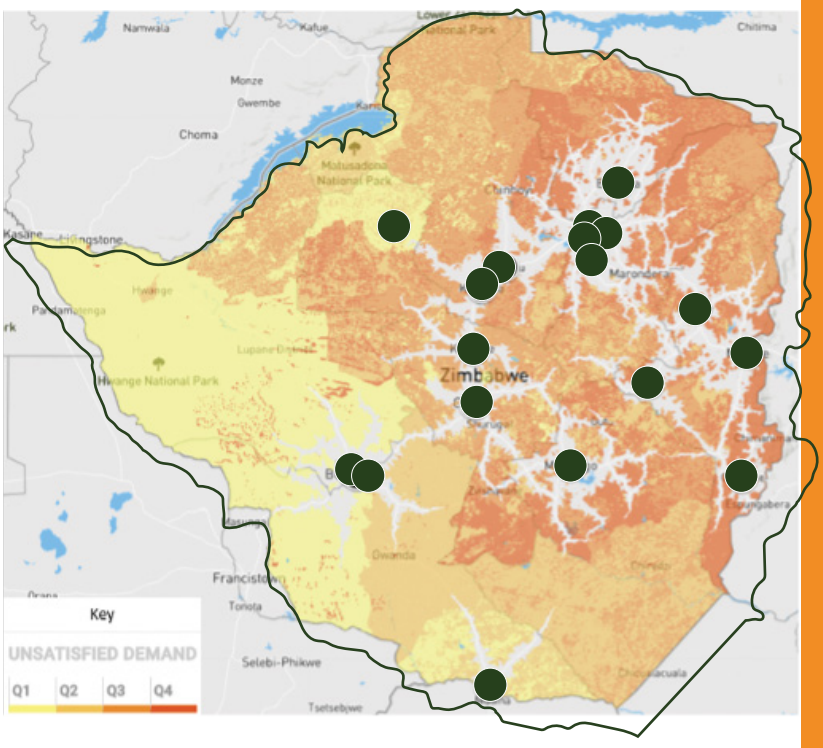

Abbreviations: AMS prog=antimicrobial stewardship; HICC=hospital infection control committee; HIS=hospital information system; ID dept=infectious diseases department; LIS=laboratory information system; MTC=medical therapeutics committee

*Figure 4: Profile of selected laboratories*

## Population coverage of laboratories

We analysed the data using the PlanWise® solution. PlanWise incorporates data on the population, road network and other variables, and applies an algorithm 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, Zimbabwe had an estimated population of 14.86 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 geo-graphical 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 population 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.

In Zimbabwe, 49% of the catchment population live within one hour of the 22 participating AMR surveillance sites. Hence, 51% of the population is not covered at all by the existing facilities. To increase the population coverage, new capacity should be introduced (either by upgrading an existing laboratory to start providing services or by constructing a new laboratory) in regions in dark red (Q4), 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[16] and the specially developed MAAP tool for the secure transfer of collected data.

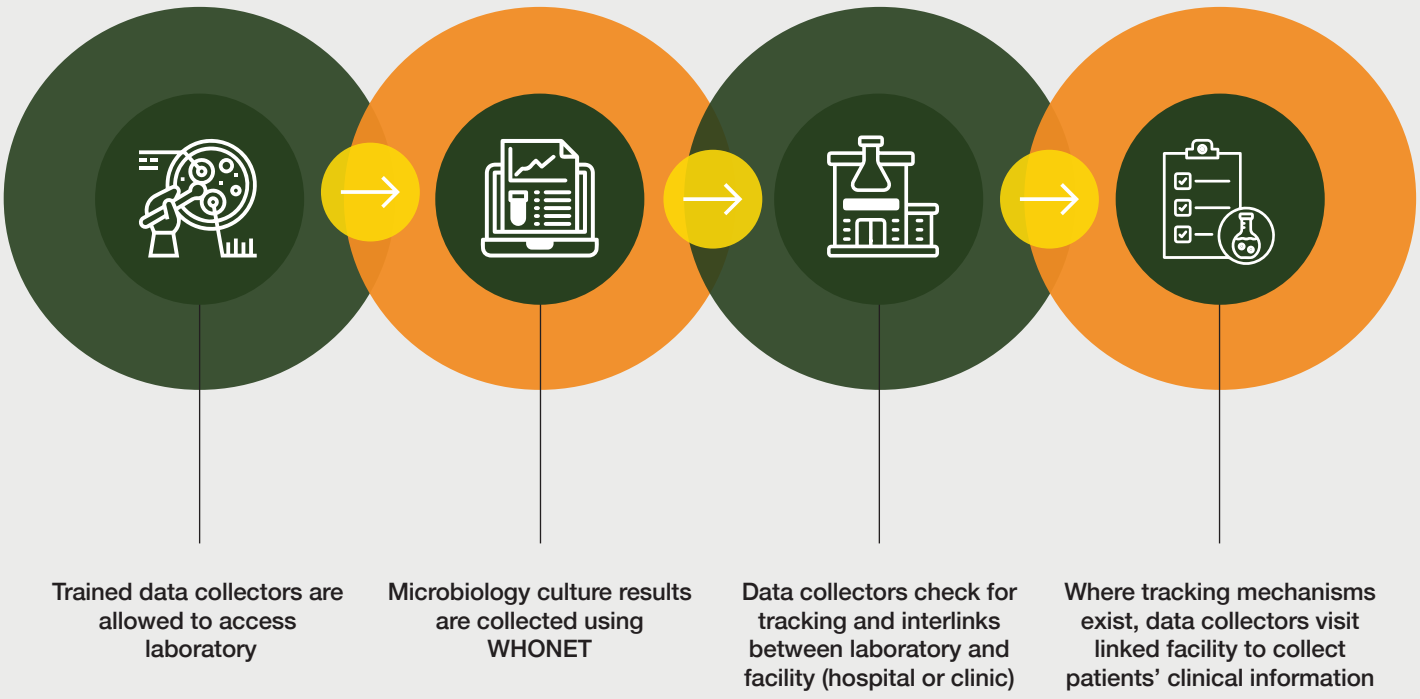



*Figure 5: Steps for AMR data collection*

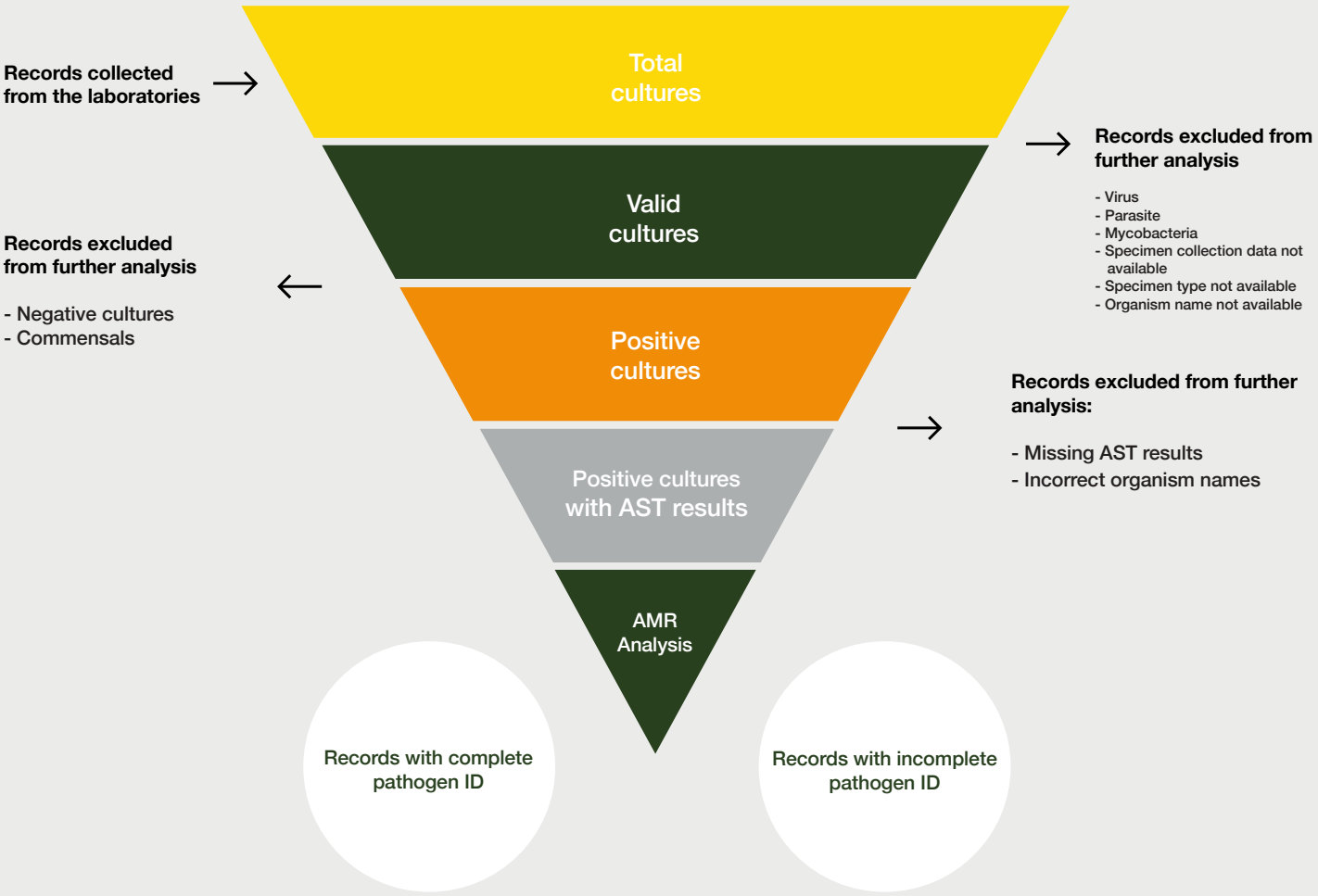
Historical data were collected for the period between 1 January 2016 and 31 December 2018. The AMR data were initially captured using WHONET, a free Windows-based database software developed for the management and analysis of microbiology laboratory data. The software allowed data entry of clinical and 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 Zimbabwean facility*

## Data analysis

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

- **Quantum of cultures:** Total cultures were the number of patient rows in the database received from the laboratories. Valid cultures were a subset of total cultures 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 the 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 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.

The maximum attainable score was 4, which corresponds to an 'Excellent' rating (Table 4).

*Table 4: Data quality rating*

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

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

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

## Results

Retrospective data from 2016–2018 were collected from 14 laboratories and their corresponding facilities in Zimbabwe.

## 1. Quantum of cultures and level of pathogen identification

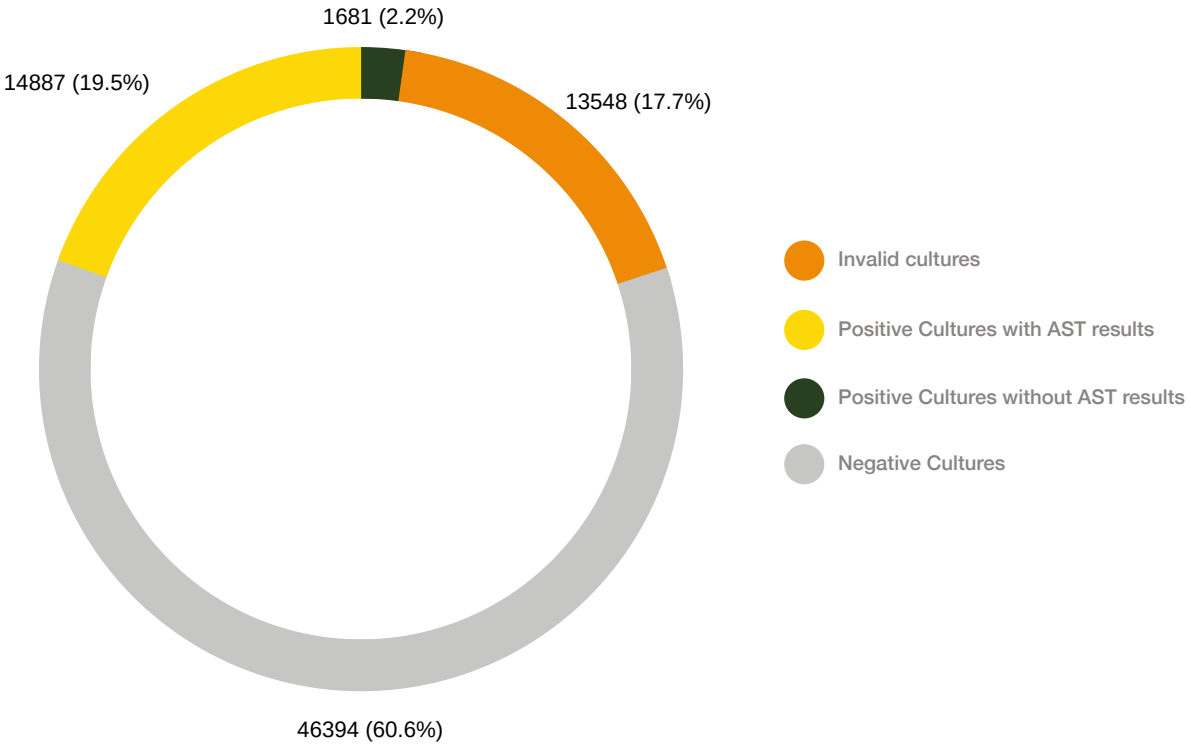
Data were retrieved for 76 494 total cultures, of which 62 965 were valid and 16 568 were positive. Of the positive cultures, AST results were available for 14 887 cultures, with the maximum (n=3 556) coming from Parirenyatwa and the least (n=144) from Beitbridge (Figures 8 and 9). Not all pathogens were identified completely (i.e., at the species level). The NMRL laboratory had the highest proportion (68.2%) of completely identified isolates, while the Chitungwiza laboratory had the lowest (15%) (Table 5).

*Table 5: Summary of data retrieved from selected facilities in Zimbabwe, 2016-2018*

| Variable (Columns) / Laboratory (Rows) | Total cultures N=76 513 | Valid cultures N=62 965 | Positive cultures N=16 568 | Positive cultures with AST results N=14 887 | Incomplete identity* N=10 621 | Complete identity* N=4 266 |
|---|---|---|---|---|---|---|
| Mpilo | 4 174 | 4 159.0 (99.6) | 1 132 (27.2) | 1 034 (91.3) | 743 (71.9) | 291 (28.1) |
| Parirenyatwa | 15 416 | 13 357.0 (86.6) | 3 922 (29.4) | 3 556 (90.7) | 2 594 (72.9) | 962 (27.1) |
| NMRL | 685 | 685.0 (100.0) | 309 (45.1) | 277 (89.6) | 88 (31.8) | 189 (68.2) |
| BRIDH | 3 287 | 3 266.0 (99.4) | 699 (21.4) | 491 (70.2) | 381 (77.6) | 110 (22.4) |
| Harare | 6 539 | 6 534.0 (99.9) | 2 257 (34.5) | 2 076 (92.0) | 1 447 (69.7) | 629 (30.3) |
| Masvingo | 3 353 | 3 344.0 (99.7) | 1 586 (47.4) | 1 446 (91.2) | 866 (59.9) | 580 (40.1) |
| Beitbridge | 1 225 | 1 225.0 (100.0) | 147 (12.0) | 144 (98.0) | 93 (64.6) | 51 (35.4) |
| Bindura | 1 169 | 1 159.0 (99.1) | 419 (36.2) | 379 (90.5) | 285 (75.2) | 94 (24.8) |
| Mutare | 4 293 | 4 285.0 (99.8) | 1 991 (46.5) | 1 838 (92.3) | 1 474 (80.2) | 364 (19.8) |
| Kwekwe | 2 122 | 2 098.0 (98.9) | 812 (38.7) | 697 (85.8) | 303 (43.5) | 394 (56.5) |
| UBH | 3 364 | 3 356.0 (99.8) | 1 165 (34.7) | 1 090 (93.6) | 908 (83.3) | 182 (16.7) |
| Chitungwiza | 3 503 | 3 476.0 (99.2) | 1 426 (41.0) | 1 332 (93.4) | 1 132 (85.0) | 200 (15.0) |
| CIMAS | 24 528 | 13 179 (53.7) | 94 (0.7) | - | - | - |
| Gweru | 2 855 | 2 842.0 (99.5) | 609 (21.4) | 527 (86.5) | 307 (58.3) | 220 (41.7) |

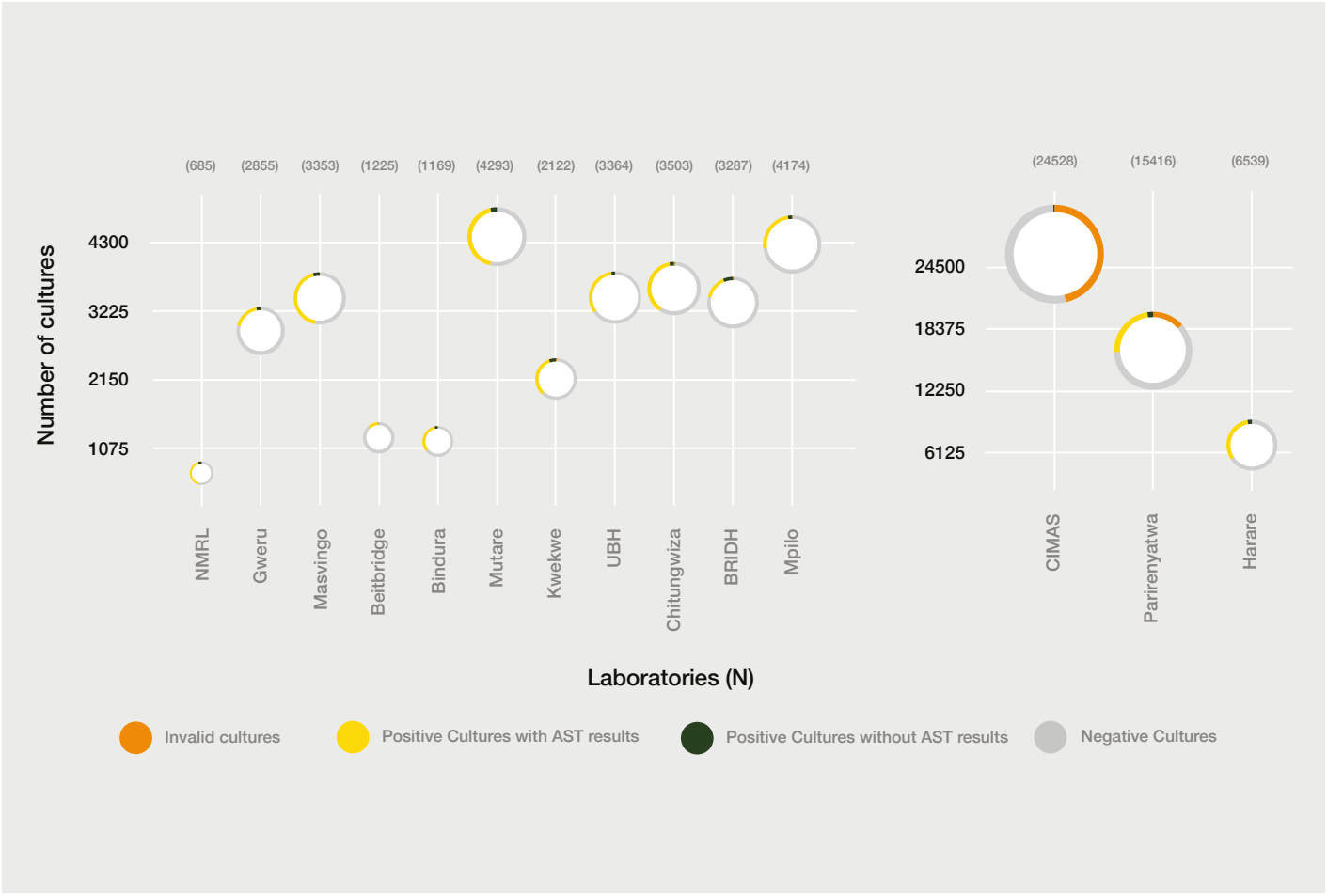
* Subsets of the category 'Positive cultures with AST results' where 'incomplete' includes cultures with only Gram- or genus-level identification and 'complete' includes cultures with species-level identification; — information not available

Abbreviations: AST=antibiotic susceptibility testing




Abbreviations: AST=antibiotic susceptibility testing

*Figure 8: Quantum of cultures across all selected laboratories in Zimbabwe, 2016-2018*




Abbreviations: AST=antibiotic susceptibility testing

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

## 2. Culture characteristics

Bacterial pathogens (14 872) were more commonly reported than fungal pathogens. Information on age was missing for 17.2% of cultures, but where available, the data showed a median age of 31 years (range: 0–90 years), with most cultures (5 558) obtained from patients aged between 18–49 years. Female patients (8 492) contributed more to the quantum of positive cultures with AST results. More data came from 2018 (5 689) than from other years (Table 6, Supplementary Table 3).

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

| Characteristics | Positive cultures with AST results N=14 887 n (%) |
|---|---|
| Gender | |
| Male | 6 392 (42.9) |
| Female | 8 492 (57.0) |
| Unknown | 3 (0.0) |
| Age, years | |
| Less than 1 | 1 032 (6.9) |
| 1 to 17 | 2 444 (16.4) |
| 18 to 49 | 5 558 (37.3) |
| 50 to 65 | 1 236 (8.3) |
| Above 65 | 2 062 (13.9) |
| Unknown age | 2 555 (17.2) |
| Year of study | |
| 2016 | 4 254 (28.6) |
| 2017 | 4 944 (33.2) |
| 2018 | 5 689 (38.2) |
| Pathogen | |
| Bacteria | 14 872 (99.9) |
| Fungi | 15 (0.1) |

## 3. Inappropriate testing

Of the 14 selected laboratories, 12 reported complying with the CLSI standards for AST testing, while two did not respond. However, during the review of AST results, the following instances of inappropriate testing were noted:

- Some laboratories tested the susceptibility of bacterial isolates to antifungals and tested the susceptibility of fungal isolates to antibiotics (Supplementary Figure 2a).
- The activities of inappropriate agents such as vancomycin, penicillin G and oxacillin were tested against Enterobacterales, and the susceptibility of S. aureus to vancomycin was determined using the disk diffusion method (Supplementary Figure 2b).

