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BASELINE INFORMATION FOR INTEGRATED ANTIMICROBIAL RESISTANCE SURVEILLANCE IN ZAMBIA

January 2020

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The report presents baseline information required for integrated surveillance of antimicrobial resistance in Zambia. It is an outcome of two workshops organized jointly by the national Antimicrobial Resistance Coordinating Committee (AMRCC) through the Zambia National Public Health Institute (ZNPHI) and the Centre for Science and Environment (CSE), India. ZNPHI and CSE would like to thank all experts who contributed to the development of this report. The list of experts is provided at the end of this report.

About ZNPHI

ZNPHI (http://znphi.co.zm/), a technical arm under the Ministry of Health, is a public health center of excellence that addresses all major public health concerns in Zambia. ZNPHI seeks to improve health of all Zambians through coordinating priority public health and health security activities and resources; leveraging strong partnerships at the international, national, and sub-national levels; generating and analyzing scientific evidence for advocacy, policies and programs; and prioritizing public health functions. It serves as co-Secretariat to the national AMRCC with the Department of Veterinary Services under the Ministry of Fisheries and Livestock, and is responsible for coordinating the implementation of Zambia's Multi-sectoral National Action Plan on Antimicrobial Resistance.

About CSE

CSE (www.cseindia.org), India is a non-profit public-interest research and advocacy organization working on issues of public health, environment and development in India and global South. The Food Safety and Toxins team at CSE has been working to address the problem of antimicrobial resistance, particularly the animal and environmental aspects of it.

A publication of AMRCC and CSE

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Foreword

Zambia has joined the fight to stem the global threat of Antimicrobial Resistance (AMR) through several initiatives. In line with the Global Action Plan on AMR, Zambia developed a 10-year National Action Plan (NAP) that provides the framework for a coherent and coordinated approach to addressing AMR at all levels within the country. A key aspect in the fight against AMR is the generation of clear and up-to-date data to inform actions and policy in the diverse and changing AMR landscape.

Well developed, coordinated and responsive surveillance systems are therefore essential to the provision of accurate and objective data on AMR at all levels ranging from institutional to national. Effective surveillance systems ought to include the capability to harness relevant data in real time, as well as ensure that such data is secure but available for analysis, including the generation of trends over time. In this vein, Zambia recently developed a framework for integrated surveillance of AMR across various sectors including human health, animal health, agriculture, and the environment. A crucial early step in implementation of Zambia's integrated surveillance system is the collation of baseline data, which forms the focus of this report. By highlighting key deficiencies and gaps in information, this report also highlights areas that require urgent strengthening to ensure that the surveillance system is fit-for-purpose and responsive to the needs of each sector and the national goals set out in the AMR NAP.

Zambia's national Antimicrobial Resistance Coordinating Committee (AMRCC) has partnered strategically with the India-based Centre for Science and Environment (CSE), a think-tank with vast experience in development and streamlining of policy, particularly around environmental issues and AMR. The AMRCC is grateful to CSE for the invaluable support in refocusing of strategies and approaches to Zambia's AMR fight, including the generation of this report.

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Director - Zambia National Public Health Institute
Chairperson - National Antimicrobial Resistance Coordinating Committee
Ministry of Health

Foreword

Antibiotics are becoming ineffective as bacteria become resistant to them. Routine surveillance of resistance developing in bacteria is a recognised critical step to contain the growing crisis of Antimicrobial Resistance (AMR) and antibiotic resistance in particular. Countries have outlined ambitious plans for AMR surveillance in their national AMR containment action plans but have also realised the challenges in its implementation. One such challenge is the limited and sporadic availability of baseline information which is essential to design an effective surveillance framework suitable to the needs of the country. For low-and-middle income countries, where resources are limited and choices are to be made among competing priorities, such data can guide targeted allocation of time, money and, energy.

Collating baseline information is a challenge in resource-constrained countries, which have limited resources to invest in data and record management. With multiple stakeholders and sectors as in the case of AMR, the task becomes even more challenging. But the value of such information is paramount. For example, an understanding on bacterial diseases, antibiotic use, and laboratories available in a country will guide antibiotic sensitivity testing programmes. An assessment of production and consumption of food from animals will assist in devising a sampling strategy in the animal sector. Similarly, hotspots for surveillance in waste and environment can be identified based on location, size and spread of farms, factories, hospitals, and sewage treatment plants in different parts of the country. Importantly, such an exercise also points towards gaps in information which could be worked upon so that monitoring is possible and most importantly, we can move towards better management and control.