## 4. Clinical information

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

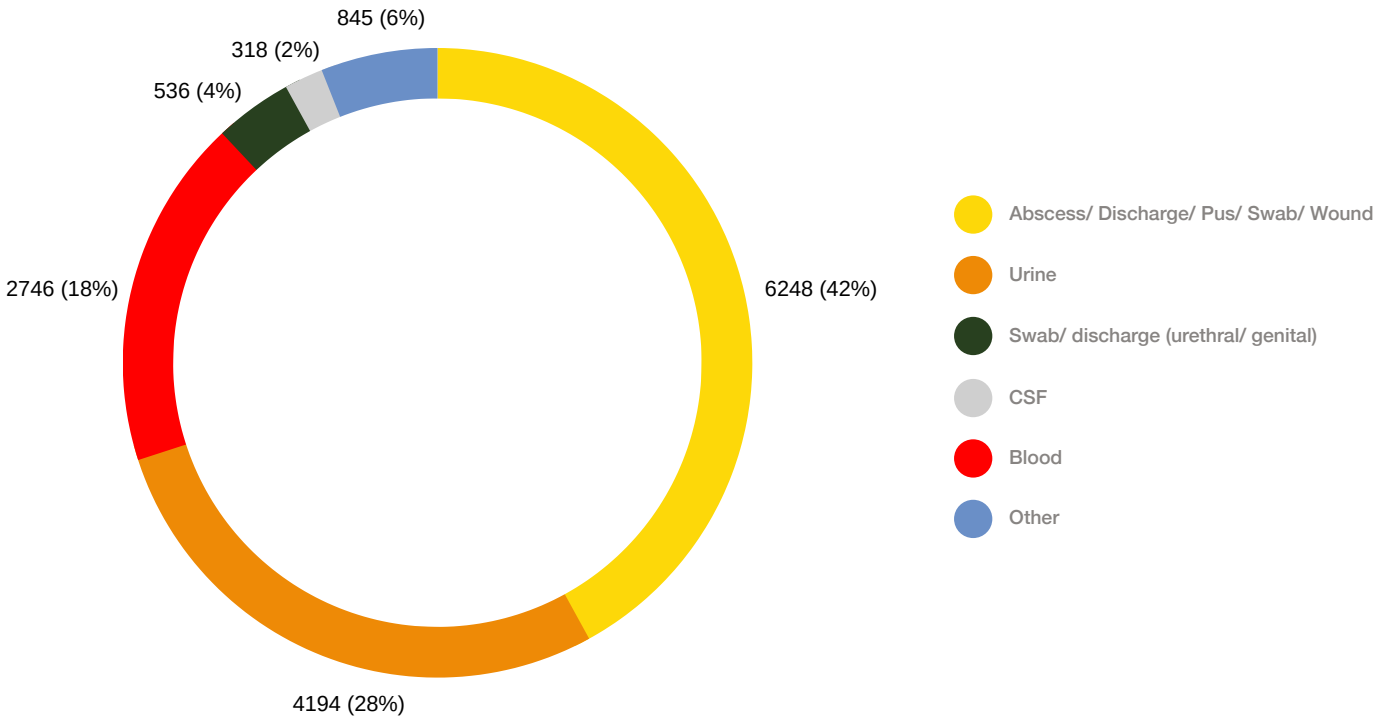
*Table 7: Clinical information of patients in selected facilities in Zimbabwe, 2016-2018*

| Laboratory | Positive cultures with AST results N=14 887 | Diagnosis data | Infection origin data* | Indwelling device data | AMU data |
|---|---|---|---|---|---|
| CIMAS | - | - | - | - | - |
| Parirenyatwa | 3 556.0 (90.7) | 3 | - | 430 | - |
| NMRL | 277.0 (89.6) | - | - | - | - |
| Gweru | 527.0 (86.5) | - | - | - | - |
| Harare | 2 076.0 (92.0) | - | - | - | - |
| Masvingo | 1 446.0 (91.2) | - | - | - | - |
| Beitbridge | 144.0 (98.0) | - | - | - | - |
| Bindura | 379.0 (90.5) | - | - | - | - |
| Mutare | 1 838.0 (92.3) | - | - | 8 | - |
| Kwekwe | 697.0 (85.8) | - | - | - | - |
| United Bulawayo | 1 090.0 (93.6) | - | - | - | - |
| Chitungwiza | 1 332.0 (93.4) | - | - | - | - |
| Beatrice | 491.0 (70.2) | - | - | - | - |
| Mpilo | 1 034.0 (91.3) | - | - | - | - |

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

## 5. Specimen characteristics

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

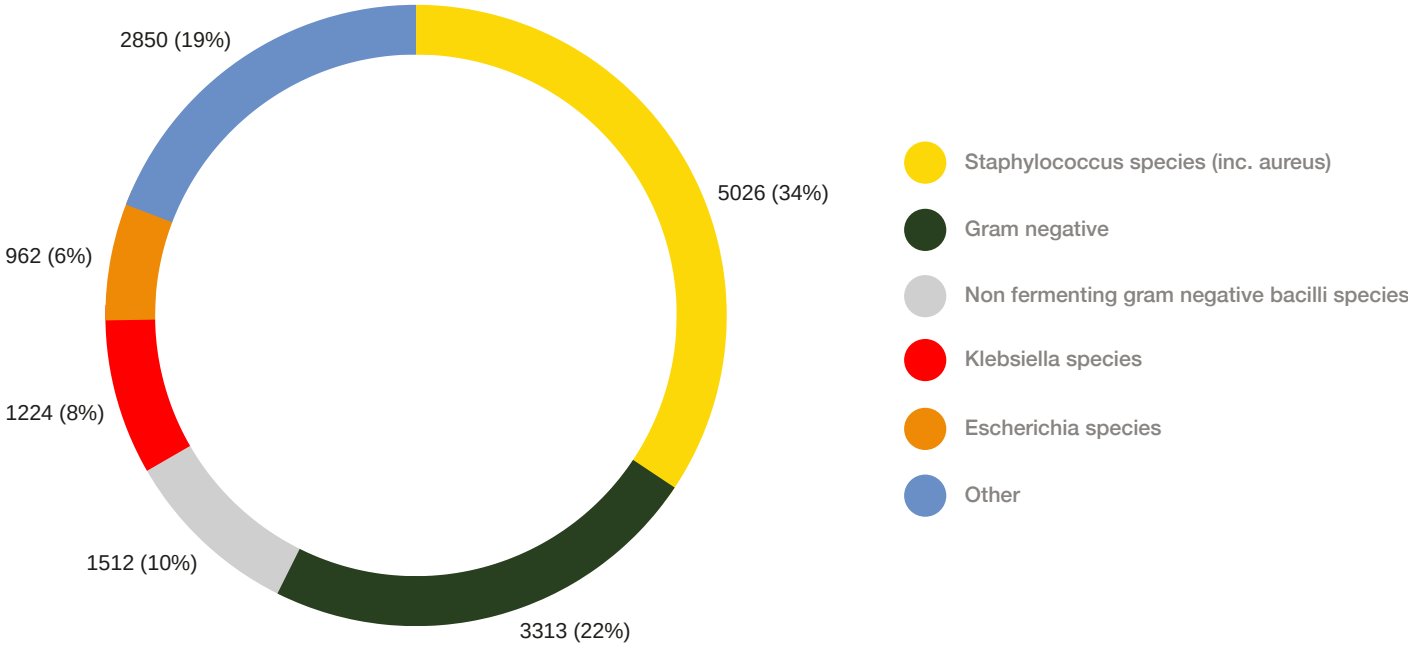



*** Others include all other specimens excluding the top 5 mentioned here**
Figure 10: Specimen distribution of positive cultures at selected facilities in Zimbabwe, 2016-2018

## 6. Identified pathogens

Staphylococcus species (33.8%), Klebsiella species (8.2%) and Escherichia species (6.5%)made up a substantial proportion of the positive cultures (Figure 11).

In 2016, of the 4 254 positive cultures with AST results, Staphylococcus species (33.2%), Klebsiella species (7.5%) and Escherichia species (6%) were the most reported. In 2017, of the 4 944 positive cultures with AST results, Staphylococcus species (30.3%), Klebsiella species (8.7%) and Escherichia species (6.5%) were again the most reported. In 2018, information was available for a greater number of cultures (5 689), and the pathogen distribution remained similar to prior years (Supplementary Table 5).




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

## 7. Quality of data

The country data quality score of the 62 965 valid culture records obtained from the 16 laboratories in Zimbabwe was 1.8, 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 of pathogens and identify the drivers of resistance.

### Estimation of AMR rates

In this report, the AMR rate is the extent to which a pathogen is resistant to a particular antimicrobial agent or class, 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 pathogens17 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), data 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.[18,19] 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.[20] 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.[21]

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 was 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 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.[22] 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. From 2016–2018, AMR rates for some organisms remained consistent, while the rates for others varied. There were high rates of third-generation cephalosporin-resistant Enterobacterales (41-54%), MRSA (35-50%) and fluoroquinolone-resistant Salmonella species (38-41%) and a low rate of carbapenem-resistant Enterobacterales (~2-12%) (Table 8, Figures 12 and 13). Statistics for vancomycin-resistant and intermediate Staphylococcus species and Staphylococcus aureus are not included.

*Table 8: AMR rate estimates for WHO priority pathogens in Zimbabwe, 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 | 4 | 1 | - | 2 (1 - 3) | 5 | 1 | - | 2 (1 - 4) | 10 | 4 | - | 3 (1 - 5) |
| P. aeruginosa | Carbapenems | 10 | 0 | - | 2 (4 - 6) | 25 | 14 | - | 4 (2 - 10) | 35 | 11 (31.4) | 15-54.4 | 5 (2 - 23) |
| Enterobacter ales | Carbapenems | 122 | 2 (1.6) | 0.3-8.7 | 6 (1 - 52) | 238 | 16 (6.7) | 3-14.5 | 10 (2 - 76) | 225 | 27 (12) | 8.3-17.1 | 9 (2 - 96) |
| Enterobacter ales | Cephalosporins (3rd generation) | 269 | 111 (41.3) | 20.6-65.6 | 11 (1 - 77) | 539 | 271 (50.3) | 30.6-69.9 | 13 (1 - 117) | 365 | 196 (53.7) | 43.2-63.9 | 11 (4 - 192) |
| E. faecium | Vancomycin | 1 | 0 | - | 1 (1) | 2 | 0 | - | 1 (2) | 3 | 0 | - | 1 (3) |
| H. influenzae | Ampicillin | - | - | - | - | - | - | - | - | - | - | - | - |
| H. pylori | Clarithromycin | - | - | - | - | - | - | - | - | - | - | - | - |
| N. gonorrhoeae | Cephalosporins (3rd generation) | - | - | - | - | - | - | - | - | - | - | - | - |
| N. gonorrhoeae | Fluoroquinolones | - | - | - | - | - | - | - | - | - | - | - | - |
| Campylobacter species | Fluoroquinolones | - | - | - | - | - | - | - | - | - | - | - | - |
| Salmonella species | Fluoroquinolones | 64 | 24 (37.5) | 11.7-73 | 3 (5 - 47) | 97 | 40 (41.2) | 27-57.1 | 5 (4 - 61) | 11 | 6 | - | 4 (2 - 4) |
| Shigella species | Fluoroquinolones | 10 | 1 | - | 4 (1 - 5) | 25 | 5 | - | 4 (1 - 12) | 12 | 3 | - | 3 (2 - 6) |
| S. aureus | Methicillin | 81 | 28 (34.6) | 22.6-48.9 | 6 (1 - 45) | 103 | 51 (49.5) | 31.8-67.4 | 8 (1 - 41) | 292 | 136 (46.6) | 39.5-53.8 | 10 (1 - 148) |
| S. pneumoniae | Beta-lactam combinations | - | - | - | - | - | - | - | - | - | - | - | - |
| S. pneumoniae | Penicillins | 2 | 0 | - | 1 (2) | 1 | 1 | - | 1 (1) | 2 | 2 | - | 1 (2) |

N = number of tested isolates; n = number of non-susceptible isolates; 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

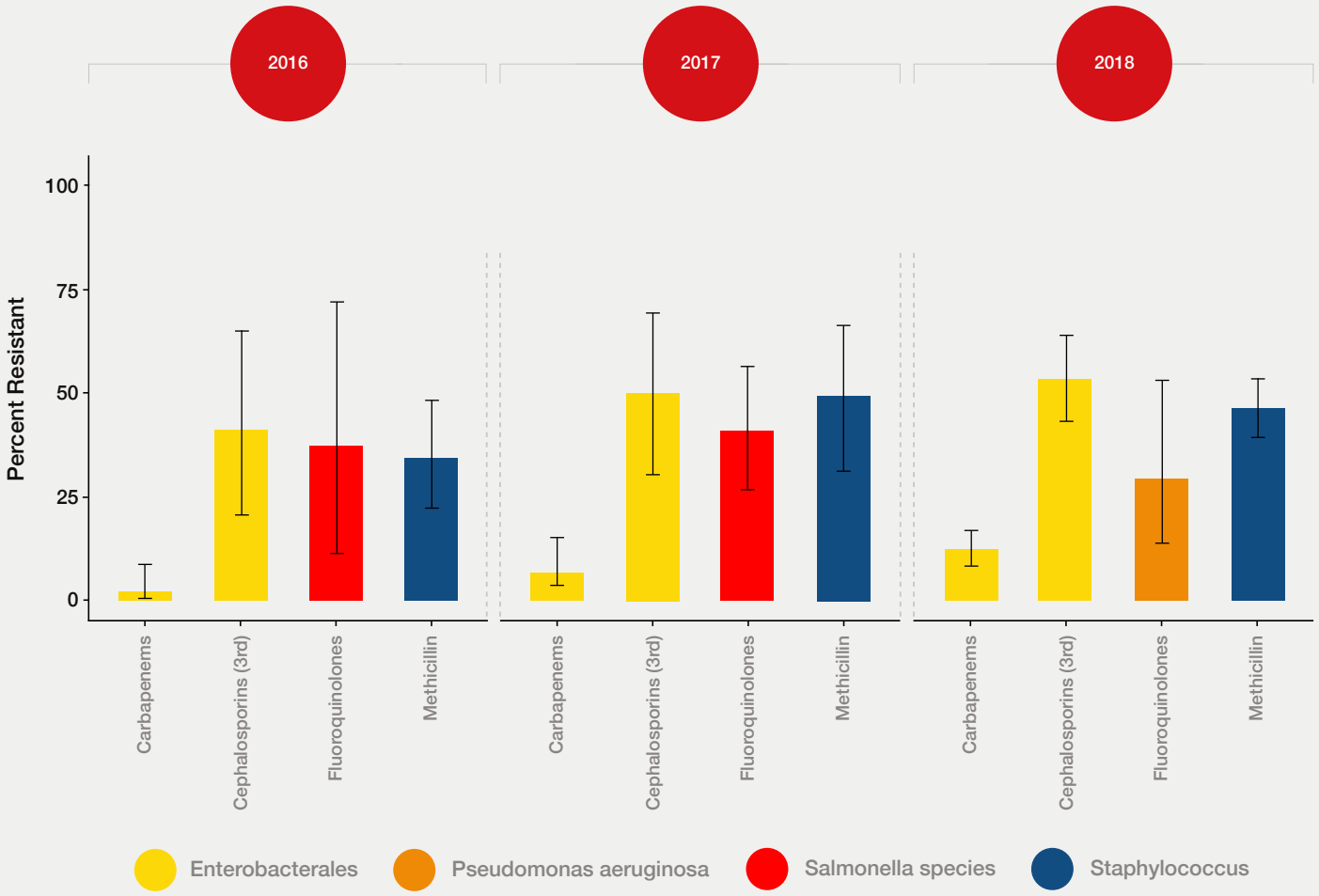



*Figure 12: AMR rate estimates for WHO priority pathogens identified at selected facilities in Zimbabwe, 2016-2018*

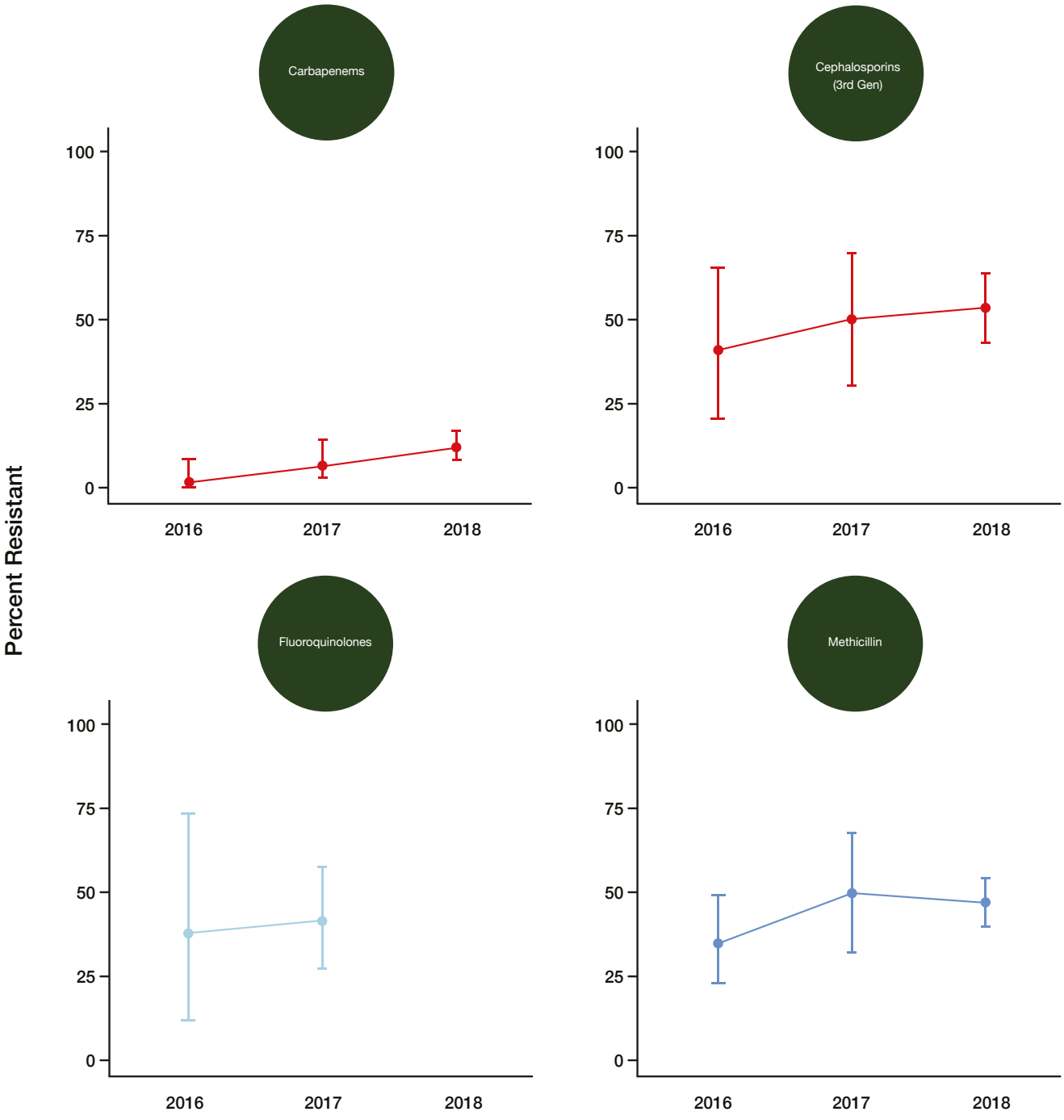



*Figure 13: AMR trends for WHO priority pathogens identified at selected facilities in Zimbabwe, 2016-2018*

## (ii) AMR rates for other pathogens of clinical importance

**The analysis of AST data from blood and CSF isolates revealed high rates of methicillin-resistant Staphylococcus species (58-66%) and third-generation cephalosporin-resistant Klebsiella species (74-85%). Rates for carbapenem-resistant Klebsiella species (2-9%) and vancomycin-resistant Enterococcus species (11-13%) were low (Table 9).**

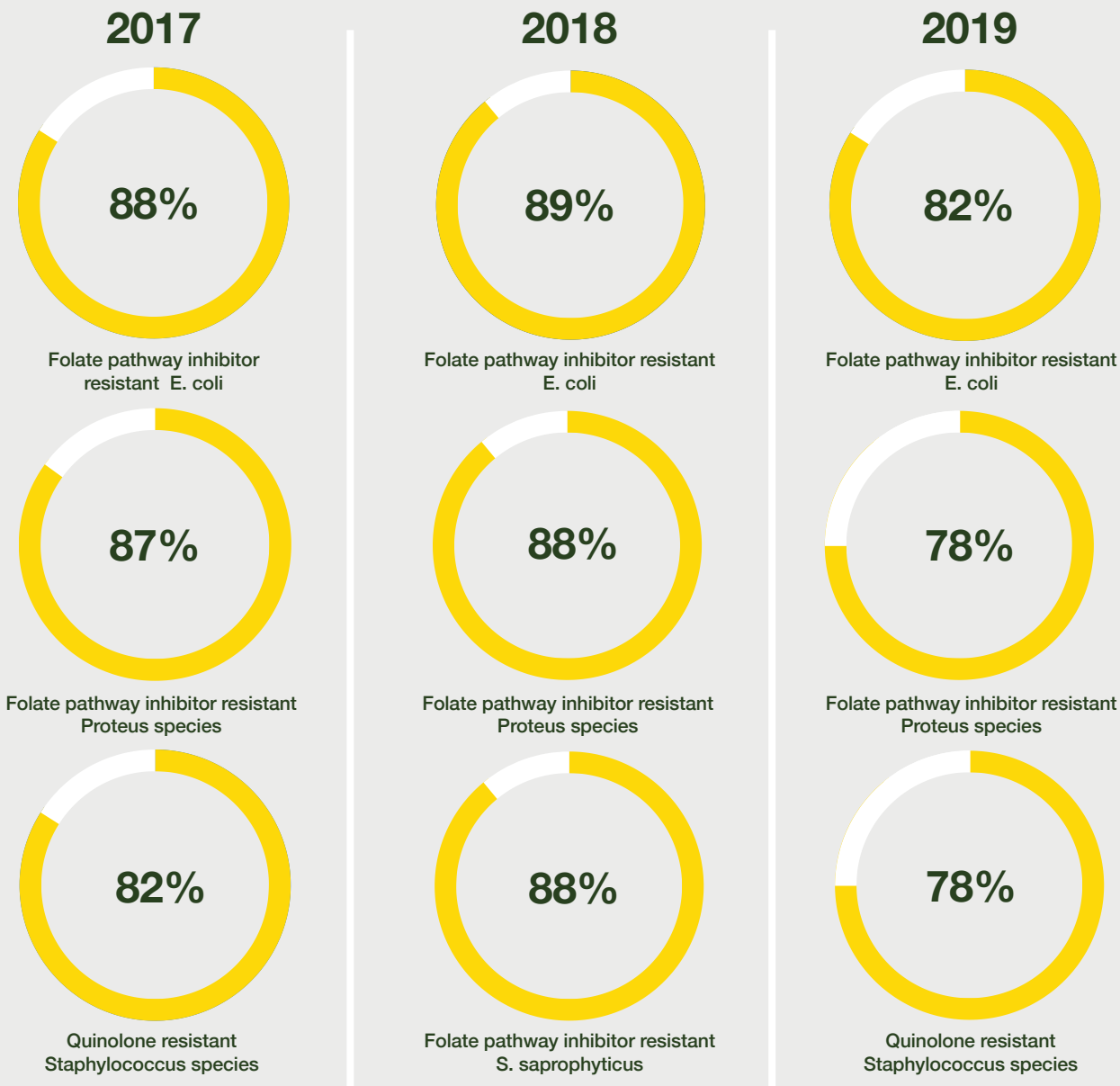
*Table 9: AMR rate estimates for other clinically important pathogens* identified at selected facilities in Zimbabwe, 2016-2018*

| | | 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 | 4 | 1 | - | 2 (1 - 3) | 6 | 1 | - | 3 (1 - 4) | 14 | 6 | - | 3 (1 - 9) |
| Acinetobacter species | Lipopeptides | - | - | - | - | - | - | - | - | - | - | - | - |
| Enterococcus species | Aminoglycosides (high level) | - | - | - | - | - | - | - | - | 2 | 0 | - | 1 (2) |
| Enterococcus species | Vancomycin | 17 | 1 | - | 4 (1 - 9) | 32 | 4 (12.5) | 4.8-29 | 4 (1 - 20) | 66 | 7 (10.6) | 4-25.2 | 3 (1 - 56) |
| H. influenzae | Ampicillin | - | - | - | - | - | - | - | - | - | - | - | - |
| H. influenzae | 3rd generation cephalosporins | - | - | - | - | - | - | - | - | - | - | - | - |
| Klebsiella species | Carbapenems | 42 | 1 (2.4) | 0.8-7.3 | 2 (2 - 40) | 23 | 0 | - | 3 (5 - 9) | 46 | 4 (8.7) | 1.8-32.7 | 4 (1 - 30) |
| Klebsiella species | Cephalosporins (3rd generation) | 34 | 29 (85.3) | 74.5-92 | 2 (6 - 28) | 25 | 16 | - | 4 (1 - 17) | 83 | 61 (73.5) | 65.5-80.2 | 6 (1 - 56) |
| N. meningitidis | Ampicillin | - | - | - | - | - | - | - | - | - | - | - | - |
| N. meningitidis | Cephalosporins (3rd generation) | - | - | - | - | - | - | - | - | - | - | - | - |
| Pseudomonas species | Carbapenems | 2 | 0 | - | 2 (1 - 1) | 2 | 0 | - | 2 (1 - 1) | 6 | 1 | - | 3 (1 - 4) |
| Pseudomonas species | Lipopeptides | - | - | - | - | - | - | - | - | - | - | - | - |
| Salmonella species | Fluoroquinolones | - | - | - | - | - | - | - | - | - | - | - | - |
| Salmonella species | Macrolides | - | - | - | - | - | - | - | - | - | - | - | - |
| Salmonella species | 3rd generation cephalosporins | - | - | - | - | - | - | - | - | - | - | - | - |
| Staphylococcus aureus | Methicillin | - | - | - | - | - | - | - | - | - | - | - | - |
| Staphylococcus species (excluding aureus) | Methicillin | 113 | 75 (66.4) | 27.8-91 | 4 (5 - 54) | 81 | 47 (58) | 34.2-78.6 | 8 (1 - 40) | 393 | 258 (65.6) | 54.3-75.5 | 4 (4 - 201) |
| S. pneumoniae | Penicillins | 2 | 0 | - | 1 (2) | - | - | - | - | 2 | 2 | - | 1 (2) |
| S. pneumoniae | Beta-lactam combinations | - | - | - | - | - | - | - | - | - | - | - | - |
| S. pneumoniae | Macrolides | 3 | 0 | - | 2 (1 - 2) | - | - | - | - | 1 | 1 | - | 1 (1) |
| S. pneumoniae | Vancomycin | 3 | 0 | - | 1 (3) | - | - | - | - | 2 | 0 | - | 1 (2) |

* 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

Based on the available data, very high resistance rates (~90%) were estimated for clinically important pathogens like Escherichia coli (vs. folate pathway inhibitors), Proteus species (vs. folate pathway inhibitors), and Staphylococcus saprophyticus (vs. folate pathway inhibitors) (Figure 14).




Pathogen nomenclature is shown as reported by laboratories; antimicrobials are reported at the class level
Figure 14: Top five highly resistant pathogens identified at selected facilities in Zimbabwe, 2016-2018

### (iv) AMR rates for fungal pathogens

The available AST data on fungal isolates were insufficient for further analysis.

## Section IV: Drivers of antimicrobial resistance

### Objective

To assess the drivers of AMR

### Methodology

AMR drivers are factors that could predispose patients to AMR. 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 odds ratios (ORs) were estimated in the univariate logistic regression analysis to describe the association between AMR and the investigated variables, and only those with $p<0.2$ were evaluated in a multiple logistic regression analysis (statistical significance was set at $p<0.05$). The Wilson score method with 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

Three variables, namely, age, gender and indwelling device were evaluated for possible association with AMR. Age data were available for 85.3% of the patients, gender data were available for 95.7%, and indwelling device data were available for 3.5%. The univariate logistic regression results showed that the three variables did not have any significant effect on the AMR rates (Table 10). Data on other patient factors were unavailable or inadequate for analysis.

*Table 10: Univariate logistic regression analysis*

| Variable | Category | N | NS (%) | Adjusted OR (95% CI) | P-value |
|---|---|---|---|---|---|
| Gender | Female | 2 047 | 47.2 | Ref | 0.6745 |
| | Male | 1 895 | 48.6 | 1.06 (0.81 - 1.38) | |
| Age | <1 | 187 | 43.3 | 0.81 (0.48 - 1.36) | 0.3464 |
| | 1-17 | 785 | 43.2 | 0.80 (0.59 - 1.10) | |
| | 18-49 | 1 508 | 48.6 | **Ref** | |
| | 50-65 | 402 | 48.8 | 1.01 (0.81 - 1.24) | |
| | >65 | 629 | 53.1 | 1.20 (0.92 - 1.56) | |
| Indwelling device | Absent | 86 | 41.9 | Ref | 0.1163 |
| | Present | 58 | 55.2 | 1.71 (0.87 - 3.35) | |

Abbreviations: N=number of tested isolates; NS (%)=proportion of non-susceptible isolates; OR=odds ratio; CI=confidence interval; Ref=reference group

# 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.[23,24] 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 Zimbabwe's One Health AMR National Action Plan.[15]

## 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, wholesalers, 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 antimicrobial).[25]

## Link between the antimicrobial usage and AMR

The unwarranted use of antimicrobials contributes to the emergence of AMR. This association implies that a reduction in the unnecessary consumption of antimicrobials could in turn reduce AMR levels.[23] 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 as a result of a lack of access to antimicrobials, thus leading to the prolonged use of particular 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.[26]

This complicated picture demonstrates the need for 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 AMC or AMU and AMR in Zimbabwe, it is important to identify prevalent gaps and areas needing intervention to 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 Zimbabwe as this would equip the country with valuable information to support the appropriate use of antimicrobials. The objective was to also 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 the usage of antimicrobials is one of the strategic objectives of the WHO Global Action Plan (GAP).[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 surveillance and AMU in Africa,[27-31] including one report on AMU from Zimbabwe.[14] Obtaining AMC or AMU data for a country provides local information on the various problems that exist with AMU and allows the monitoring of the accessibility of antimicrobials.

Obtaining AMC or AMU data permits a continuous local assessment of correlations between antimicrobial usage and emerging local AMR. In addition, local surveillance data can better inform stewardship programmes. 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 and policies, which will optimise the use of antimicrobials in Zimbabwe. In addition, the local surveillance will provide the country with a reference point to measure the impact and success of future 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 Zimbabwe

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 Zimbabwe

**Methodology**

### AMC and AMU data sources

Through open-structured key informant interviews (KIIs) (AMC Appendix 1), the AMRCC contacts shared their insights about the current landscape of AMC surveillance in the country as well as the best sources of national AMC data. Based on the findings of the KIIs, the National Pharmaceutical Company (NatPharm) mechanism for public sector procurement and the imports and locally manufactured products records held by the Medicines Control Authority of Zimbabwe (MCAZ) were identified as potential sources of national AMC data for Zimbabwe.

Under the guidance of Zimbabwe's AMRCC, MAAP aimed to recruit and obtain data from twice as many pharmacies as the selected AST laboratories (i.e., a total of 32 pharmacies). Pharmacy-level AMC data were to be collected from the pharmacies that were co-located in the same facility with AST laboratories (n=16) (AMC Appendix 2). In addition, community pharmacies (n=16) were also targeted. These pharmacies were nominated by the co-located pharmacies 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. The availability of retrospective data from 2016-2018 and willingness to share the data were key criteria considered during the selection.

AMU data were also targeted for collection from hospital pharmacies (n=16) and this was to be abstracted 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 retail medicinal products (prescription-only and over-the-counter medicines) to a specific community group or region; this does not include unregulated and informal medicine dispensers. Hospital pharmacies, on the other hand, are pharmacies that are located within a hospital for the provision of 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 a full list of selected antimicrobials in Zimbabwe). P01AB and J02 ATC antimicrobials are part of the WHO core and optional monitored medicine classes respectively for AMC surveillance.[32] AMC data on these medicine categories were collected from January 2016 to December 2018.

## Data collection

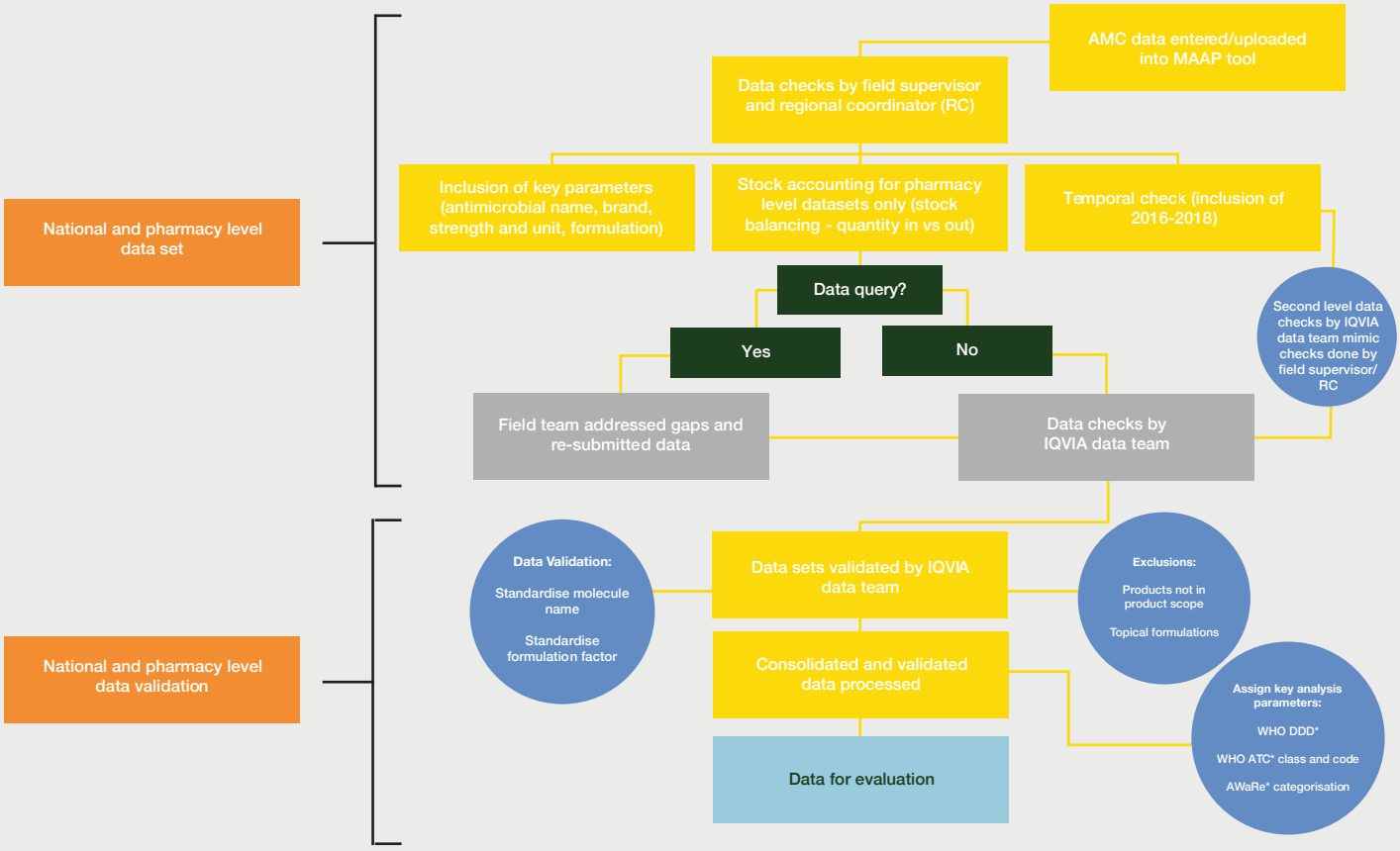
The NatPharm and MCAZ AMC datasets were provided directly to MAAP field data collectors from the respective agencies. Both the NatPharm and MCAZ datasets were provided in an electronic format (i.e., in Excel™ spreadsheets). The datasets were reviewed and cleaned by the data collection teams using Excel™ before being transferred securely using the MAAP tool. The MAAP tool captured all the antimicrobials 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.

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

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 the indications 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 dose, strength, frequency and duration of the prescription).

## Data cleaning and validation

The national-level AMC datasets from NatPharm and MCAZ were provided to the regional coordinator for processing. Once the datasets were received by MAAP, both the national- and pharmacy-level AMC data were then subjected to a series of data validation checks to ensure accuracy and consistency (Figure 15). Here, the pharmacy- and national-level AMC data were subjected to secondary and tertiary checks by field supervisors, the regional coordinator and the IQVIA data team. These checks involved ensuring that key variables were complete (e.g., antimicrobial strength and formulation), that net AMC stocks consumed were accurate (i.e., stock received balanced against stock dispensed) and that standard molecule names were used throughout different data collection sites. Data validation and processing were carried out by the IQVIA regional coordinator and IQVIA data team.



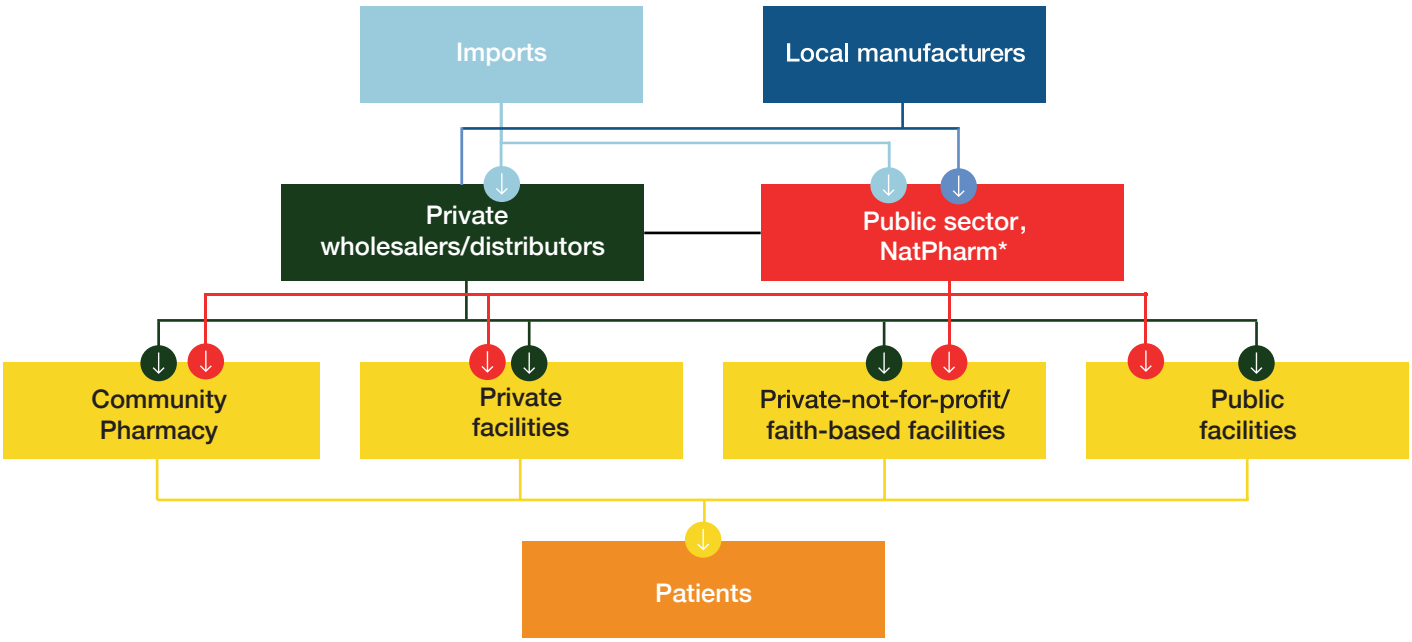

*WHO World Health Organisation - *DDD Defined Daily Dose - * AWaRe Access, Watch, and Reserve

*Figure 15: Flow chart of the data checks and validation processes conducted for the national- and pharmacy-level AMC data collected in Zimbabwe*

Results

## Flow of antimicrobials in the country

To characterise the pathways through which antimicrobials get to patients in the country, three KIIs were conducted with stakeholders in the national AMRCC, MCAZ (the regulatory body), and the Ministry of Health and Child Care (MoHCC) through the Directorate of Pharmacy Services. In Zimbabwe, medicines, including antimicrobials, are either imported or locally manufactured. After importation or local production, private for-profit wholesalers or distributors, national public-sector central medical stores (CMSs), and NatPharm then pass along the antimicrobials to the community pharmacies, private (both for-profit and non-profit) facilities and public facilities, who eventually issue the antimicrobials to patients (Figure 16).




*NatPharm: National Pharmaceutical Company

*Figure 16: The flow of antimicrobials to patients in Zimbabwe*

## Regulation of antimicrobials consumption

In Zimbabwe, MCAZ regulates and licenses all pharmaceutical products imported and manufactured locally. The antimicrobials for human consumption are regulated under the Medicines and Allied Substances Control Act Chapter 15.03, 1969.[13] This law stipulates that requisite antimicrobials can only be sourced from registered suppliers and can only be dispensed upon a valid prescription. Despite this regulation on the dispensation of antimicrobial medicines, poor enforcement has led to widespread, unregulated and over-the-counter availability of antimicrobials without a prescription in Zimbabwe.14 This unauthorised over-the-counter retail practice for prescription antimicrobial agents may lead to their overuse and/or misuse. Overuse and misuse of antimicrobials are significant contributors to the emergence of AMR. Therefore, to address these issues and other prevalent gaps, Zimbabwe developed the One Health AMR National Action Plan,[15] which seeks to further build regulations around AMC to curb the emergence of 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=13). Unfortunately, no AMU data was obtained during MAAP data collection because the participating pharmacies used stock issuance record cards that do not track which patient specifically received what medicines. MAAP was thus unable to receive 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 Zimbabwe.

## Availability of data for AMC surveillance

### National-level data

The national AMC data for 2017 and 2018 were obtained from NatPharm and MCAZ. MAAP was unable to access 2016 national-level AMC datasets from both agencies due to disparate reasons. Per MCAZ's requirements, the 2016 national AMC data had to first be converted into an electronic format before it could be shared with IQVIA. MAAP could thus not obtain the data for analysis as the additional MCAZ personnel hours required to perform this conversion would have exceeded the data collection timeline set. On the other hand, the 2016 national AMC data from NatPharm only contained records from a minority of importers and manufacturers, thus rendering it incomplete and unsuitable for annual consumption analysis. Therefore, only the 2017 and 2018 national AMC data are presented in this report. The NatPharm and MCAZ datasets that were availed to the MAAP field team consisted of private- (including not-for-profit) and public-sector procurements. We thus assumed that the AMC data collected in 2017 and 2018 represented 100% coverage of all antimicrobials consumed in Zimbabwe. The national-level data from both MCAZ and NatPharm contained all the variables required to conduct AMC analysis, namely, transaction date, antibiotic name, pack size, strength and formulation (e.g., tablets, capsules, suspensions, syrups or injections).

### Facility-level data

A total of 14 AST laboratories were recruited for data collection. However, one was excluded as it was a stand-alone national microbiology reference laboratory (i.e., without a co-located hospital pharmacy). Consequently, to reach the target pharmacy sample size (n=32), MAAP set out to recruit two community pharmacies from the recruited hospital pharmacies (n=13). Hence, 19 community pharmacies nominated by the recruited hospital pharmacies were targeted. In total, pharmacy-level data were successfully collected in the 32 targeted pharmacies, including 13 hospital pharmacies and 19 community pharmacies. As the total number of hospital or community pharmacies in Zimbabwe was unknown, the representativeness of the data at the facility level could not be assessed.