This document is being prepared with this objective in mind. We hope that this will assist the Government of Zambia to work towards an integrated AMR surveillance framework. This report puts together baseline information on key sectors—human-health, animal, plants and the environment. It also highlights information gaps, specifically as in the case of environment and plants sectors. We are confident that our colleagues from the Zambia National Public Health Institute and the national Antimicrobial Resistance Coordinating Committee, who have successfully worked together to develop this comprehensive report, will find it useful in shaping their data collection and AMR surveillance efforts. We wish them the best. We also hope that this report is useful for stakeholders in Africa and beyond in their fight against AMR—truly a global pandemic, but one in which countries of Africa and Asia must show the way ahead. We have to find ways in which we can build and safeguard the health of our people and their livelihood, but without first contaminating and then cleaning up.

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Centre for Science and Environment

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Centre for Science and Environment

Abbreviations

AIDS—Acquired Immunodeficiency Syndrome
AMR—Antimicrobial Resistance
AMRCC—Antimicrobial Resistance Coordinating Committee
AST—Antimicrobial Susceptibility Test
BSL—Biosafety Level
CDC—Centers for Disease Control and Prevention
CLSI—Clinical and Laboratory Standards Institute
CSE—Centre for Science and Environment
CSO—Central Statistical Office
CVRI—Central Veterinary Research Institute
Estab—Establishment
ESBL—Extended Spectrum Beta Lactamase
FDCL—Food and Drug Control Laboratory
FIND—Foundation for Innovative New Diagnostics
FAO—Food and Agriculture Organization of the United Nations
GIT—Gastrointestinal Tract
GRZ—Government of the Republic of Zambia
HC—Health Centre
HH—Household
HIV—Human Immunodeficiency Virus
HPCZ—Health Professions Council of Zambia
LMIC—Low- and Middle-Income Country
MFL—Ministry of Fisheries and Livestock
MoH—Ministry of Health
MoHE—Ministry of Higher Education
MRSA—Multidrug Resistant *Staphylococcus aureus*
MT—Metric Tonne
MWDSEP—Ministry of Water Development, Sanitation and Environmental Protection
NAP—National Action Plan
PACRA—Patents and Companies Registration Agency
PCR—Polymerase Chain Reaction
RDL—Regional Diagnostic Laboratory
SDG—Sustainable Development Goal
TB—Tuberculosis
TDRC—Tropical Diseases Research Centre
UNZA—University of Zambia
UNZAVET—University of Zambia-School of Veterinary Medicine
UTH—University Teaching Hospital
VCZ—Veterinary Council of Zambia
WHO—World Health Organization
ZAMRA—Zambia Medicines Regulatory Authority
ZARI—Zambia Agriculture Research Institute
ZEMA—Zambia Environmental Management Agency
ZNPHI—Zambia National Public Health Institute

1. Introduction

Antimicrobial Resistance (AMR), particularly antibiotic resistance, has become a global public health threat. With AMR on the rise, common infections are becoming increasingly untreatable. Moreover, this is putting modern medical and surgical interventions at risk leading to longer hospital stays, expensive treatments, and higher economic burden to individuals and nations.[1] AMR can also impact food safety, nutrition, health security, livelihood, and attainment of certain Sustainable Development Goals (SDGs).[2] The major contributors to AMR include misuse and overuse of antibiotics in humans, animals, and agriculture along with poor waste management across factories, healthcare settings, farms and community settings.

The importance of robust surveillance systems to guide AMR containment efforts has been emphasized in the Global Action Plan on Antimicrobial Resistance.[3] AMR surveillance is required to gather knowledge and build an evidence base to support regional and national interventions on AMR. To date, only a few developed countries such as Canada, Denmark, England, Japan, Netherlands, Sweden and the United States have systems for routine AMR surveillance in humans, animals and food products. However, routine AMR surveillance in the environment and plant sectors is largely missing across the world.

Responding to the global call by the World Health Organization (WHO), countries have planned for multi-sectoral AMR surveillance in their National Action Plans (NAPs).[4] The design of effective AMR surveillance programmes is linked to the availability and analysis of baseline information available in a country. For instance, information on diseases and antimicrobial use in a country can help guide resistance studies. Similarly, understanding food consumption patterns can help focus surveillance on specific food-animal sectors. In addition, the impact of interventions to contain AMR can be evaluated if baseline information is available.