In the case of pharmacy-level data, the necessary variables were available in the stock cards or electronic records of 32 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 or 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 the 13 hospital pharmacies. Of the 19 recruited community pharmacies, four pharmacies did not provide data for 2016 and 2017 as they either did not have the archived 2016-2017 data in their systems or declined to share the data.

Of the 13 participating hospital pharmacies that were co-located with the AST laboratories, 12 were in public government hospitals (five tertiary care facilities and seven secondary care facilities) while the remaining one was located in a private, faith-based hospital offering secondary care services (Table 11). Due to the lack of any national AMC surveillance policy and reporting requirement during the reviewed period, none of the recruited pharmacies actively reported AMC data regionally or centrally.

Table 11: Characteristics of the recruited community pharmacies and the recruited hospital pharmacies co-located with antimicrobial susceptibility testing (AST) laboratories in Zimbabwe

| | 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) | Masvingo Provincial Hospital | Secondary care | Public | Masvingo | Manual | No | No |
| | Mutare Provincial Hospital | Secondary care | Public | Mutare | Manual | No | No |
| | Gweru Provincial Hospital | Secondary care | Public | Gweru | Manual | No | No |
| | Kwekwe General Hospital | Secondary care | Public | Kwekwe | Manual | No | No |
| | Mpilo Central Hospital | Tertiary care | Public | Bulawayo | Electronic | No | No |
| | United Bulawayo Hospital (UBH) | Tertiary care | Public | Bulawayo | Electronic | No | No |
| | Harare Central Hospital | Tertiary care | Public | Harare | Manual | No | No |
| | Parirenyatwa Central Hospital | Tertiary care | Public | Harare | Electronic | No | No |
| | Chitungwiza General Hospital | Tertiary care | Public | Chitungwiza | Manual | No | No |
| | Beatrice Road Infectious Disease Hospital (BRIDH) | Secondary care | Public | Harare | Manual | No | No |
| | Beitbridge District Hospital | Secondary care | Public | Beitbridge | Manual | No | No |
| | Bindura Provincial Hospital | Secondary care | Public | Bindura | Manual | No | No |
| | Materdei Hospital | Secondary care | Private, faith-based | Bulawayo | Electronic | Yes | No |
| Community pharmacies | Manica Pharmacy (community) | Dispensing | Private | Mutare | Electronic | N/A | No |
| | Nu Makoni Pharmacy (Chitungwiza) | Dispensing | Private | Chitungwiza | Electronic | N/A | No |
| | New Hope Pharmacy (Chitungwiza) | Dispensing | Private | Chitungwiza | Electronic | N/A | No |
| | Best Pharmacy (Masvingo) | Dispensing | Private | Masvingo | Electronic | N/A | No |
| | BerryNell Pharmacy (Masvingo) | Dispensing | Private | Masvingo | Electronic | N/A | No |
| | Value Pharmacy (Masvingo) | Dispensing | Private | Masvingo | Electronic | N/A | No |
| | Copa Cabbana Pharmacy (Harare) | Dispensing | Private | Harare | Electronic | N/A | No |
| | Impali Private Pharmacy (Bindura) | Dispensing | Private | Bindura | Electronic | N/A | No |
| | Good Hope Pharmacy (Harare) | Dispensing | Private | Harare | Electronic | N/A | No |
| | Vital Pharmacy (Harare) | Dispensing | Private | Harare | Electronic | N/A | No |
| | Viller Pharmacy (Bindura) | Dispensing | Private | Bindura | Electronic | N/A | No |
| | Materdei Private Pharmacy (Bulawayo) | Dispensing | Private | Bulawayo | Electronic | N/A | No |
| | Ascot Private Pharmacy (Bulawayo) | Dispensing | Private | Bulawayo | Electronic | N/A | No |
| | Greenwood Pharmacy (Mutare) | Dispensing | Private | Mutare | Electronic | N/A | No |
| | Greenwood Pharmacy (Borrowdale) | Dispensing | Private | Harare | Electronic | N/A | No |
| | Greenwood Pharmacy (Fife) | Dispensing | Private | Harare | Electronic | N/A | No |
| | Greenwood Pharmacy (First Street) | Dispensing | Private | Harare | Electronic | N/A | No |
| | Greenwood Pharmacy (Gweru) | Dispensing | Private | Gweru | Electronic | N/A | No |
| | Greenwood Pharmacy (Kamfinsa) | Dispensing | Private | Harare | Electronic | N/A | No |

#Secondary care describes district-level hospitals while tertiary care describes provincial hospitals providing specialist services e.g., surgery, gynaecology and obstetrics, general medicine, etc. NB: There is a quaternary care level in Zimbabwe that describes national-level central hospitals that act as referral centres for complex cases and provide specialist care

*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
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 17, AMC Appendix 6).32,33 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 2020 DDD guide, the total consumed milligrams per antimicrobial were divided against the standard DDD value issued by the WHO to obtain total DDDs.[34] Total DDDs were then adjusted for the country's population size[35] 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 DDD per the number of inpatients and presented as DDD per 100 patient bed days. However, the use of the WHO DDD per 100 patient bed days presented limitations at the point of analysis as patient bed days was not an appropriate denominator to use across the pharmacy-level AMC datasets. In addition, 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 is presented in this report as absolute DDD to aid comparisons of AMC between the hospital and community pharmacies. All calculations were done in Microsoft Excel™ software.

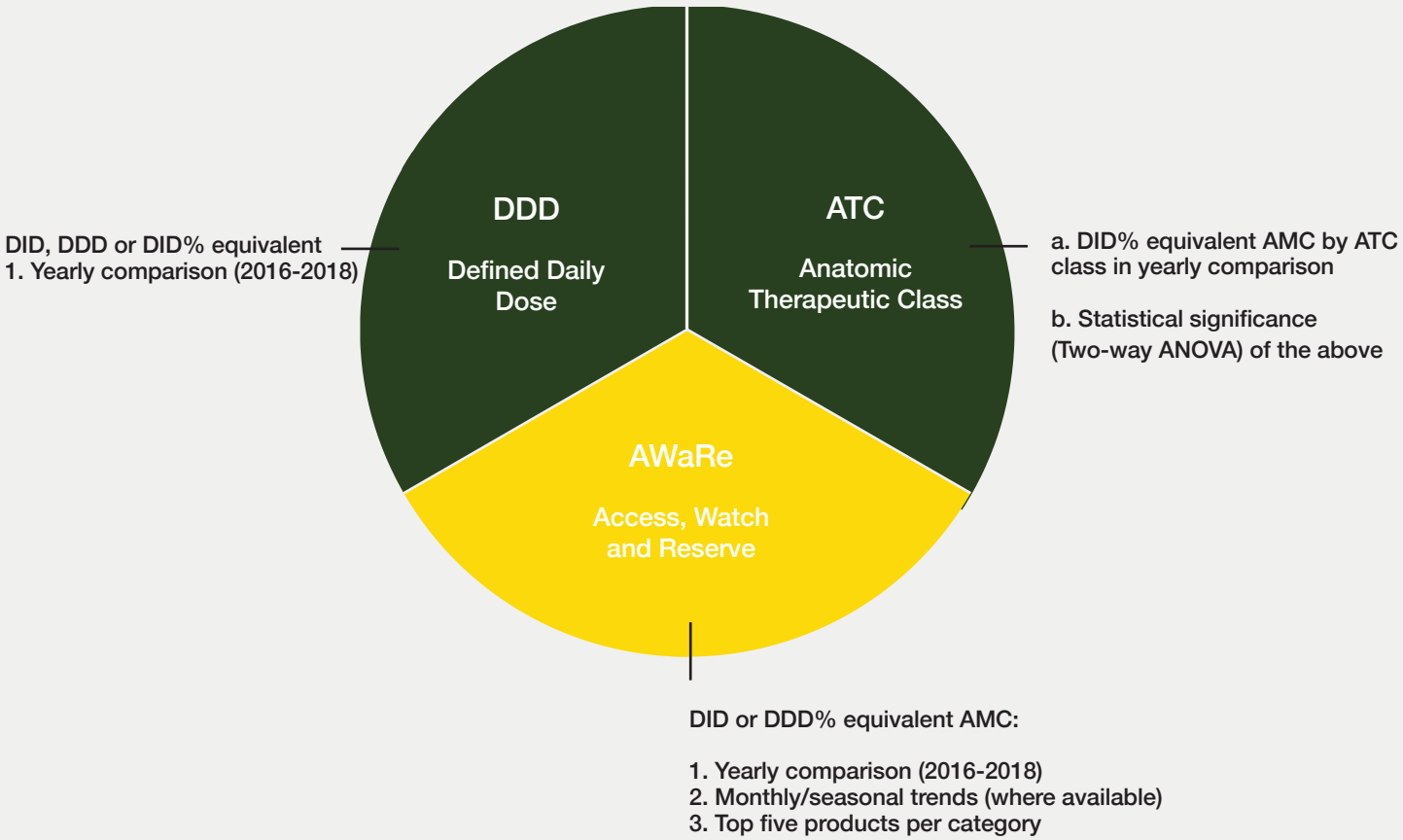
### ii. Anatomic Therapeutic Chemical (ATC) Classification

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, an attempt was made to conduct statistical testing to determine whether there were year-on-year differences within each ATC class. However, this was not possible as some of the datasets were missing core components required for analysis (i.e., the month of the transaction).

### 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, available at all times and quality assured in the country or facilities. The 'Watch' group antibiotics are those indicated for only a specific and limited number of infective syndromes 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 option. They are indicated in cases of life-threatening infections due to multi-drug 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 list[36] using Microsoft Excel™. The total DDDs in each WHO AWaRe category were then analysed to determine the proportion of antimicrobials consumed per category and over time (yearly and monthly), where possible. The WHO recommends that at least 60% of a country's total AMC should come from the 'Access' category of antibiotics. Finally, 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 17: Methods and indicators used for the analysis of the data collected in Zimbabwe. 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)

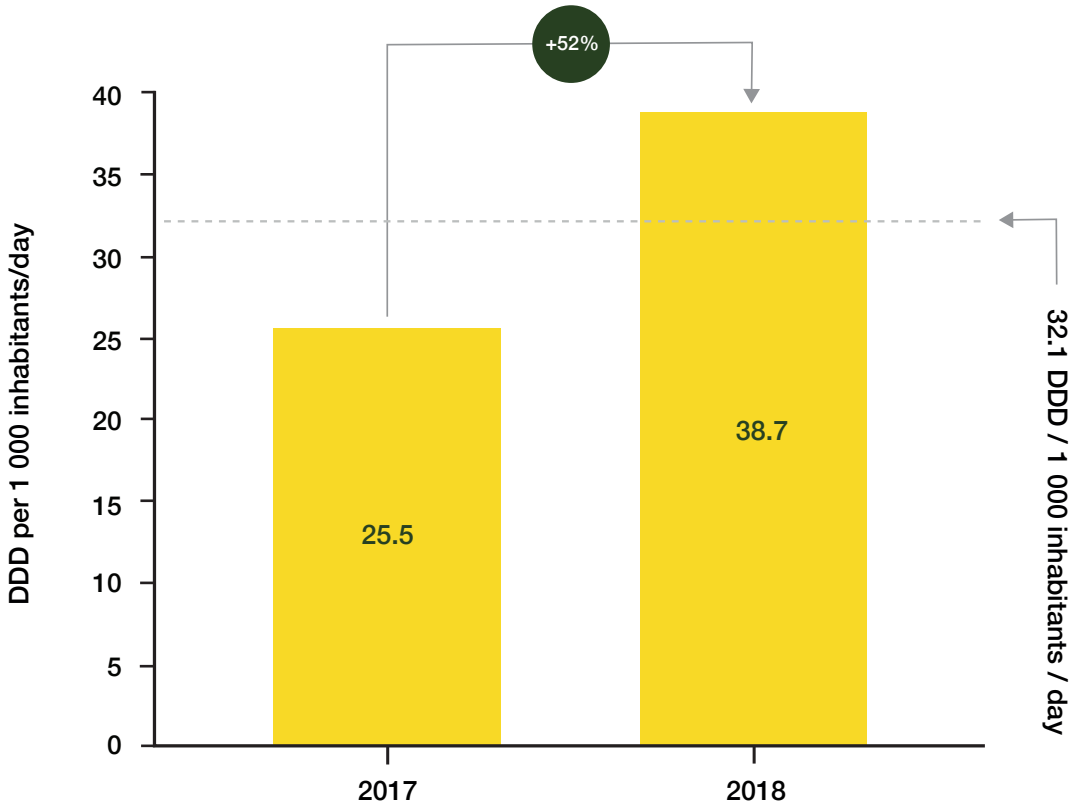
According to the WHO, essential medicines are those that satisfy the priority healthcare needs of a population. They are selected with due regard to disease prevalence and public health relevance, evidence of efficacy and safety and comparative cost-effectiveness. They are intended to always be available 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 Essential Medicines List for Zimbabwe (EDLIZ)[37] and against the documented antimicrobials from the national- and pharmacy-level data. The comparison was conducted using WHO-defined AWaRe categories.

Results

## National AMC datasets analysed by DDD per year

National AMC datasets analysed by DDD per year

The average total AMC between 2017 and 2018 was 32.1 DID. There was a 52% increase in total AMC between 2017 and 2018 (Figure 18).




Abbreviations: DDD=defined daily dose

*Figure 18: Variation in the national-level total defined daily dose per 1 000 inhabitants per day between 2017 and 2018 in Zimbabwe.*

## National AMC analysed by ATC classification

Combinations of sulfonamides and trimethoprim, including derivatives (J01EE) were the most frequently consumed ATC class in Zimbabwe across the reviewed period (44.4% in 2017 and 36.7% in 2018) (Figure 19). The sulfamethoxazole/trimethoprim combination was the most frequently consumed antibiotic within this class. Penicillins with extended spectrum (J01CA) and second-generation cephalosporins (J01DC) were the second and third leading ATC classes, with amoxicillin and cefuroxime being the most consumed antimicrobials within these ATC classes, respectively. The top five most consumed antimicrobials were sulfamethoxazole/trimethoprim, amoxicillin, cefuroxime, doxycycline and ciprofloxacin. Together, they accounted for 82.0% 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.

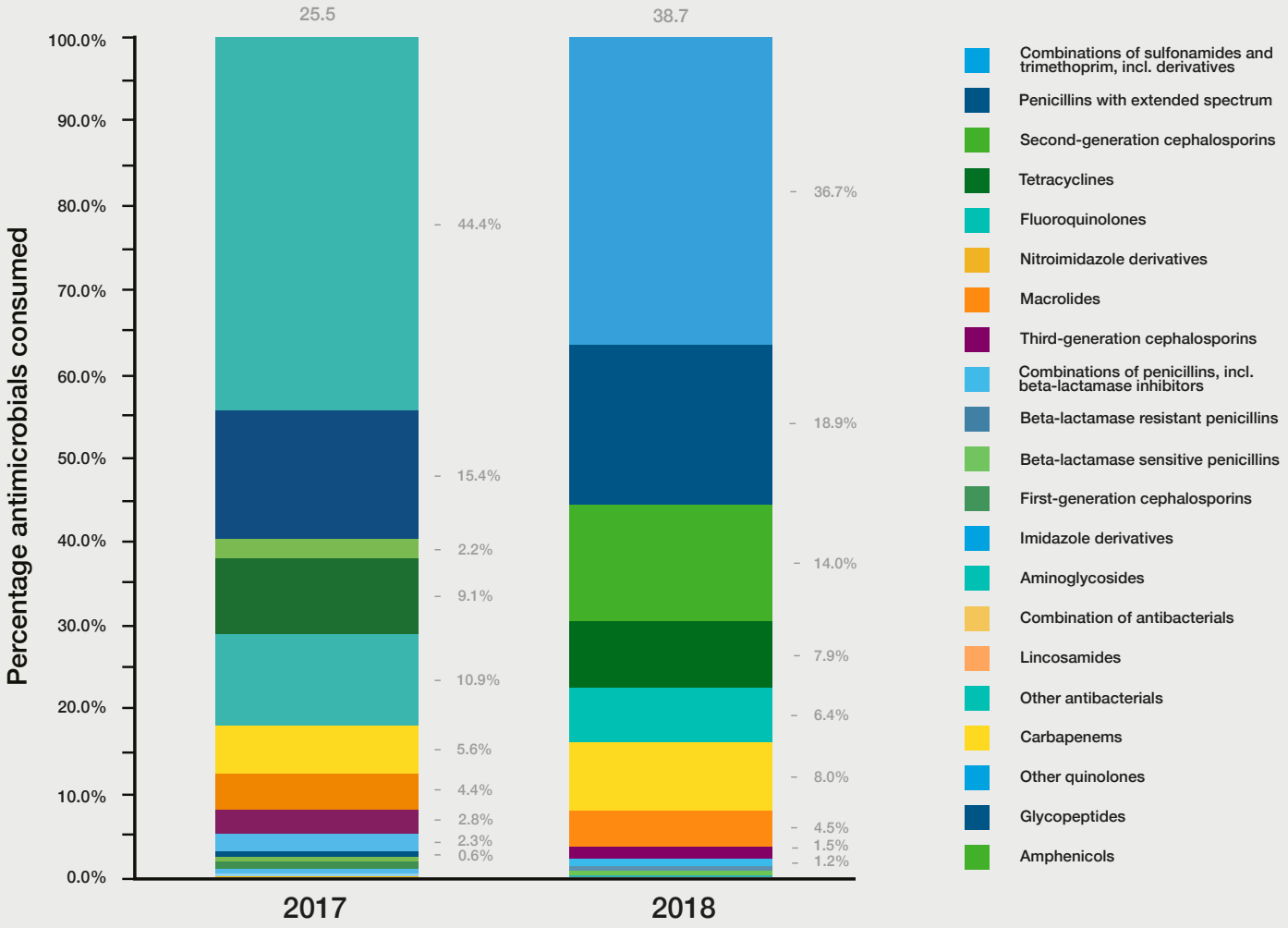



*Figure 19: National-level antimicrobial consumption (AMC) in Zimbabwe between 2017 and 2018. The bars show the percentage of antimicrobials consumed broken down by Anatomic Therapeutic Chemical (ATC) classes. The annual national-level total defined daily dose per 1 000 inhabitants per day (DID) is shown at the top of each bar. The 'Combinations of sulfonamides and trimethoprim, including derivatives' class of molecules were the highest consumed antimicrobials in 2017 and 2018. See AMC Appendix 8 for a more detailed breakdown of AMC by ATC classes.*

## National and pharmacy AMC analysed by WHO AwaRe categorization

Across the two years reviewed (2017-2018), 75.9% of all antimicrobials consumed were in the 'Access' category, 24.1% were in the 'Watch' category, and <0.1% were in the 'Reserve' category. Annual AMC trends indicated a 6.2% decrease in the consumption share of 'Access' antibiotics between 2017 and 2018, with a corresponding 6.1% increase in the consumption share of 'Watch' antibiotics during the same period (Figure 20). On average (between 2017-2018) and within each year analysed, the consumption of 'Access' category antibiotics in Zimbabwe exceeded the 60% minimum consumption threshold set by the WHO. Two antimicrobials, representing a small proportion of the total AMC (i.e., <0.1 DID), did not have any WHO AWaRe categorisation (2019) and were omitted from the analysis.