For low- and middle-income countries (LMICs), which are typically resource-constrained, availability of such information becomes even more crucial for better allocation of resources. It is a huge challenge where baseline information is either not available or is limited to sporadic research studies. This adds to existing resource limitations, capacity constraints, and exacerbates the problem of prioritization in LMICs. The effectiveness of AMR surveillance is further limited by the lack of organized systems to collect, store or share data, and inadequate national coordination systems. At the level of the country, therefore, systems and processes for efficient collection of baseline information across all sectors need to be built.

As part of the collaboration between the Ministry of Health in the Republic of Zambia and the Centre for Science and Environment (CSE), India to support the implementation of Zambia's multi-sectoral NAP on AMR, a joint workshop was organized in March 2019 in Lusaka by the Zambia National Public Health Institute (ZNPHI) and CSE. One of the aims of this workshop was to identify key elements of baseline information required for integrated AMR surveillance in Zambia and to identify viable sources for such information. This was achieved with the help of stakeholders and experts from Zambia, select African and European countries as well as India and the United States across human-health, animal, plant, food, drug sectors and the environment. The work was further built upon in a subsequent ZNPHI-CSE joint meeting in August 2019.

This report presents the baseline information which would contribute to integrated surveillance of AMR in Zambia. It brings together presently available data across human-health, animal, plant sectors and the environment. In the human-health sector, information on key infectious diseases, antibiotics used, AMR trends, and laboratory capacity is identified. Similarly, data on animal population, food production, diseases, antimicrobial use patterns, and AMR trends is documented in the animal sector. The plant sector highlights crop production statistics, antimicrobials used and the laboratory capacities available. The focus in the environment sector is on identifying waste generation sources, waste disposal methods and laboratories that have the capacity to perform microbiological and analytical studies in environmental samples. The framework of this report can be useful for other countries as well.

2. Approach adopted to collate baseline information for integrated AMR surveillance

Expert deliberations at the ZNPHI-CSE workshop in March 2019 identified that for effective integrated surveillance of AMR in Zambia, there is a need for baseline information from multiple sectors such as human-health, animal, plant sector and the environment. To do so, experts also identified key elements under which baseline information would be collected across each sector and the key stakeholders in Zambia who could provide such information. These included elements such as key infectious diseases in humans, animals and crops; key antimicrobials used; historical AMR trends and laboratory infrastructure in these sectors; food-animal population and food production data in animal sector; point and non-point sources of waste generation and methods of waste disposal in Zambia etc.

Preliminary information was collected using secondary research, responses to workshop surveys, and email-based questionnaires from different Zambian stakeholders who could possibly have the information. Reference was also made to existing research literature and key policy documents such as Zambia's NAP on AMR, integrated AMR surveillance strategy (draft), situation analysis report on AMR, and livestock and aquaculture census report.[5]

The collected information was presented to stakeholders in a subsequent ZNPHI-CSE expert meeting in August 2019 in Lusaka, where it was validated and further built upon. A drafting committee, comprising of members from human-health, animal, environment, plant, and food and drug sectors in Zambia was constituted in this meeting, which worked towards filling the gaps in information.

3. Baseline information: Human-health sector

Information collected from the Ministry of Health (MoH), University Teaching Hospital (UTH), ZNPHI and Zambia Medicines Regulatory Authority (ZAMRA) is presented in *Table 1: Baseline information in the human-health sector*.

Table 1: Baseline information in the human-health sector

Key infectious diseases and causative organisms
<u>Routinely identified bacteria</u> • Bacteraemia (*Acinetobacter baumannii*, *Enterococcus* spp., *Escherichia coli*, *Klebsiella* spp., *Pseudomonas aeruginosa,* and *Staphylococcus aureus*) • Gastrointestinal infections (*Campylobacter jejuni, Salmonella* spp., *Shigella* spp., and *Vibrio cholerae*) • Meningitis (*Haemophilus influenzae, Neisseria meningitides,* and *Streptococcus pneumoniae*) • Respiratory infections (*Haemophilus influenzae*, *Klebsiella pneumonia, Moraxella catarrhalis*, *Staphylococcus aureus,* and *Streptococcus pneumoniae*) • Urinary tract infections (*Acinetobacter* spp., *Enterococcus* spp., *Escherichia coli*, *Klebsiella* spp., *Pseudomonas aeruginosa,* and *Staphylococcus saprophyticus*) • Wound and soft tissue infections (*Acinetobacter* spp., *Enterococcus* spp., *Escherichia coli*, MRSA, *Proteus* spp., *Pseudomonas* spp., *Staphylococcus aureus*, and *Streptococcus pyogenes*) <u>Epidemic-prone diseases</u> Cholera (*Vibrio cholerae*), dysentery (*Shigella dysenteriae* type 1), plague (*Yersinia pestis*), typhoid (*Salmonella typhi* and *Salmonella paratyphi*) <u>High burden diseases of public health importance</u> Malaria (*Plasmodium falciparum*), tuberculosis (*Mycobacterium tuberculosis*) <u>Disease outbreaks</u> Cholera (*Vibrio cholerae;* 1990–2004), meningococcal meningitis (*Neisseria meningitides* serotypes A and W135), pneumonia (*Klebsiella pneumoniae*), typhoid (*Salmonella typhi;* 2010–2012)
<u>Viral diseases</u> Hepatitis (Hepatitis virus; Hepatitis B and C virus), measles (Rubeola virus), polio (Polio virus), rotavirus diarrhoea and gastroenteritis (Rotavirus) <u>High burden diseases of public health importance</u> AIDS (Human Immunodeficiency Virus), influenza (Influenza virus)
<u>Fungal diseases</u> Bloodstream and urinogenital infections (*Candida* spp.), cryptococcal meningitis (*Cryptococcus neoformans*)
Disease burden
<u>Leading causes of mortality (Disease; Number of deaths in 2015)</u> Malaria (2360), acute respiratory infections/pneumonia (1890), tuberculosis (1576), non-bloody diarrhoea (1281) <u>Leading causes of morbidity (Disease; Incidence per 1000 population in 2018)</u> Malaria (280), non-bloody diarrhoea (90), acute respiratory infections/pneumonia (46)

Key antibiotics used	
• Aminoglycosides: Amikacin, gentamicin, streptomycin • Carbapenems: Ertapenem, imipenem • Cephalosporins: Cefepime, cefotaxime, cefoxitin, ceftazidime, ceftriaxone, cefuroxime • Glycopeptides: Vancomycin • Glycylcyclines: Tigecycline • Lincosamides: Clindamycin • Lipopeptides: Daptomycin • Macrolides: Azithromycin, erythromycin • Nitrofurans: Nitrofurantoin • Oxazolidinones: Linezolid • Penicillins: Amoxicillin-clavulanic acid, ampicillin, ampicillin-sulbactum, oxacillin, penicillin G, piperacillin, piperacillin/tazobactam, ticarcillin, ticarcillin/tazobactam • Polymyxins: Colistin • Quinolones: Ciprofloxacin, levofloxacin • Sulfonamides: Trimethoprim/sulfamethoxazole • Tetracyclines: Doxycycline, minocycline, tetracycline	
Historical AMR trends *(A)-All specimens; (B)-Blood; (C)-Cerebrospinal fluid; (P)- Pus; (S)-Stool; (U)-Urine; text in black: ≤50% resistance, text in red: >50% resistance*	
Acinetobacter spp.[6]	Ampicillin/sulbactam (A 38%), cefepime (A 37%), ceftazidime (A 53%), ceftriaxone (A 81%), ciprofloxacin (A 71%), gentamicin (A 52%), imipenem (A 17%), tetracycline (A 67%), piperacillin/tazobactam (A 29%), tobramycin (A 24%), trimethoprim/sulfamethoxazole (A 100%)
Pseudomonas aeruginosa[7]	Cefepime (A 23%), ceftazidime (A 23%), ciprofloxacin (A 26%), gentamicin (A 25%), imipenem (A 10%), piperacillin/tazobactam (A 33%), tobramycin (A 26%)
Escherichia coli[8]	Amoxicillin/Clavulanic acid (A 61%), ampicillin (A 96%), ampicillin/salbactum (A 81%), cefuroxime (A 59%), cefazolin (A 65%), cefepime (A 35%), ceftazidime (A 48%), ceftriaxone (A 59%), ciprofloxacin (A 61%), gentamicin (A 51%), nitrofurantoin (A 29%), imipenem (A 0.6%), ertapenem (A 2%), tetracycline (A 80%), piperacillin/tazobactam (A 18%), tobramycin (A 55%), trimethoprim/sulfamethoxazole (A 100%)
Klebsiella pneumoniae[9]	Cefuroxime (A 85%), cefazolin (A 90%), cefepime (A 27%), ceftazidime (A 59%), ceftriaxone (A 89%), ciprofloxacin (A 51%), nitrofurantoin (A 63%), gentamicin (A 67%), imipenem (A 0.4%), ertapenem (A 4%), tetracycline (A 61%), piperacillin/tazobactam (A 18%), tobramycin (A 85%), trimethoprim/sulfamethoxazole (A 100%)
Staphylococcus aureus[10]	Ciprofloxacin (A 38%), clindamycin (A 18%), erythromycin (A 51%), gentamicin (A 28%), oxacillin (A 46%), penicillin (A 100%), linezolid (A 0%), rifampicin (A 38%), quinpristin/dalfopristin (A 16%), tetracycline (A 43%), co-trimoxazole (A 100%), vancomycin (A 0.3%)
Salmonella spp.[11]	Ampicillin (S 80%), cefotaxime (S 57%), ciprofloxacin (S 50%)
Salmonella typhi[12]	Ampicillin (S 94%), cefotaxime (S 17%), ciprofloxacin (S 12%)
Shigella spp.[13]	Ampicillin (S 74%), cefotaxime (S 10%), trimethoprim/sulfamethoxazole (S 80%), nalidixic acid (S 0%), ciprofloxacin (S 0%)
Acinetobacter spp.[14]	Gentamicin (B 50%)