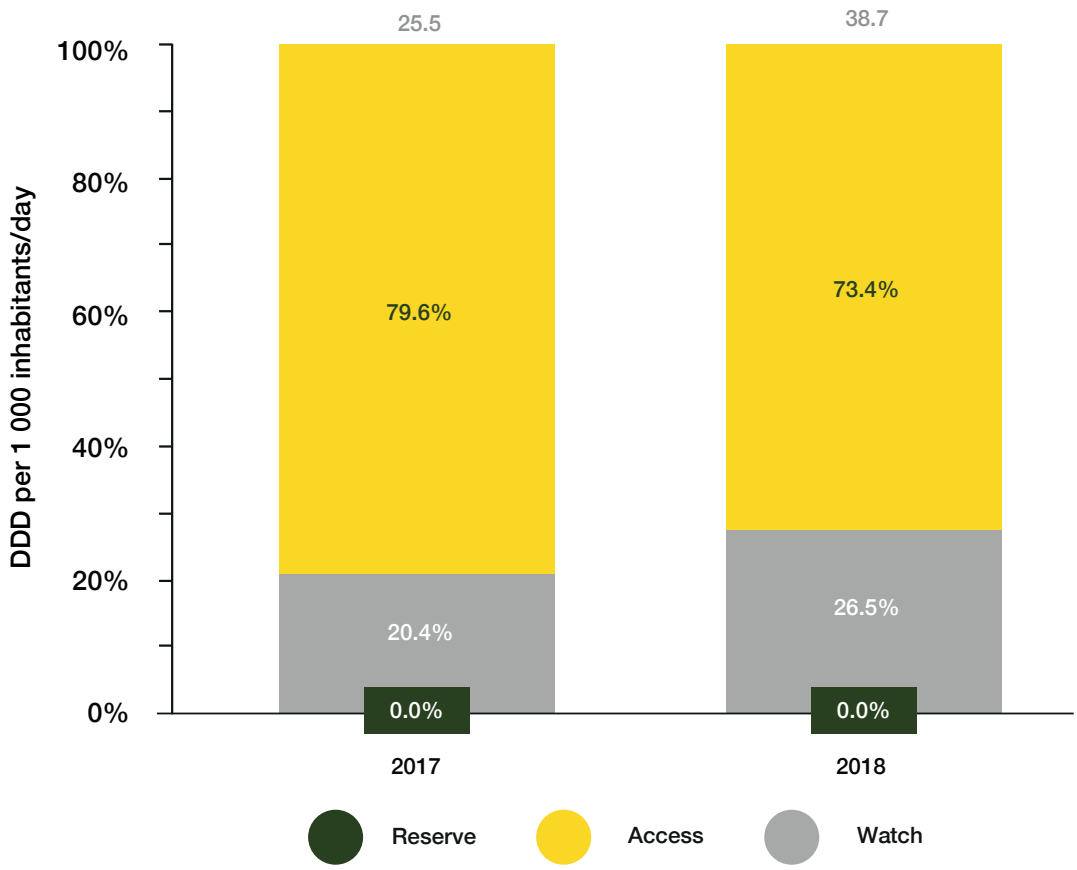
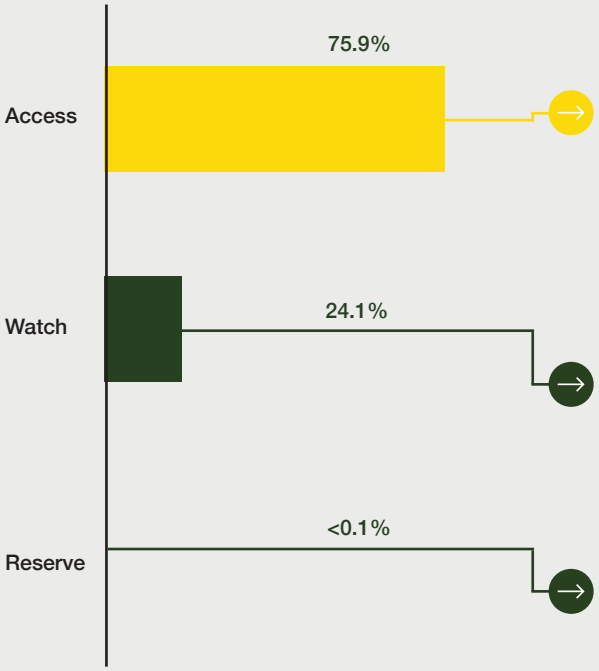



*Figure 20: Antimicrobial consumption in Zimbabwe between 2017 and 2018. The bars show the percentage of antibiotics consumed broken down by WHO AWaRe categories. The annual total defined daily dose per 1 000 inhabitants per day (DID) is shown at the top of each bar. Also, it shows the percentage difference in consumption of 'Access' and 'Watch' category antibiotics from the year 2017 to 2018*

Further analysis was done to identify the most frequently consumed antibiotics nationally within each WHO AWaRe category (Figure 21). In the 'Access' category, the top five most consumed antibiotics accounted for 97.8% of all AMC within this group. While in the 'Watch' category, the top five antibiotics accounted for 93.5% of all AMC within this group. In the 'Reserve' category, national consumption was only recorded for one antibiotic, linezolid, representing 100% of the consumption within this category.




| Molecule Name | % Total | Mean DDD/1000 inhabitants/ day |
|---|---|---|
| Sulfamethoazole/Trimethoprim | 52.4% | 12.8 |
| Amoxicillin | 23.0% | 5.6 |
| Doxycycline | 10.9% | 2.7 |
| Metronidazole | 9.6% | 2.3 |
| Amoxicillin/Clavulanic Acid | 1.9% | 0.5 |

| Molecule Name | % Total | Mean DDD/1000 inhabitants/ day |
|---|---|---|
| Cefuroxime | 37.7% | 2.9 |
| Ciprofloxacin | 30.2% | 2.3 |
| Azithromycin | 12.2% | 0.9 |
| Cefixime | 8.2% | 0.6 |
| Erythromycin | 5.2% | 0.4 |

| Molecule Name | % Total | Mean DDD/1000 inhabitants/ day |
|---|---|---|
| Linezolid | 100% | <0.1 |

Abbreviations: DDD=defined daily dose

*Figure 21: Breakdown of antibiotics consumed at the national level in Zimbabwe by WHO AWaRe ('Access', 'Watch' and 'Reserve') categories, 2017–2018. The inset tables show the top five most consumed antibiotics in each category.*

Aggregated pharmacy-level data from the 32 participating pharmacies were analysed by the pharmacy type (hospital pharmacies vs community pharmacies), hospital service level (secondary care vs tertiary care) and proportional consumption of WHO AWaRe category antibiotics. The hospital pharmacies (93.9% consumption) and community pharmacies (99.7%) far exceeded the WHO threshold of 60% consumption of antibiotics in the 'Access' category. We further analysed the data to identify the reasons for the relatively high consumption of 'Access' antibiotics within the recruited pharmacies and found that four public hospital pharmacies recorded high consumption of the sulfamethoxazole/trimethoprim combination (accounting for up to 90% of the 'Access' group consumption in those pharmacies). The sulfamethoxazole/trimethoprim combination is largely used as a prophylactic treatment against opportunistic infections among HIV/AIDS-positive populations and exists as a routine intervention in HIV treatment programmes.

The unrestrained consumption of the sulfamethoxazole/trimethoprim combination skewed the AMC data towards the 'Access' category antibiotics and necessitated a repeat of the analysis with the exclusion of this outlier. In addition, a notably high consumption of amoxicillin was recorded in one of the private community pharmacies, accounting for almost 100% of the 'Access' group consumption in that pharmacy. This outlier also shifted the consumption trend towards the 'Access' category antibiotics. Therefore, to better understand the consumption trends within the 'Access' category, the pharmacy-level data were represented with and without the consumption of the sulfamethoxazole/trimethoprim combination as well as amoxicillin in one community pharmacy (Table 12).

Despite the removal of these outliers, the hospital pharmacies (83.1% consumption) and community pharmacies (90.2%) maintained a greater than 60% average consumption of 'Access' group antibiotics. In addition, without the sulfamethoxazole/trimethoprim combination and amoxicillin outliers, the hospital pharmacies consumed, on average, 7.1% more 'Watch' category antibiotics compared to community pharmacies. The private faith-based hospital pharmacy, on the other hand, consumed 39.1% more 'Watch' category antibiotics compared to the public hospital pharmacies and failed to meet the WHO 'Access' antibiotics consumption threshold of 60%. Further analyses revealed that three hospital pharmacies and five community pharmacies failed to meet the WHO 'Access' antibiotics consumption threshold. There were no stocks of 'Reserve' category antibiotics supplied to any of the recruited pharmacies during the reviewed period.

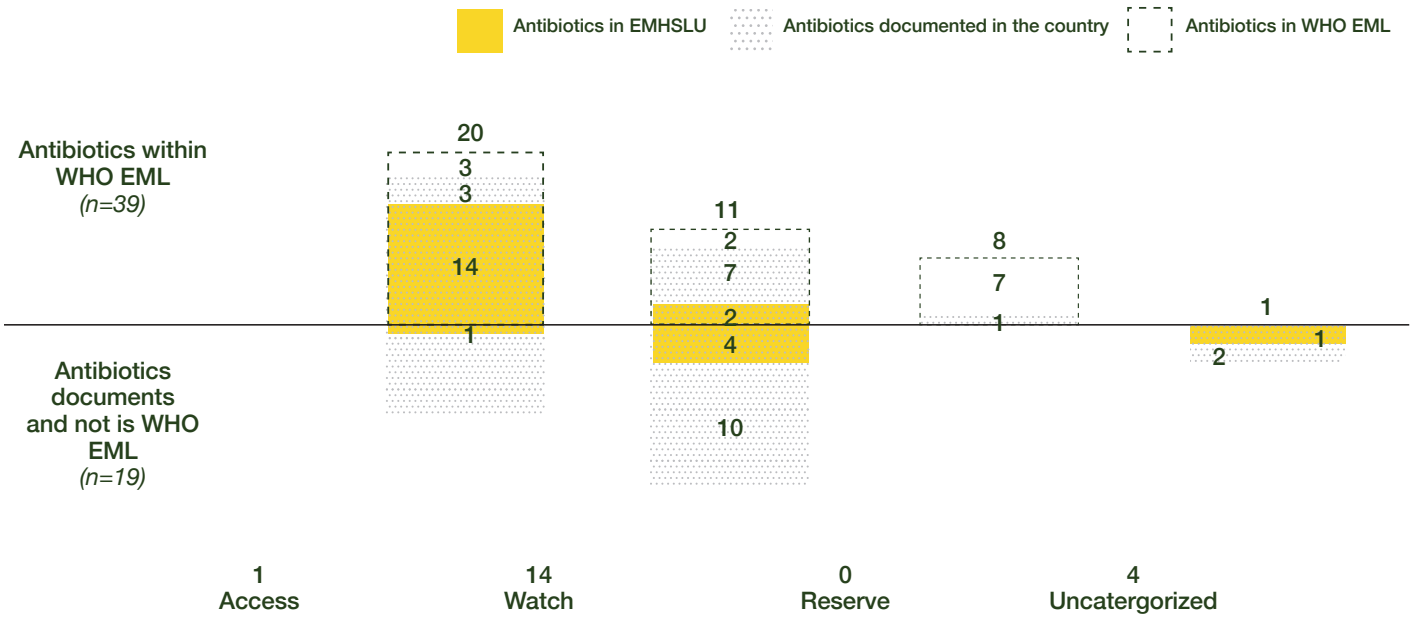
*Table 12: Antimicrobial consumption broken down by WHO AWaRe ('Access', 'Watch' and 'Reserve') categories at the recruited hospital and community pharmacies in Zimbabwe between 2016-2018*

| Pharmacy Type | AWaRe Categorisation | |
|---|---|---|
| | Access | Watch |
| | Percentage share (Absolute DDD) | |
| Community pharmacies (19/32) | 99.7% (8.2 billion) | 0.3% (24.2 million) |
| Hospital pharmacies (13/32) | 93.9% (86.8 million) | 6.1% (5.6 million) |
| Public hospital pharmacies (12/32) | 93.9% (86.7 million) | 6.1% (5.6 million) |
| Secondary care hospitals (7/12) | 90.8%(3.5 million) | 9.2% (360 079) |
| Tertiary care hospitals (5/12) | 94.1%(83.1 million) | 5.9% (5.2 million) |
| Private faith-based hospital pharmacy (1/32) | 47.9% (69 857) | 52.1% (75 906) |
| Grand Total | 99.7% (8.3 billion) | 0.4% (29.9 million) |
| Excluding sulfamethoxazole/trimethoprim and one amoxicillin outlier | | |
| Community pharmacies (19/32) | 90.2% (222.2 million) | 9.8% (24.2 million) |
| Hospital pharmacies (13/32) | 83.1% (27.8 million) | 16.9% (5.6 million) |
| Public hospital pharmacies (12/32) | 83.2% (27.7 million) | 16.8% (5.6 million) |
| Secondary care hospitals (7/12) | 68.3% (774 340) | 31.7% (360 079) |
| Tertiary care hospitals (5/12) | 83.7% (27 million) | 16.3% (5.2 million) |
| Private faith-based hospital pharmacy (1/32) | 44.1% (59 986) | 55.9% (75 907) |
| Grand Total | 89.3% (250.1 million) | 10.7% (29.9 million) |

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

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

The WHO EML includes 39 antibiotics across the AWaRe categories. A total of 58 antibiotics were documented during national- and pharmacy-level data collection. Figure 22 shows, for each AWaRe category, the number of antibiotics in the WHO EML and the EDLIZ, thereby indicating if the antibiotic was documented during data collection. Three antibiotics in the 'Access' category, seven in the 'Watch' category and one in the 'Reserve' category are listed in the WHO EML and were documented during data collection but are not part of the EDLIZ. In addition, three 'Access' category antibiotics, two 'Watch' category antibiotics and seven 'Reserve' category antibiotics are part of the WHO EML but are not listed in the EDLIZ and were not documented during data collection. Interestingly, one 'Access' category antibiotic, four 'Watch' category antibiotics and one uncategorised antibiotic were listed in the EDLIZ and documented during data collection but are not listed in the WHO EML. Some uncategorised and 'Watch' category antibiotics that are not listed in the WHO EML or the EDLIZ were documented during data collection. The detailed breakdown of antibiotics documented and their inclusion in the WHO EML and the EDLIZ is provided in AMC Appendix 9.




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

*Figure 22: AWaRe analysis of documented antibiotics in national- and pharmacy-level data in Zimbabwe (2016 to 2018) compared to the WHO EML and EDLIZ 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[38,39]. 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.[40,41]

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 estimate was found to be high (66.6%; 95% CI: 52.6-80.6%), implying low antibiotic effectiveness, which is a threat to effective infectious disease management and calls for urgent policy intervention (Figure 23).

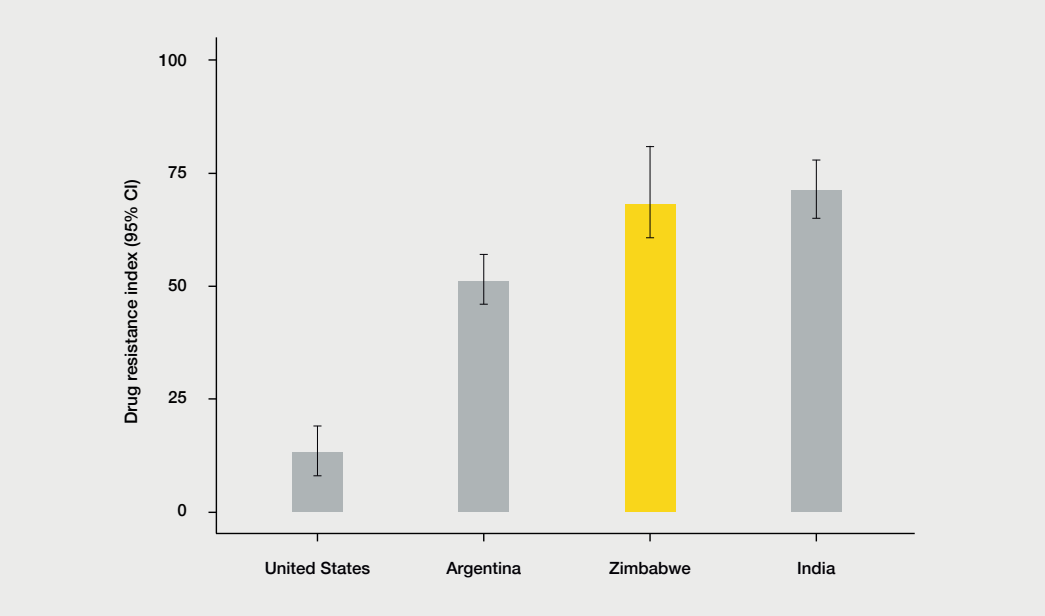



*Figure 23: Drug Resistance Index in Zimbabwe, 2016-2018, compared to the drug resistance index estimates from the United States, Argentina, and India*

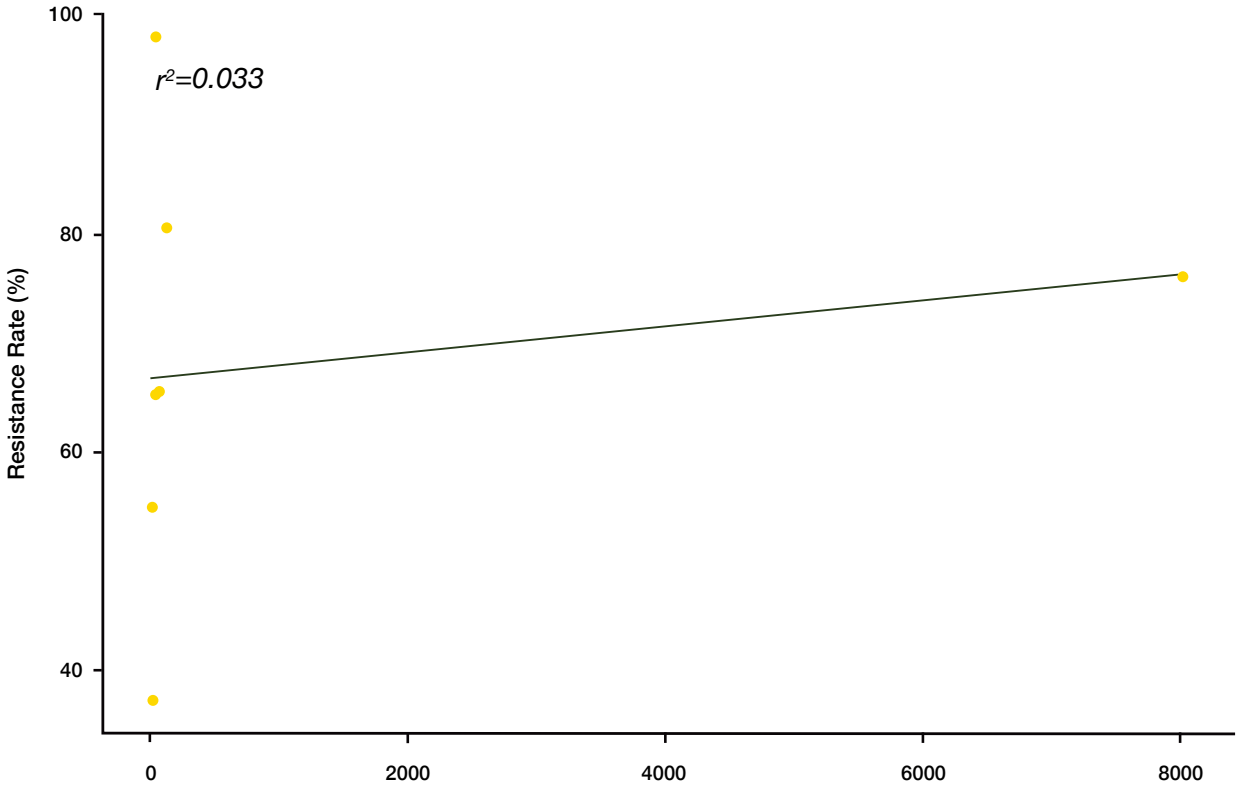
## AMC and AMR correlation

The top three highly consumed antibiotic classes at the facility level were aminopenicillins, folate pathway inhibitors and tetracyclines. The AMR rates were highest for nitroimidazoles (98.3%), folate pathway inhibitors (80.5%) and aminopenicillins (76.0%) (Table 13). Pearson's correlation analysis revealed a weak positive correlation (r2=0.07) between AMR and AMC, implying that antibiotic consumption may be a potential driver of AMR in Zimbabwe (Figure 24).

*Table 13: AMC and AMR rates across antibiotic classes in Zimbabwe, 2016-2018*

| Antibiotic class | Year | Total DDD in thousands | Resistance rate (%) |
|---|---|---|---|
| Aminopenicillins | 2016-2018 | 8020.0 | 76.0 |
| Folate pathway inhibitors | 2016-2018 | 126.0 | 80.5 |
| Tetracyclines | 2016-2018 | 61.75 | 65.5 |
| Methicillin | 2016-2018 | 45.73 | 65.4 |
| Nitroimidazoles | 2016-2018 | 43.53 | 98.3 |
| Fluoroquinolones | 2016-2018 | 15.63 | 37.2 |
| Macrolides | 2016-2018 | 14.67 | 54.9 |