Historical AMR trends *(A)-All specimens; (B)-Blood; (C)-Cerebrospinal fluid; (P)- Pus; (S)-Stool; (U)-Urine; text in black: ≤50% resistance, text in red: >50% resistance*	
Escherichia coli[15]	Ampicillin (B 95%, U 100%), co-trimoxazole (B 100%, U 100%), ciprofloxacin (B 50%, U 70%), ceftriaxone (B 70%, U 55%), ceftazidime (B 45%, U 50%), cefepime (B 40%, U 45%), imipenem (B 0%, U 0%), ertapenem (B 0%, U 0%)
Klebsiella pneumoniae[16]	Co-trimoxazole (B 100%, U 100%), ciprofloxacin (B 45%, U 78%), ceftriaxone (B 98%, U 90%), ceftazidime (B 55%, U 78%), cefepime (B 20%, U 45%), imipenem (B 0%, U 0%), ertapenem (B 0%, U 10%)
Streptococcus pneumoniae[17]	Penicillin (C 25%), ceftriaxone (C 0.1%)
Vibrio cholerae O1[18]	Tetracycline (S 2%), chloramphenicol, trimethoprim/ sulfamethoxazole (10%), erythromycin (S 4%), azithromycin (S 2%), ciprofloxacin (S 94%; 83% intermediate)
Streptococcus pneumoniae[19]	Co-trimoxazole (C 74%), tetracycline (C 47%), penicillin (C 39%), chloramphenicol (C 19%), erythromycin (C 4%), clindamycin (C 3%), ceftriaxone (C 1%), levofloxacin (C 0%), vancomycin (C 0%)
Vibrio cholerae O1[20]	Ampicillin (S 28%), doxycycline (S 0%), chloramphenicol (S 0%), azithromycin (S 0%), trimethoprim/sulfamethoxazole
Staphylococcus aureus[21]	Cefoxitin (B,P 43%), trimethoprim/sulfamethoxazole (B,P 100%), penicillin G (B,P 95%), ciprofloxacin (B,P 95%), erythromycin (B,P 78%), tetracycline (B,P 78%), gentamicin (B,P 68%), vancomycin (B,P 0%), teicoplanin (B,P 0%), clindamycin (B,P 2.5%) (Dtest identified erythromycin-induced clindamycin 68.3%)
Salmonella typhi[22]	Cefotaxime (30.4%), chloramphenicol (61.1%), ciprofloxacin (9.9%), nalidixic acid (33.3%)
Mycobacterium tuberculosis[23]	Ethambutol (4.1%), isoniazid (12.6%), rifampicin (4.8%), streptomycin (10.7%), multidrug resistance (49%), polyresistance (18.8%)
Salmonella enterica serovar senftenberg[24]	Amoxicillin plus clavulanic acid, ampicillin, cefepime, cefotaxime, cefpodoxime, ceftazidime, ceftiofur, ceftriaxzone, chloramphenicol, ciprofloxacin, gentamicin, nalidixan, neomycin, spectinomycin, streptomycin, sulfamethoxazole, tetracycline, trimethoprim—AST and genomic methods
Extended spectrum βlactamase, *Klebsiella pneumoniae*[25]	Cefotaxime (B 100%), cefpodoxime (B 100%), ceftazidime (B 100%), chloramphenicol (B 97.8%), ciprofloxacin (B 95.6%), co-trimoxazole (B 100%), gentamicin (B 97.8%), tetracycline (B 100%)—AST (CLSI)
Candida albicans[26]	Amphotericin B (10%), fluconazole (18.3%), caspofungin (2%)—agar-based E-test

Laboratory capacity

- 359 clinical laboratories

Province	HC#	L1#	L2#	L3#
Central	24	8	2	0
Copperbelt	55	6	7	4
Eastern	18	9	1	1
Luapula	17	7	2	0
Lusaka	38	13	2	4
Muchinga	14	4	2	0
Northern	16	6	3	0
North Western	11	11	2	0
Southern	23	8	6	1
Western	22	10	2	0
Total	**238**	**82**	**29**	**10**

- Four fixed functional BSL-3 laboratories, one mobile BSL-3 laboratory
  - The University Teaching Hospital (UTH)
  - Tropical Diseases Research Centre (TDRC)
  - University of Zambia-School Of Veterinary Medicine (UNZAVET)
  - Chest Diseases Laboratory
- Laboratories with capacity for AST
  - Arthur Davison Children Hospital
  - Centre for Infectious Disease Research in Zambia (CIDRZ)
  - Chest Diseases Laboratory
  - Chilenje Level 1 Hospital
  - Chilonga Mission General Hospital
  - Levy Mwanawasa Hospital
  - Matero Level 1 Hospital
  - Ndola Teaching Hospital
  - Tropical Diseases Research Centre
  - UTH (additional capacity for gene-level surveillance)
- Referral Laboratories
  - Chest Diseases Laboratory (National Tuberculosis Reference Laboratory)—for TB surveillance
  - UTH TB laboratory and Tropical Diseases Research Centre—for TB surveillance
  - UTH microbiology laboratory—for priority pathogens
- Laboratory networks
  - TB, HIV, malaria laboratory networks

Retailers, wholesalers and manufacturers of pharmaceuticals
(data as of 2019)

Province	Retail[27]	Wholesale[28]	Manufacture[29]
Central	11	0	1
Copperbelt	65	6	1
Eastern	11	1	0
Lusaka	256	42	4
Muchinga	3	0	0
Northern	2	0	0
North Western	4	0	0
Southern	32	2	0
Western	9	0	0
Zambia	**393**	**49**	**6**

Sources of funding

- Government of the Republic of Zambia (GRZ)
- Fleming Fund
- Foundation for Innovative New Diagnostics (FIND) for capturing and sharing AMR data focused on a multi-sector integrated surveillance platform

#Health centres (HC), level 1 (L1), level 2 (L2), level 3 (L3) hospitals

Notes: 1. The following areas of information could be considered for collection in future:
- Antibiotics used in hospitals vs community
- Data on AMR trends from private laboratories in Zambia

2. Additional baseline information can be obtained from other stakeholders such as the CDC, HPCZ, WHO

4. Baseline information: Animal sector

Information collected from stakeholders such as Ministry of Fisheries and Livestock (MFL) and ZAMRA is presented in *Table 2: Baseline information in the animal sector*.

Table 2: Baseline information in the animal sector

Animal households and establishments[30] (data as of 2017–18)						
	Cattle	**Pig**	**Goat**	**Sheep**	**Fish**	
Province	HH	HH	HH	HH	HH	Estab
Central	50,462	14,841	63,382	2,000	463	9
Copperbelt	7,589	8,455	21,246	1,234	902	14
Eastern	104,989	58,691	68,571	6,021	499	5
Luapula	1,868	6,030	40,913	544	1,111	10
Lusaka	13,436	3,464	29,346	1,277	542	13
Muchinga	10,132	14,893	32,610	681	1,017	18
Northern	10,126	15,014	50,128	1,014	3,255	25
North Western	11,777	8,306	38,437	891	1,394	21
Southern	104,677	34,833	124,887	6,150	288	11
Western	31,974	14,321	12,447	97	145	0
Total HH	**347,031**	**178,848**	**481,968**	**19,909**	**9,615**	
Total Estab	**1049**	**263**	**588**	**285**		**126**