*Abbreviations: DDD=defined daily dose*



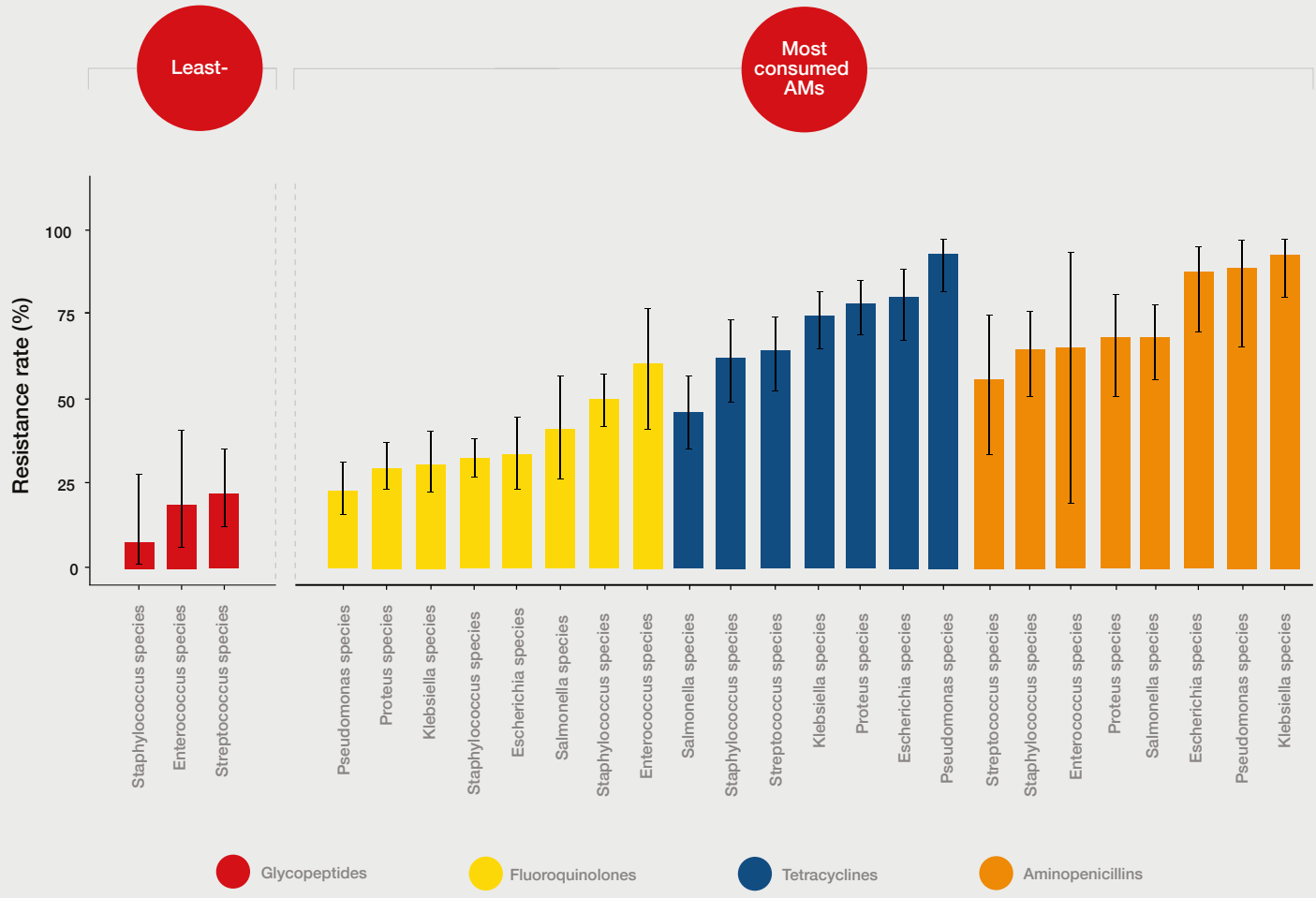

Abbreviations: DDD=defined daily dose

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

## Resistance profiles of most and least consumed antimicrobial classes

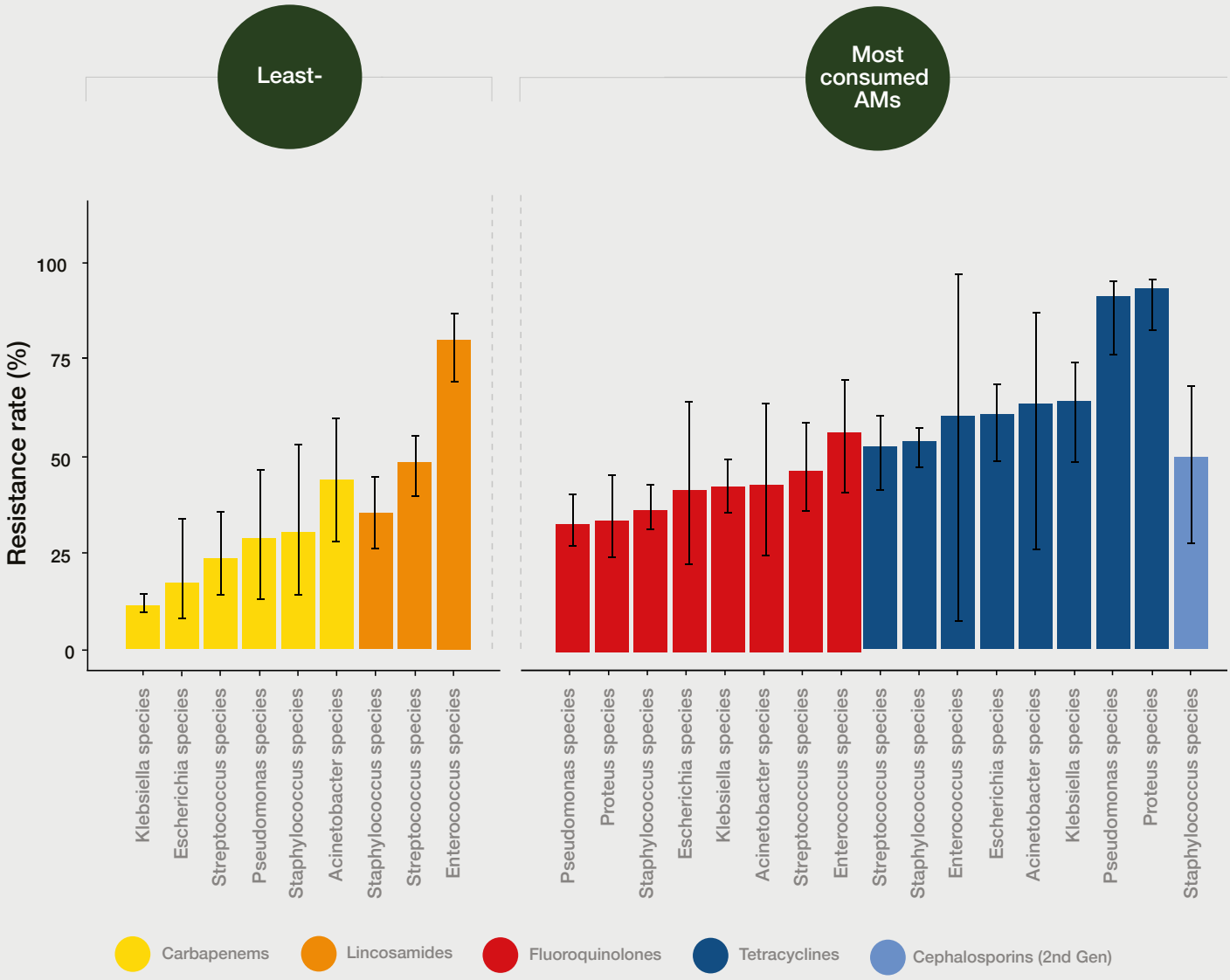
The most consumed antimicrobial classes in 2017 and 2018 (AMC data were not available for 2016) were fluoroquinolones, tetracyclines, aminopenicillins, and cephalosporins (second-generation). In 2017, there were high rates (>75%) of tetracycline-resistant Pseudomonas species, Escherichia species and Proteus species, as well as aminopenicillin-resistant Klebsiella species, Pseudomonas species and Escherichia species. In 2018, there were high rates (>75%) of tetracycline-resistant Proteus species and Pseudomonas species (Figures 25 and 26).

The least consumed antimicrobial classes across the study years were nitroimidazoles, carbapenems, oxazolidinones, phenicols, glycopeptides and lincosamides. Even though the consumption of these antimicrobial classes was low, high resistance rates were noted across many pathogen-antimicrobial class combinations. In 2018, >75% of Enterococcus species were lincosamide-resistant, >40% of Acinetobacter species were cephalosporin (second generation)-resistant and >40% of Enterococcus species were lincosamide-resistant.




Abbreviations: AMs=antimicrobials

*Figure 25: Rates of resistance to the least (left) and most (right) consumed antimicrobial classes in Zimbabwe in 2017*




**Abbreviations: AMs=antimicrobials**

*Figure 26: Rates of resistance to the least (left) and most (right) consumed antimicrobial classes in Zimbabwe in 2018*

# Part D: Recommendations

AMR is a major threat to medical advancements and has drawn global attention over the past few years and more so recently due to the COVID-19 pandemic. Unfortunately, owing to inconsistent surveillance data, the AMR burden is not well quantified in most countries. A recent review reported the non-availability of AMR data for more than 40% of African countries and expressed concerns about the quality of the microbiology data that did exist.[42]

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 Zimbabwe.

# Significance of AMR and DRI data and recommendations

The analysis of available AMR data from Zimbabwe revealed high rates of third-generation cephalosporin-resistant Enterobacterales (41-54%), MRSA (35-50%) and fluoroquinolone-resistant Salmonella species (38-41%).

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

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

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

Salmonella (a member of the Enterobacterales order) strains are known causes of enteric fever, food-borne gastroenteritis and invasive infections. Salmonella infections are transmitted through the oral-faecal route and various risk factors (e.g., age, malaria, schistosomiasis, hemoglobinopathies, immunocompromised state and chronic liver disease) predispose to non-typhoidal Salmonella bacteraemia. Although simple antibiotics like ampicillin, trimethoprim-sulfamethoxazole and chloramphenicol were once effective against Salmonella, multidrug resistance has rapidly spread and fluoroquinolone non-susceptibility is currently a global concern. Food and water safety, screening of food handlers for chronic carrier state and typhoid vaccination of vulnerable populations are critical measures for controlling Salmonella infections. Patients must complete their full antibiotic regimens and be monitored for carriage and relapse. The use of fluoroquinolones in hospitals and animal husbandry must be restricted, and patterns of antimicrobial resistance must be monitored.

The estimated DRI for Zimbabwe was also high and indicates decreasing effectiveness of antimicrobials. Clearly, this calls for targeted interventions such as improved stewardship and infection prevention as well as regulations on the use of high-end antibiotics.

## Service delivery

The laboratory network in Zimbabwe was found to consist of 1 630 laboratories, of which only 23 were identified as bacteriological laboratories and 22 confirmed their AST capabilities. While most of the surveyed laboratories reported implementing QMS, not all were certified or accredited. Considering the country's population of over 14.9 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 up-to-date records on training and competence and only 59% had at least one qualified microbiologist. For high-quality microbiology testing and reporting, it is essential to train staff on laboratory standards, identification of common pathogens and data management.43 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 paper-based records or a combination of electronic and paper-based records and very few had linkages to patients' clinical records. In the current study, involving 14 laboratories over a three-year period, susceptibility results could be collected for just 14 887 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, antimicrobial histories, as well as the molecular profile 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 Zimbabwe to optimise the observed AMC trends and facilitate future surveillance activities.

## Feasibility of obtaining AMC and AMU data in Zimbabwe and recommendations

MAAP successfully collected and analysed national- and pharmacy-level AMC data in Zimbabwe. This implies that conducting AMC surveillance is possible and that Zimbabwe can respond to the WHO's call to participate in GLASS, which now has an AMC reporting component. However, AMC data for the year 2016 were either missing (NatPharm data) or inaccessible (MCAZ data). In addition, the MCAZ data required considerable data verification and cleaning before it could be used. Conversely, the accessed NatPharm data were complete and standardised and required minimal cleaning. Given the unavailability of the 2016 national AMC data as well as the disparity in the quality of the available data, a comprehensive guiding policy for routine AMC data surveillance is required in the country.

This AMC surveillance policy would fall in line with the strategic objectives of the Zimbabwe National Action Plan, which outlines the need to develop tools for AMU monitoring. 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. The development of such a policy will also ensure that the data used is accurate and usable for informing country policies.

The retrieved national AMC data did not indicate which antimicrobials were distributed to the public or private sectors, thus making it difficult to analyse consumption trends between these two sectors. Therefore, MAAP recommends that efforts should be made by the suppliers of AMC datasets to also provide distribution-related information. Furthermore, the policy should outline the minimum duration for which the 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. Efforts should also 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 mainly 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 Zimbabwe, which would have helped to characterise antimicrobial use and prescriptions at the facility level as per the country's guidelines and the WHO's drug use research methodology.[44] 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 issued. Hence, it was not possible to retrieve the relevant clinical and laboratory files for any patients who received antimicrobials. Nevertheless, a recent situational analysis[14] successfully collected AMU data from 18 facilities in Zimbabwe through the use of the global point-prevalence survey methodology.[33] The success of this AMU study implies that in settings with sub-optimal data systems, retrieval of AMU data can only be achieved through the design of point-prevalence studies. In point-prevalence studies, data collection procedures are intentionally set up to assess the patient in real time throughout the cascade of care.

MAAP, in alignment with the WHO guide on facility AMU assessment, would recommend that future AMU surveillance attempts in the country be conducted through large-scale point-prevalence surveys to give a nationally representative portrait of in-country antimicrobial use.[19] However, such an approach is time-consuming unlike retrospective data collection and often requires the engagement of trained data collection teams for prolonged durations, making it expensive and challenging to undertake 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, cross-department unique patient identifiers and a functional and efficient patient record retention system.

## Overview of AMC consumption trends and recommendations

The total AMC levels documented in this report provide a useful benchmark for comparing future in-country AMC levels following the implementation of in-country stewardship programmes. The observed AMC levels in Zimbabwe exceed the levels described in reports from Burundi, Burkina Faso, Cote d'Ivoire[23] and Sierra Leone[27], but were lower than the levels observed in Tanzania.[45] The data for Zimbabwe included public and private wholesaler data compared to the Burundi report, which only included data from the public sector. The Tanzania report used import data, not local production data, to calculate the DDD for the population. This may explain the observed lower AMC levels in Zimbabwe compared to Tanzania. The disparities in AMC levels between the compared countries might also be due to relative differences in the burden of infectious diseases within each country or the limited availability of laboratories and point-of-care diagnostics at the health facility level. These factors may lead to presumptive treatment and unnecessary prescriptions of antimicrobials. The widespread availability of antimicrobials over the counter and unexplained use of some antimicrobials in the animal health sector may be additional contributing factors.[23] Due to the relatively higher rates of AMC in Zimbabwe, 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. During the reviewed period, an overall increase in the national AMC was observed. As we only collected data for two years (2017 and 2018), it is difficult to determine whether this increase represents a trend.

An evaluation of the antibiotics consumed according to the WHO AWaRe categories showed that the proportion of narrow-spectrum 'Access' category antibiotics consumed in Zimbabwe exceeded the WHO-recommended minimum consumption threshold.[19] We also observed a minimal consumption of the broader-spectrum 'Watch' category 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 and last-resort antibiotics in the 'Watch' and 'Reserve' categories. 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. Similarly, only one antibiotic was consumed in the 'Reserve' 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.[46] This narrow consumption of antibiotics within the 'Access', 'Watch' and 'Reserve' categories of antibiotics can also make the country susceptible to stock-outs in the event of manufacturing and supply chain issues. 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. This could include offering incentives for the importation and distribution of other antibiotics in the WHO AWaRe categories and the country's EML.

Interestingly, upon a closer review of the pharmacy-level AMC data, hospital pharmacies showed a very high consumption of 'Access' category antibiotics due to the high consumption of the sulfamethoxazole/trimethoprim combination. The sulfamethoxazole/trimethoprim combination is used for prophylaxis against opportunistic infections among HIV/AIDS-positive populations and is a routine intervention in HIV treatment programmes in Zimbabwe. This prophylactic use of sulfamethoxazole/trimethoprim contributed to the high use observed in the country, which is well above the minimum recommended consumption threshold. However, the consumption of 'Access' category antibiotics remained above the WHO-recommended minimum consumption threshold of 60% even after the exclusion of sulfamethoxazole/trimethoprim. This finding implies that 'Access' category antibiotics, which make up most of the antibiotics listed in the EDLIZ, are widely available in the country.[37]

Although the review of pharmacy-level AMC data revealed that, on average, the hospital pharmacies met the WHO's minimum consumption threshold for 'Access' antibiotics, there was a notable variance in consumption amongst them. The public hospital pharmacies consumed far more 'Access' category antibiotics compared to the private faith-based hospital pharmacy. In addition, the private faith-based hospital pharmacy failed to meet the WHO-recommended consumption threshold for 'Access' category antibiotics. This variation in the consumption of 'Access' category antibiotics may be due to the purchasing power and less oversight of prescribers in the private sector compared to the public sector.

Although no consumption of WHO 'Reserve' group antibiotics was observed within any of the sampled hospital or community pharmacies over the three years reviewed, consumption was recorded on a national level. However, the national-level consumption of linezolid (a 'Reserve' category antibiotic) could not be traced to a particular sector. Interestingly, the country's EML does not include any of the eight 'Reserve' category antibiotics listed in the WHO EML. The MoHCC, the Directorate of Pharmacy Services and the AMRCC need to urgently review the country's EML and treatment guidelines to ensure the availability of 'Reserve' category antibiotics in the country. This approach will ensure that the most vital antibiotics are available for all patients.

Data generated from AMC and AMU surveillance activities can provide unique insights for national stewardship programmes for the formulation of policies to stem the emergence of AMR. Zimbabwe 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 82% of all antibiotics consumed in this category. Table 14 describes the next steps for AMC and AMU surveillance in Zimbabwe.

*Table 14: Next steps for AMC and AMU surveillance in Zimbabwe*

**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) and help 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 national stewardship programmes, led by the AMRCC, could work to review the EDLIZ and national treatment guidelines to ensure the availability and appropriate use of the essential 'Reserve' antibiotics.

**B.**

### Service Delivery

Future attempts to collect AMU data in the country should seek to identify facilities that have unique patient identifiers and fully electronic medical records. 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.[33]

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 EML.

**C.**

### Medical products and technologies

National stewardship programmes should collaborate with pharmacists and medicine importers to increase the availability of more varieties of antibiotics as per the EDLIZ, including the availability of 'Reserve' category antibiotics in selected facilities.

*Abbreviations: AMC=antimicrobial consumption; AMRCC=antimicrobial resistance coordinating committee; AMU=antimicrobial use; EDLIZ=Essential Medicines List for Zimbabwe; EML=essential medicines list; GLASS=Global Antimicrobial Resistance Surveillance System; MAAP=Mapping Antimicrobial resistance and Antimicrobial use Partnership; MoH=Ministry of Health; 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 14 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 14.9 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. A sample of 32 pharmacies were purposively selected for AMC data collection. However, this sample size was a relatively small proportion of the total number of pharmacies in Zimbabwe and did not represent all regions and health zones in Zimbabwe. Therefore, a more systematic sampling strategy that factors in the populations and geographical locations served will be required to draw more representative conclusions from the pharmacy-level data. Despite this, as the national-level AMC data represents 100% AMC coverage, the trends observed are a true representation of Zimbabwe's antimicrobials consumption.

6. 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 the 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 processes), 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: Terms of Reference and Data Sharing Agreements

**Data-Sharing Agreement**

**Between**

**Ministry of Health and Child Care of Zimbabwe**

***(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.



DIRECTOR ORAL HEALTH SERVICES
SECRETARY FOR HEALTH AND
CHILD CARE
05 JUN 2019
P.O. BOX CY 1122, CAUSEWAY
HARARE, ZIMBABWE

3.1.2 The data recipient will not release individual addresses, nor will the recipient present the results of data analysis (including maps) in any manner that would reveal individual addresses.

3.1.3 Both parties shall comply with all Federal and State laws and regulations governing the confidentiality of the information that is the subject of this Agreement.

3.1.4 The data recipient will not release data to a third party without prior approval from the data provider.

3.1.5 The data recipient will not share, publish, or otherwise release any findings or conclusions derived from analysis of data obtained from the data provider without prior approval from the data provider.

3.1.6 The data recipient shall be responsible for the storage of the data in appropriate medium and location ensuring that provider has unlimited access to their data.

**4. Representatives**

4.1 In witness whereof, ASLM and The Provider have caused this agreement to be signed and delivered by their authorized representatives as of the date set forth below.

ASLM's representatives to represent ASLM for the purpose of this Agreement shall be Nqobile Ndlovu (nndlovu@aslm.org), Acting CEO of ASLM. The daily management of the grant will be conducted by Pascale Ondoa (pondoa@aslm.org), ASLM Director of Science and New Initiatives, on behalf of Mr. Nqobile Ndlovu.

For and on behalf of ASLM:

Name: Ndlovu Nqobile
Position: Acting CEO
Signature:
Date: 17 June 2019

"PROVIDER's Representative" to represent the PROVIDER for the purpose of this Agreement shall be :

For and on behalf of Provider:

Name: DOUGLAS MATHUANYA
Position: DIRECTOR LABORATORY SERVICES
Signature:
Date: 5/06/2019

DIRECTOR OF ... SECRETARIAT FOR ... 05 JUN 2019 P.O. ... CAUSEWAY HARARE, ZIMBABWE

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

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

## Appendix 7: Pathogen Phenotype Definitions

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

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

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

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

Appendix 8: Pathogens and antimicrobials for AMR drivers and DRI

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

## AMR Supplementary Tables

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

| Affiliation | Surveyed N = 22 n (%) | Reference N = 4 n (%) | Regional/ Intermediate N = 5 n (%) | District/ Community N = 8 n (%) | Unspecified N = 5 n (%) |
|---|---|---|---|---|---|
| Government | 19 (86.36) | 4 (100.0) | 5 (100.0) | 8 (100.0) | 2 (40.0) |
| Private | 3 (13.64) | 0 | 0 | 0 | 3 (60.0) |
| NGO | 0 | 0 | 0 | 0 | 0 |
| Others | 0 | 0 | 0 | 0 | 0 |

## Supplementary Table 2: Assessment of preparedness for AMR surveillance

| Parameters | Surveyed laboratories N=22 n (%) |
|---|---|
| **Commodity and equipment status** | |
| Regular power supply and functional back up | 17 (77.3) |
| Continuous water supply | 17 (77.3) |
| Certified and functional biosafety cabinets | 16 (72.7) |
| Automated methods for pathogen identification | 4 (18.2) |
| Automated methods for antimicrobial susceptibility testing | 4 (18.2) |
| Methods for testing antimicrobial resistance mechanisms | 9 (40.9) |
| **QMS implementation** | |
| **Reported QMS Implementation** | |
| • Reported QMS tool (n=19) | 19 (86.4) |
| • LQMS | - |
| • SLIPTA | - |
| • SLMTA | - |
| • Mentoring | - |
| • Combination‡ | - |
| • Others | - |
| **Quality Certification** | 11 (50.0) |
| • Reported certification type (n=11) | |
| • SLIPTA | - |
| • College of American Pathologists | - |
| • Others | - |
| Accreditation | 4 (18.2) |
| Participation in proficiency testing | 18 (81.8) |
| Utilisation of reference strains | 16 (72.7) |
| Reported consistent maintenance of QC records | 21 (95.5) |
| Designated focal quality person | 18 (81.8) |
| Reported compliance to standard operating procedures | 21 (95.5) |
| Reported compliance to antimicrobial susceptibility testing standards | 12 (54.5) |
| **Personnel and training status** | |
| Presence of at least one qualified microbiologist | 13 (59.1) |
| Presence of an experienced laboratory scientist/technologist | 22 (100) |
| Up-to-date and complete records on staff training and competence | 19 (86.4) |
| **Specimen Management status** | |
| Reported compliance to standard operating procedures on specimen collection and testing | 22 (100) |
| Reported compliance to standard operating procedures on specimen rejection | 22 (100) |
| Availability on average number of specimens processed for culture and sensitivity in year 2018 | 21 (95.5) |
| **Laboratory Information System and Linkage to Clinical Data** | |
| Assigned specimen (laboratory) identification number | 22 (100) |
| Availability of system/database to store patient data | 18 (81.8) |
| • System/database format (n=18) | |
| • Paper-based | 10 (55.5) |
| • Electronic | 2 (11.1) |
| • Mixed | 6 (33.3) |
| Captured patients' demographics and clinical information on test request forms | 22 (100) |
| • Retrievable test request forms (n=22) | 12 (54.5) |

**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** | | **15762** | **21296** | **25907** | **4663** | **5468** | **6437** | **4254** | **4944** | **5689** |
| Pathogen type | bacteria | | | | 4376 (93.8) | 5226 (95.6) | 6050 (94.0) | 4243 (99.7) | 4942 (100.0) | 5687 (100.0) |
| | fungi | | | | 287 (6.2) | 242 (4.4) | 387 (6.0) | 11 (0.3) | 2 (0.0) | 2 (0.0) |
| Age, years | Less than 1 | 1570 (10.0) | 966 (4.5) | 1832 (7.1) | 289 (6.2) | 286 (5.2) | 522 (8.1) | 267 (6.3) | 268 (5.4) | 497 (8.7) |
| | 1 to 17 | 2721 (17.3) | 3335 (15.7) | 3500 (13.5) | 830 (17.8) | 986 (18.0) | 865 (13.4) | 773 (18.2) | 899 (18.2) | 772 (13.6) |
| | 18 to 49 | 6157 (39.1) | 10510 (49.4) | 10679 (41.2) | 2013 (43.2) | 2227 (40.7) | 2085 (32.4) | 1809 (42.5) | 1955 (39.5) | 1794 (31.5) |
| | 50 to 65 | 1263 (8.0) | 2065 (9.7) | 2291 (8.8) | 424 (9.1) | 462 (8.4) | 452 (7.0) | 400 (9.4) | 431 (8.7) | 405 (7.1) |
| | Above 65 | 1507 (9.6) | 2309 (10.8) | 1979 (7.6) | 704 (15.1) | 841 (15.4) | 632 (9.8) | 675 (15.9) | 797 (16.1) | 590 (10.4) |
| | Unknown Age | 2544 (16.1) | 2111 (9.9) | 5626 (21.7) | 403 (8.6) | 666 (12.2) | 1881 (29.2) | 330 (7.8) | 594 (12.0) | 1631 (28.7) |
| Gender | Male | 7644 (48.5) | 9395 (44.1) | 10644 (41.1) | 2133 (45.7) | 2404 (44.0) | 2488 (38.7) | 1968 (46.3) | 2193 (44.4) | 2231 (39.2) |
| | Female | 8116 (51.5) | 11901 (55.9) | 15257 (58.9) | 2529 (54.2) | 3064 (56.0) | 3947 (61.3) | 2285 (53.7) | 2751 (55.6) | 3456 (60.7) |
| | Unknown gender | 2 (0.0) | | 6 (0.0) | 1 (0.0) | | 2 (0.0) | 1 (0.0) | | 2 (0.0) |
| Laboratory | CIMAS | | 5765 (27.1) | 7414 (28.6) | | | 94 (1.5) | | | |
| | Parirenyatwa | 2952 (18.7) | 3178 (14.9) | 7227 (27.9) | 391 (8.4) | 817 (14.9) | 2714 (42.2) | 355 (8.3) | 794 (16.1) | 2407 (42.3) |
| | NMRL | 374 (2.4) | 301 (1.4) | 10 (0.0) | 176 (3.8) | 123 (2.2) | 10 (0.2) | 160 (3.8) | 107 (2.2) | 10 (0.2) |
| | Gweru | 855 (5.4) | 1020 (4.8) | 967 (3.7) | 155 (3.3) | 367 (6.7) | 87 (1.4) | 150 (3.5) | 295 (6.0) | 82 (1.4) |
| | Harare | 3036 (19.3) | 1207 (5.7) | 2291 (8.8) | 825 (17.7) | 523 (9.6) | 909 (14.1) | 742 (17.4) | 489 (9.9) | 845 (14.9) |
| | Masvingo | 971 (6.2) | 1710 (8.0) | 663 (2.6) | 532 (11.4) | 754 (13.8) | 300 (4.7) | 496 (11.7) | 682 (13.8) | 268 (4.7) |
| | Beitbridge | 78 (0.5) | 321 (1.5) | 826 (3.2) | 9 (0.2) | 65 (1.2) | 73 (1.1) | 9 (0.2) | 64 (1.3) | 71 (1.2) |
| | Bindura | 272 (1.7) | 332 (1.6) | 555 (2.1) | 101 (2.2) | 122 (2.2) | 196 (3.0) | 92 (2.2) | 108 (2.2) | 179 (3.1) |
| | Mutare | 2220 (14.1) | 1740 (8.2) | 325 (1.3) | 1010 (21.7) | 797 (14.6) | 184 (2.9) | 932 (21.9) | 737 (14.9) | 169 (3.0) |
| | Kwekwe | 288 (1.8) | 927 (4.4) | 883 (3.4) | 80 (1.7) | 406 (7.4) | 326 (5.1) | 76 (1.8) | 343 (6.9) | 278 (4.9) |
| | UBH | 1531 (9.7) | 1285 (6.0) | 540 (2.1) | 570 (12.2) | 444 (8.1) | 151 (2.3) | 542 (12.7) | 426 (8.6) | 122 (2.1) |
| | Chitungwiza | 1166 (7.4) | 988 (4.6) | 1322 (5.1) | 460 (9.9) | 346 (6.3) | 620 (9.6) | 430 (10.1) | 326 (6.6) | 576 (10.1) |
| | BRIDH | 794 (5.0) | 1077 (5.1) | 1395 (5.4) | 98 (2.1) | 266 (4.9) | 335 (5.2) | 58 (1.4) | 162 (3.3) | 271 (4.8) |
| | Mpilo | 1225 (7.8) | 1445 (6.8) | 1489 (5.7) | 256 (5.5) | 438 (8.0) | 438 (6.8) | 212 (5.0) | 411 (8.3) | 411 (7.2) |

## Supplementary Table 4: Specimen characteristics

| Specimen Type | All years* N = 14887 n (%) | 2016 N = 4254 n (%) | 2017 N = 4944 n (%) | 2018 N = 5689 n (%) |
|---|---|---|---|---|
| Abscess/Discharge/Pus/Swab/Wound | 6232 (41.9) | 1779 (41.8) | 2048 (41.4) | 2405 (42.3) |
| Aspirate/discharge | 3 (0) | 1 (0) | 2 (0) | - |
| Blood | 2746 (18.4) | 530 (12.5) | 731 (14.8) | 1485 (26.1) |
| Catheter (unspecified) | 72 (0.5) | 6 (0.1) | 55 (1.1) | 11 (0.2) |
| Catheter (urinary) | 6 (0) | - | 3 (0.1) | 3 (0.1) |
| Catheter tip | 160 (1.1) | 30 (0.7) | 57 (1.2) | 73 (1.3) |
| CSF | 318 (2.1) | 134 (3.1) | 32 (0.6) | 152 (2.7) |
| Fluid (abdominal/peritoneal) | 16 (0.1) | 3 (0.1) | - | 13 (0.2) |
| Fluid (cyst) | 1 (0) | - | - | 1 (0) |
| Fluid (joint/synovial) | 2 (0) | - | - | 2 (0) |
| Fluid (pericardial) | 2 (0) | - | - | 2 (0) |
| Fluid (pleural) | 31 (0.2) | 3 (0.1) | 9 (0.2) | 19 (0.3) |
| Fluid (sinus) | 1 (0) | - | - | 1 (0) |
| Fluid (unspecified) | 1 (0) | - | - | 1 (0) |
| Respiratory-Lower | 24 (0.2) | - | 2 (0) | 22 (0.4) |
| Respiratory-Upper | 136 (0.9) | 20 (0.5) | 29 (0.6) | 87 (1.5) |
| Scraping | 2 (0) | - | - | 2 (0) |
| Scraping (cornea) | 3 (0) | - | - | 3 (0.1) |
| Stool | 317 (2.1) | 146 (3.4) | 111 (2.2) | 60 (1.1) |
| Swab (high vaginal) | 505 (3.4) | 222 (5.2) | 151 (3.1) | 132 (2.3) |
| Swab (rectal) | 17 (0.1) | 1 (0) | 9 (0.2) | 7 (0.1) |
| Swab/discharge | 4 (0) | 1 (0) | 2 (0) | 1 (0) |
| Swab/discharge (ear) | 6 (0) | 3 (0.1) | - | 3 (0.1) |
| Swab/discharge (genital) | 4 (0) | - | - | 4 (0.1) |
| Swab/discharge (nose) | 1 (0) | - | 1 (0) | - |
| Swab/discharge (skin) | 2 (0) | - | - | 2 (0) |
| Swab/discharge (urethral) | 27 (0.2) | 15 (0.4) | 9 (0.2) | 3 (0.1) |
| Tissue/biopsy | 52 (0.3) | 2 (0) | - | 50 (0.9) |
| Ulcer | 1 (0) | - | - | 1 (0) |
| Unknown | 1 (0) | - | - | 1 (0) |
| Urine | 4194 (28.2) | 1358 (31.9) | 1693 (34.2) | 1143 (20.1) |

**Indicates positive cultures with AST results*

Supplementary Table 5: Pathogen identification

| Pathogen | All years* N= 14887 n (%) | 2016 N = 4254 n (%) | 2017 N = 4944 n (%) | 2018 N = 5689 n (%) |
|---|---|---|---|---|
| **Positive cultures with specific pathogen name** | 4264 (28.7) | 1218 (28.7) | 1361 (27.5) | 1685 (29.6) |
| Acinetobacter baumannii | 41 (0.3) | 8 (0.2) | 10 (0.2) | 23 (0.4) |
| Acinetobacter calcoaceticus | 1 (0) | - | - | 1 (0) |
| Alloiococcus otitidis | 1 (0) | - | - | 1 (0) |
| Bacteroides fragilis | 1 (0) | 1 (0) | - | - |
| Brevundimonas diminuta | 1 (0) | 1 (0) | - | - |
| Candida albicans | 2 (0) | - | 1 (0) | 1 (0) |
| Citrobacter freundii | 2 (0) | - | 1 (0) | 1 (0) |
| Citrobacter koseri | 1 (0) | - | - | 1 (0) |
| Corynebacterium diphtheriae | 1 (0) | - | - | 1 (0) |
| Enterobacter cloacae | 2 (0) | - | 1 (0) | 1 (0) |
| Enterococcus faecalis | 10 (0.1) | - | 3 (0.1) | 7 (0.1) |
| Enterococcus faecium | 7 (0) | 2 (0) | 2 (0) | 3 (0.1) |
| Enterococcus gallinarum | 2 (0) | 1 (0) | 1 (0) | - |
| Escherichia coli | 960 (6.4) | 255 (6) | 319 (6.5) | 386 (6.8) |
| Klebsiella oxytoca | 107 (0.7) | 30 (0.7) | 38 (0.8) | 39 (0.7) |
| Klebsiella pneumoniae | 66 (0.4) | 22 (0.5) | 18 (0.4) | 26 (0.5) |
| Lactobacillus fermentum | 46 (0.3) | - | 23 (0.5) | 23 (0.4) |
| Morganella morganii | 8 (0.1) | 1 (0) | 4 (0.1) | 3 (0.1) |
| Neisseria gonorrhoeae | 2 (0) | - | 2 (0) | - |
| Proteus mirabilis | 53 (0.4) | 32 (0.8) | 13 (0.3) | 8 (0.1) |
| Proteus vulgaris | 34 (0.2) | 7 (0.2) | 20 (0.4) | 7 (0.1) |
| Pseudomonas aeruginosa | 560 (3.8) | 144 (3.4) | 187 (3.8) | 229 (4) |
| Pseudomonas putida | 4 (0) | 1 (0) | 1 (0) | 2 (0) |
| Salmonella typhi | 185 (1.2) | 76 (1.8) | 102 (2.1) | 7 (0.1) |
| Shewanella putrefaciens | 1 (0) | - | - | 1 (0) |
| Shigella boydii | 1 (0) | - | 1 (0) | - |

| | | | | |
|---|---|---|---|---|
| Shigella dysenteriae | 7 (0) | 5 (0.1) | 2 (0) | - |
| Shigella flexneri | 89 (0.6) | 42 (1) | 29 (0.6) | 18 (0.3) |
| Shigella sonnei | 8 (0.1) | 2 (0) | 3 (0.1) | 3 (0.1) |
| Sphingomonas paucimobilis | 1 (0) | - | 1 (0) | - |
| Staphylococcus aureus | 1556 (10.5) | 433 (10.2) | 432 (8.7) | 691 (12.1) |
| Staphylococcus auricularis | 2 (0) | - | 2 (0) | - |
| Staphylococcus capitis | 1 (0) | - | - | 1 (0) |
| Staphylococcus epidermidis | 96 (0.6) | 44 (1) | 15 (0.3) | 37 (0.7) |
| Staphylococcus haemolyticus | 15 (0.1) | 6 (0.1) | 4 (0.1) | 5 (0.1) |
| Staphylococcus hominis | 3 (0) | 1 (0) | 1 (0) | 1 (0) |
| Staphylococcus saccharolyticus | 4 (0) | - | 1 (0) | 3 (0.1) |
| Staphylococcus saprophyticus | 183 (1.2) | 64 (1.5) | 67 (1.4) | 52 (0.9) |
| Staphylococcus sciuri | 3 (0) | - | 2 (0) | 1 (0) |
| Stenotrophomonas (xanthomonas) maltophilia | 1 (0) | - | - | 1 (0) |
| Streptococcus agalactiae | 7 (0) | 1 (0) | 2 (0) | 4 (0.1) |
| Streptococcus mitis | 2 (0) | - | 1 (0) | 1 (0) |
| Streptococcus pneumoniae | 8 (0.1) | 5 (0.1) | 1 (0) | 2 (0) |
| Streptococcus pyogenes | 51 (0.3) | 10 (0.2) | 23 (0.5) | 18 (0.3) |
| Streptococcus viridans | 113 (0.8) | 18 (0.4) | 26 (0.5) | 69 (1.2) |
| Succinimonas amylolytica | 3 (0) | - | 2 (0) | 1 (0) |
| Vibrio cholerae | 12 (0.1) | 6 (0.1) | - | 6 (0.1) |
| Positive cultures with non-specific pathogen name | 10623 (71.3) | 3036 (71.3) | 3583 (72.5) | 4004 (70.4) |
| Acinetobacter Sp. | 56 (0.4) | - | 3 (0.1) | 53 (0.9) |
| Actinomyces Sp. | 1 (0) | - | - | 1 (0) |
| Bacillus Sp. | 2 (0) | - | 1 (0) | 1 (0) |
| Brevibacterium Sp. | 4 (0) | 2 (0) | - | 2 (0) |
| Citrobacter Sp. | 4 (0) | - | 3 (0.1) | 1 (0) |
| Corynebacterium Sp. | 18 (0.1) | 3 (0.1) | 5 (0.1) | 10 (0.2) |

| | | | | |
|---|---|---|---|---|
| Enterobacter Sp. | 8 (0.1) | 1 (0) | 3 (0.1) | 4 (0.1) |
| Enterococcus Sp. | 236 (1.6) | 28 (0.7) | 56 (1.1) | 152 (2.7) |
| Escherichia Sp. | 2 (0) | - | 1 (0) | 1 (0) |
| Klebsiella Sp. | 1051 (7.1) | 269 (6.3) | 372 (7.5) | 410 (7.2) |
| Lactobacillus Sp. | 6 (0) | - | 3 (0.1) | 3 (0.1) |
| Leuconostoc Sp. | 2 (0) | - | - | 2 (0) |
| Micrococcus Sp. | 5 (0) | 1 (0) | 1 (0) | 3 (0.1) |
| Moraxella Sp. | 2 (0) | 1 (0) | - | 1 (0) |
| Non fermenting gram negative bacilli | 1512 (10.2) | 459 (10.8) | 555 (11.2) | 498 (8.8) |
| Pantoea Sp. | 5 (0) | 1 (0) | 1 (0) | 3 (0.1) |
| Proteus Sp. | 408 (2.7) | 139 (3.3) | 164 (3.3) | 105 (1.8) |
| Pseudallescheria Sp. | 11 (0.1) | 10 (0.2) | - | 1 (0) |
| Pseudomonas Sp. | 37 (0.2) | 5 (0.1) | 14 (0.3) | 18 (0.3) |
| Salmonella Sp. | 65 (0.4) | 19 (0.4) | 36 (0.7) | 10 (0.2) |
| Serratia Sp. | 2 (0) | - | 1 (0) | 1 (0) |
| Shigella Sp. | 3 (0) | - | - | 3 (0.1) |
| Sphingobacterium Sp. | 3 (0) | 2 (0) | - | 1 (0) |
| Staphylococcus Sp. | 3163 (21.2) | 866 (20.4) | 975 (19.7) | 1322 (23.2) |
| Streptococcus Sp. | 635 (4.3) | 193 (4.5) | 193 (3.9) | 249 (4.4) |
| Unspecified (Gram negative bacilli) | 3302 (22.2) | 1017 (23.9) | 1167 (23.6) | 1118 (19.7) |
| Unspecified (Gram negative bacteria) | 5 (0) | - | 2 (0) | 3 (0.1) |
| Unspecified (Gram negative cocci) | 3 (0) | - | 3 (0.1) | - |
| Unspecified (Gram negative coccobacilli) | 2 (0) | - | - | 2 (0) |
| Unspecified (Gram positive bacilli) | 24 (0.2) | 3 (0.1) | 5 (0.1) | 16 (0.3) |
| Unspecified (Gram positive bacteria) | 1 (0) | 1 (0) | - | - |
| Unspecified (Gram positive cocci) | 42 (0.3) | 14 (0.3) | 18 (0.4) | 10 (0.2) |
| Unspecified (Gram variable coccobacilli) | 1 (0) | 1 (0) | - | - |
| Yeast | 2 (0) | 1 (0) | 1 (0) | - |

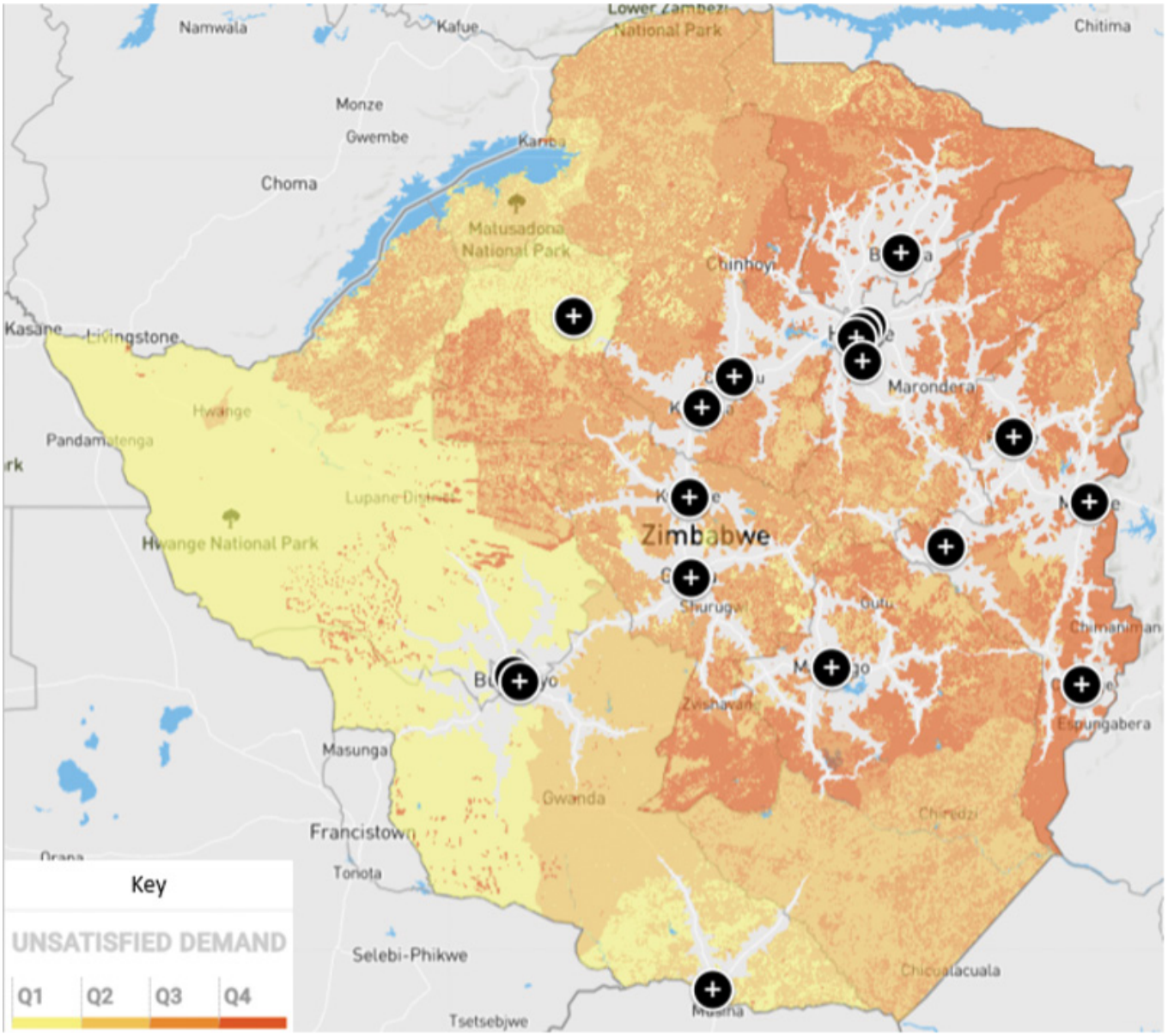
*Note: * indicates positive cultures with AST results; '-' means information was not available.*

Supplementary Table 6: Laboratory data scoring

| Laboratory name | Laboratory data score (out of 4) | | | |
|---|---|---|---|---|
| | 2016 | 2017 | 2018 | Average |
| Mpilo | 1 | 2 | 2 | 1.7 |
| Parirenyatwa | 2 | 1 | 2 | 1.7 |
| NMRL | 3 | 4 | 4 | 3.7 |
| BRIDH | 2 | 2 | 1 | 1.7 |
| Harare | 2 | 2 | 2 | 2 |
| Masvingo | 3 | 2 | 3 | 2.7 |
| Beitbridge | - | 2 | 2 | 2 |
| Bindura | 1 | 1 | 2 | 1.3 |
| Mutare | 1 | 1 | 2 | 1.3 |
| Kwekwe | 3 | 3 | 3 | 3 |
| UBH | 1 | 1 | 1 | 1 |
| Chitungwiza | 1 | 1 | 1 | 1 |
| CIMAS | - | - | - | - |
| Gweru | 2 | 2 | 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 |
|---|---|---|---|---|---|
| Klebsiella pneumoniae ss. pneumoniae | Amphotericin B | AMB_ND10 | R | Disk | 2018 |
| Escherichia coli | Amphotericin B | AMB_ND10 | R | Disk | 2018 |
| Escherichia coli | Amphotericin B | AMB_ND10 | R | Disk | 2018 |
| Escherichia coli | Amphotericin B | AMB_ND10 | R | Disk | 2018 |
| Enterococcus faecalis | Amphotericin B | AMB_ND10 | R | Disk | 2018 |
| Klebsiella pneumoniae ss. pneumoniae | Amphotericin B | AMB_ND10 | R | Disk | 2018 |
| Vibrio cholerae | Amphotericin B | AMB_ND10 | I | Disk | 2018 |
| Escherichia coli | Amphotericin B | AMB_ND10 | R | Disk | 2018 |
| Enterococcus faecalis | Amphotericin B | AMB_ND10 | R | Disk | 2018 |
| Escherichia coli | Amphotericin B | AMB_ND10 | R | Disk | 2018 |
| Escherichia coli | Amphotericin B | AMB_ND10 | R | Disk | 2018 |
| Klebsiella pneumoniae ss. pneumoniae | Amphotericin B | AMB_ND10 | R | Disk | 2018 |
| Proteus mirabilis | Amphotericin B | AMB_ND10 | R | Disk | 2018 |
| Escherichia coli | Amphotericin B | AMB_ND10 | R | Disk | 2018 |
| Enterococcus sp. | Amphotericin B | AMB_ND10 | R | Disk | 2018 |
| Escherichia coli | Amphotericin B | AMB_ND10 | I | Disk | 2018 |
| Escherichia coli | Amphotericin B | AMB_ND10 | R | Disk | 2018 |

## Supplementary Figure 2b: Inappropriate testing B

| Organism Name | Antimicrobial Agent | Agent Code | Interpreted Results | Antimicrobial Susceptibility Method | Year |
|---|---|---|---|---|---|
| Staphylococcus aureus ss aureus | Vancomycin | VAN_ND30 | R | Disk | 2018 |
| Staphylococcus aureus ss aureus | Vancomycin | VAN_ND30 | R | Disk | 2018 |
| Staphylococcus aureus ss aureus | Vancomycin | VAN_ND30 | R | Disk | 2018 |
| Escherichia coli | Vancomycin | VAN_ND30 | S | Disk | 2016 |
| Escherichia coli | Oxacillin | OXA_ND1 | R | Disk | 2018 |
| Klebsiella sp. | Penicillin G | PEN_ND10 | R | Disk | 2018 |
| Escherichia coli | Penicillin G | PEN_ND10 | R | Disk | 2018 |
| Escherichia coli | Penicillin G | PEN_ND10 | R | Disk | 2018 |
| Escherichia coli | Penicillin G | PEN_ND10 | R | Disk | 2018 |
| Klebsiella pneumoniae ss. pneumoniae | Penicillin G | PEN_ND10 | R | Disk | 2018 |
| Proteus vulgaris | Oxacillin | OXA_ND1 | R | Disk | 2017 |
| Klebsiella sp. | Oxacillin | OXA_ND1 | R | Disk | 2017 |
| Escherichia coli | Oxacillin | OXA_ND1 | R | Disk | 2017 |
| Escherichia coli | Oxacillin | OXA_ND1 | R | Disk | 2017 |
| Escherichia coli | Oxacillin | OXA_ND1 | R | Disk | 2017 |

# AMC Appendices

## Appendix 1: Key Informant Interview (KII) tool

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

### Domestic Producers and Importers

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

### Procurement, Storage and Distribution

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

### Public Sector

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

### Private Sector

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

### Donor Funded Supply

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

## 2. Data and Information Systems

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

## 3. Informal Supply Chains

| | |
|---|---|
| 3.1 | Is there an estimate of the antibiotic black-market size in the country? |
| | |
| | |
| 3.2 | Are there any mechanisms 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 |

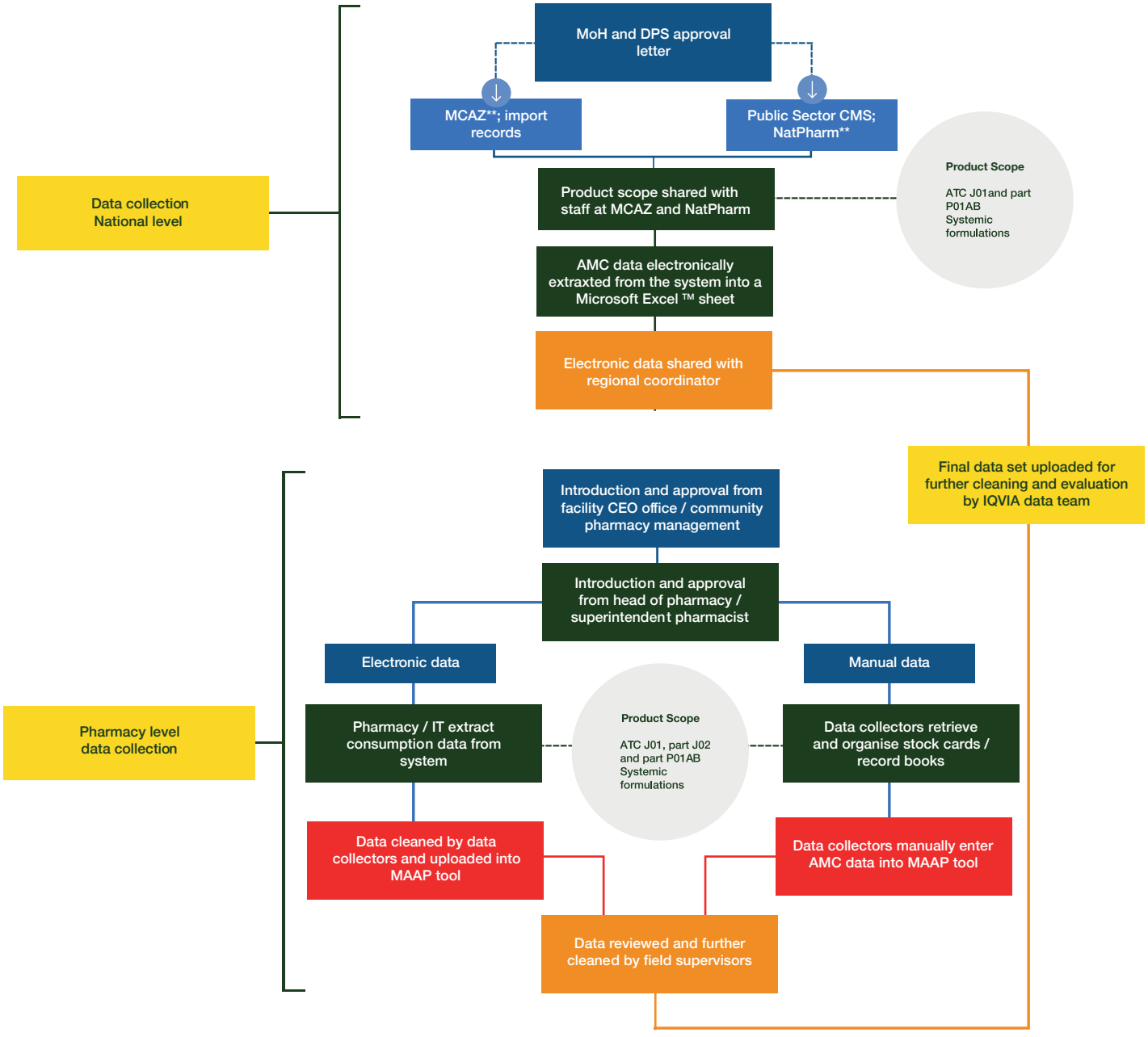
| | | |
|---|---|---|
| Ciprofloxacin/Metronidazole | J01RA10 | U |
| Ciprofloxacin/Tinidazole | J01RA11 | U |
| Ciprofloxacin/Ornidazole | J01RA12 | U |
| Norfloxacin/Tinidazole | J01RA13 | U |
| Vancomycin | J01XA01 | W |
| Teicoplanin | J01XA02 | W |
| Telavancin | J01XA03 | R |
| Dalbavancin | J01XA04 | 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 data is a subset of the national level data; the two data sets were analysed and presented separately*
*** MCAZ: Medicines Control Agency of Zimbabwe; CMS: Central Medical Store; NatPharm: National Pharmaceutical Company*

## 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 Zimbabwe population at a national level; includes all age and gender groups and used the known population numbers as the denominator (obtained from the Worldometer Population Database).

**The below formula summarises how this calculation was done:**

DDD/1000 Inhabitants/day =

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

*Zimbabwe population estimated for 2016-2018 obtained from: https://www.worldometers.info/world-population/zimbabwe-population/

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

**DDD equivalent (%) =**

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

*WHO approved DDDs for antibiotics:

WHO Anatomical Therapeutic Chemical (ATC) classification

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

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

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

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

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

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

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

**Description of the AWaRe categories below:**

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

'Watch': These antibiotics generally have a broader spectrum of activity against microbes and are to be used sparingly as first or second choice treatment options for specified infectious syndromes; they are indicated for specific, limited number of infective syndromes or patient groups. These medicines are also preferred over access antibiotics in serious infections. β-lactams (54.54%) constitute the larger share of the watch group antibiotics followed by macrolides (18.18%), aminoglycosides (9.09%), and carbapenems (9.09%). Watch group compromises of 110 antibiotics; 11 of which are included in the WHO's EML. Watch group antibiotics should be prioritised as key targets of stewardship 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; 7 of which are included in the WHO's EML. The use of antibiotics in this group should be closely monitored and prioritised as targets for AMS to ensure their continued effectiveness.

## Appendix 7: National AMC by Antimicrobial molecules

| ATC Class Rank | AWaRe category | Molecule | 2016 | 2017 | Mean DDD/1000 inhabitant-days |
|---|---|---|---|---|---|
| | | | DDD/1000 inhabitant-days (%*) | | |
| J01 Class | | Total | 24.08 (100) | 35.57 (100) | 29.82 |
| 1 | Access | Sulfamethoxazole/Trimethoprim | 11.331337 (47.1) | 14.228285 (40) | 12.78 |
| 2 | Access | Amoxicillin | 3.92041 (16.3) | 7.30294 (20.5) | 5.61 |
| 3 | Watch | Cefuroxime | 0.469287 (1.9) | 5.375117 (15.1) | 2.92 |
| 4 | Access | Doxycycline | 2.32305 (9.6) | 2.99023 (8.4) | 2.66 |
| 5 | Watch | Ciprofloxacin | 2.442816 (10.1) | 2.235721 (6.3) | 2.34 |
| 6 | Watch | Azithromycin | 0.728656 (3) | 1.161681 (3.3) | 0.95 |
| 7 | Watch | Ceftriaxone | 0.710419 (2.9) | 0.5645 (1.6) | 0.64 |
| 8 | Access | Amoxicillin/Clavulanic Acid | 0.580905 (2.4) | 0.349672 (1) | 0.47 |
| 9 | Watch | Erythromycin | 0.312268 (1.3) | 0.490785 (1.4) | 0.40 |
| 10 | Access | Cloxacillin | 0.163767 (0.7) | 0.169369 (0.5) | 0.17 |
| 11 | Watch | Levofloxacin | 0.196917 (0.8) | 0.107283 (0.3) | 0.15 |
| 12 | Access | Cefalexin | 0.237498 (1) | 0.037098 (0.1) | 0.14 |
| 13 | Watch | Moxifloxacin | 0.129379 (0.5) | 0.1277 (0.4) | 0.13 |
| 14 | Access | Metronidazole | 0.156274 (0.6) | 0.035067 (0.1) | 0.10 |
| 15 | Access | Benzylpenicillin | 0.091891 (0.4) | 0.095949 (0.3) | 0.09 |
| 16 | Watch | Cefaclor | 0.09332 (0.4) | 0.039297 (0.1) | 0.07 |
| 17 | Watch | Roxithromycin | 0.053961 (0.2) | 0.068888 (0.2) | 0.06 |

| | | | | | |
|---|---|---|---|---|---|
| 18 | Access | Procaine benzylpenicillin | 0.002213 (0) | 0.094874 (0.3) | 0.05 |
| 19 | Access | Gentamicin | 0.039566 (0.2) | 0.041336 (0.1) | 0.04 |
| 20 | Watch | Kanamycin | 0.045015 (0.2) | 0.008383 (0) | 0.03 |
| 21 | Watch | Clarithromycin | 0.021015 (0.1) | 0.013946 (0) | 0.02 |
| 22 | Access | Benzathine benzylpenicillin | 0.022268 (0.1) | 0.006527 (0) | 0.01 |
| 23 | Watch | Norfloxacin | 0.004301 (0) | 0.009814 (0) | 0.01 |
| 24 | Access | Clindamycin | 0.00101 (0) | 0.003801 (0) | 0.00 |
| 25 | Reserve | Linezolid | 0.000895 (0) | 0.003867 (0) | 0.00 |
| 26 | Watch | Meropenem | 0.00185 (0) | 0.000102 (0) | 0.00 |
| 27 | Access | Ampicillin | 0.000034 (0) | 0.00141 (0) | 0.00 |
| 28 | Uncategorised | Nalidixic Acid | 0.001203 (0) | 0.000166 (0) | 0.00 |
| 29 | Access | Flucloxacillin | 0 (0) | 0.001186 (0) | 0.00 |
| 30 | Watch | Cefixime | 0.001155 (0) | 0 (0) | 0.00 |
| 31 | Access | Chloramphenicol | 0.000321 (0) | 0.000269 (0) | 0.00 |
| 32 | Watch | Ofloxacin | 0.000481 (0) | 0 (0) | 0.00 |
| 33 | Watch | Imipenem/Cilastatin | 0.000122 (0) | 0.000034 (0) | 0.00 |
| **P01AB Class** | | **Total** | **1.44 (100)** | **3.08 (100)** | **2.26** |
| 1 | Access | Metronidazole | 1.421428 (99) | 3.084938 (100) | 2.25 |
| 2 | Uncategorised | Secnidazole | 0.013998 (1) | 0 (0) | 0.01 |

**Antibiotics marked as 'uncategorised' have not been awarded a category within the 2019 WHO AWaRe database, including not being placed within the 'not recommended' list.

## Appendix 8: Breakdown of national AMC by ATC classes

| ATC class | % consumption 2016 | 2017 |
|---|---|---|
| Combinations of sulfonamides and trimethoprim, incl. derivatives | 44.4% | 36.7% |
| Penicillins with extended spectrum | 15.4% | 18.9% |
| Second-generation cephalosporins | 2.2% | 14.0% |
| Tetracyclines | 9.1% | 7.9% |
| Fluoroquinolones | 10.9% | 6.4% |
| Nitroimidazole derivatives | 5.6% | 8.0% |
| Macrolides | 4.4% | 4.5% |
| Third-generation cephalosporins | 2.8% | 1.5% |
| Combinations of penicillins, incl. beta-lactamase inhibitors | 2.3% | 0.9% |
| Beta-lactamase resistant penicillins | 0.6% | 0.4% |
| Beta-lactamase sensitive penicillins | 0.5% | 0.5% |
| First-generation cephalosporins | 0.9% | 0.1% |
| Imidazole derivatives | 0.6% | 0.1% |
| Aminoglycosides | 0.3% | 0.1% |
| Combinations of antibacterials | 0.1% | 0.0% |
| Lincosamides | 0.004% | 0.01% |
| Other antibacterials | 0.004% | 0.01% |
| Carbapenems | 0.01% | 0.0004% |
| Other quinolones | 0.005% | 0.0004% |
| Glycopeptides | 0.0% | 0.002% |
| Amphenicols | 0.001% | 0.001% |

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

| Standardised Molecule Name | WHO AWaRe Categorisation | WHO ATC Code | WHO EML | National EML | Documented Data |
|---|---|---|---|---|---|
| Amikacin | Access | J01GB06 | Y | N | Y |
| Amoxicillin | Access | J01CA04 | Y | Y | Y |
| Amoxicillin/ Clavulanic Acid | Access | J01CR02 | Y | N | Y |
| Ampicillin | Access | J01CA01 | Y | Y | Y |
| Azithromycin | Watch | J01FA10 | Y | N | Y |
| Benzathine benzylpenicillin | Access | J01CE08 | Y | Y | Y |
| Benzylpenicillin | Access | J01CE01 | Y | Y | Y |
| Cefaclor | Watch | J01DC04 | N | N | Y |
| Cefalexin | Access | J01DB01 | Y | N | Y |
| Cefazolin | Access | J01DB04 | Y | N | N |
| Cefiderocol | Reserve | J01DI04 | Y | N | N |
| Cefixime | Watch | J01DD08 | Y | N | Y |
| Cefotaxime | Watch | J01DD01 | Y | N | N |
| Cefpodoxime Proxetil | Watch | J01DD13 | N | N | Y |
| Ceftazidime | Watch | J01DD02 | Y | N | Y |
| Ceftazidime/avibactam | Reserve | J01DD52 | Y | N | N |
| Ceftriaxone | Watch | J01DD04 | Y | Y | Y |
| Cefuroxime | Watch | J01DC02 | Y | N | Y |
| Chloramphenicol | Access | J01BA01 | Y | Y | Y |
| Ciprofloxacin | Watch | J01MA02 | Y | Y | 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 |
| Fluconazole | | | N | Y | N |
| Fosfomycin (IV) | Reserve | J01XX01 | Y | N | N |
| Gentamicin | Access | J01GB03 | Y | Y | Y |
| Imipenem/Cilastatin | Watch | J01DH51 | N | N | Y |
| Kanamycin | Watch | J01GB04 | N | Y | Y |

| | | | | | |
|---|---|---|---|---|---|
| Ketoconazole | | J02AB02 | N | N | Y |
| Levofloxacin | Watch | J01MA12 | N | N | Y |
| Linezolid | Reserve | J01XX08 | Y | N | Y |
| Meropenem | Watch | J01DH02 | Y | N | Y |
| Meropenem/ vaborbactam | Reserve | J01DH52 | Y | N | N |
| Metronidazole | Access | P01AB01, J01XD01 | Y | Y | Y |
| Moxifloxacin | Watch | J01MA14 | N | N | Y |
| Nalidixic Acid | | J01MB02 | N | Y | Y |
| Nitrofurantoin | Access | J01XE01 | Y | Y | Y |
| Norfloxacin | Watch | J01MA06 | N | Y | Y |
| Ofloxacin | Watch | J01MA01 | N | N | Y |
| Oxytetracycline | Watch | J01AA06 | N | N | 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 |
| Roxithromycin | Watch | J01FA06 | N | N | Y |
| Secnidazole | | P01AB07 | N | N | Y |
| Sparfloxacin | Watch | J01MA09 | N | N | Y |
| Spectinomycin | Access | J01XX04 | Y | N | N |
| Spiramycin | Watch | J01FA02 | N | N | Y |
| Streptomycin | Watch | J01GA01 | N | Y | Y |
| Sulfamethoxazole/ Trimethoprim | Access | J01EE01 | Y | Y | Y |
| Trimethoprim | Access | J01EA01 | Y | N | N |
| Vancomycin | Watch | J01XA01 | Y | N | Y |

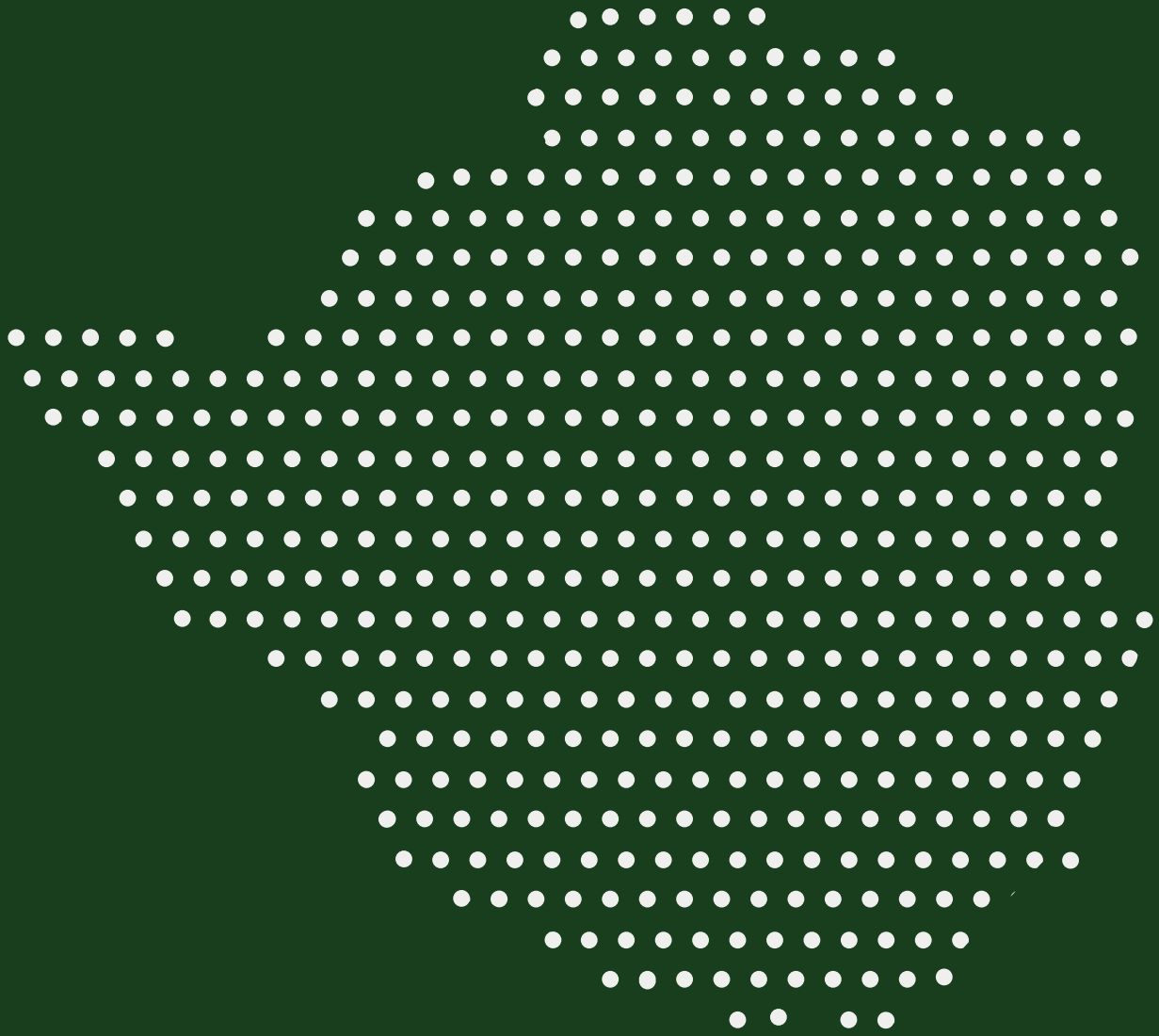
## Appendix 10: AMC data collection and expired drug and losses tool

AMC Data Collection Tool

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

Expired Drug and Losses Tool

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



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Mapping AMR & AMU Partnership

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