Animal population[31] (data as of 2017–18)								
	Cattle		**Village/ indigenous chicken**		**Broiler chicken**		**Layer chicken**	
Province	HH	Estab	HH	Estab	HH	Estab	HH	Estab
Central	743,595	92,025	2,618,909	11,332	409,017	220,849	56,670	315,550
Copperbelt	74,628	18,801	1,377,544	43,336	1,795,154	84,859	48,284	211,527
Eastern	597,149	4,772	2,011,608	1,913	322,271	44,069	9,237	12,007
Luapula	10,789	1,597	796,075	906	160,328	9,778	1,237	4,335
Lusaka	147,574	25,186	1,254,527	7,731	2,282,752	272,000	557,679	316,491
Muchinga	81,829	3,333	1,148,255	3,427	172,853	5,701	16,140	6,081
Northern	47,841	689	1,299,368	848	141,943	1,610	8,196	-
North Western	95,484	3,188	755,366	601	354,068	2,995	10,433	27,040
Southern	1,225,090	90,148	3,150,184	7,248	409,691	49,407	17,538	36,942
Western	450,116	833	901,944	28	30,615	-	17,566	-
Total	**3,474,095**	**240,572**	**15,313,780**	**77,370**	**6,078,693**	**691,228**	**742,981**	**929,973**
Zambia	**3,714,667**		**15,391,150**		**6,769,921**		**1,672,954**	

	Pig		Goat		Sheep	
Province	HH	Estab	HH	Estab	HH	Estab
Central	93,225	9,105	578,825	9,873	23,462	6,461
Copperbelt	106,545	5,783	163,903	2,600	11,979	2,196
Eastern	305,956	571	357,761	1,486	30,196	328
Luapula	20,861	269	165,292	383	1,897	80
Lusaka	67,664	25,183	334,759	2,918	15,265	2,676
Muchinga	66,807	550	159,187	511	3,151	604
Northern	52,929	328	215,317	203	3,771	10
North Western	52,420	177	230,185	575	5,056	459
Southern	176,021	5,762	1,284,510	6,346	53,880	8,706
Western	92,630	5	68,875	187	289	21
Total	**1,035,057**	**47,708**	**3,558,614**	**25,082**	**148,946**	**21,539**
Zambia	**1,082,765**		**3,583,696**		**170,262**	

Food production *(data as of 2018)*
Meat production Cattle meat (beef): 6,103,281 metric tonnes (MT) Chicken meat: 5,111,098 MT Pig meat (pork): 555,270.2 MT Fish production 118,799 MT (capture: 89,234 MT; aquaculture: 29,565 MT) Milk production 1,686,400 MT Egg production 1,642,693,000

Key infectious diseases and causative organisms	
Bacterial diseases	
Cattle	Anaplasmosis (*Anaplasma centrale, Anaplasma marginale*), anthrax (*Bacillus anthracis*), blackleg (*Clostridium chauvoei*), brucellosis (*Brucella abortus*), campylobacteriosis (*Campylobacter jejuni*), colibacillosis (*Escherichia coli*), contagious bovine pleuropneumonia (*Mycoplasma mycoides*), dermatophilosis (*Dermatophilus congolensis*), foot rot (*Fusobacterium necrophorum*), haemorrhagic septicaemia (*Pasteurella multocida*), heartwater (*Ehrlichia ruminantium*), mastitis (*Escherichia coli, Staphylococcus aureus,* other *Staphylococcus* spp., *Streptococcus agalactiae,* other *Streptococcus* spp.), salmonellosis (*Salmonella typhimurium, Salmonella dublin*), tuberculosis (*Mycobacterium bovis*)
Chicken	Colibacillosis (*Escherichia coli*), fowl cholera (*Pasteurella multocida*), GIT infections (*Clostridium* spp., *Escherichia coli*, *Salmonella* spp.), infectious coryza (*Haemophilus paragallinarum*), mycoplasmosis (*Mycoplasma gallisepticum*, *Mycoplasma synoviae*), necrotic enteritis (*Clostridium perfringens*), omphalitis (coliforms—*Escherichia* spp., *Enterobacter* spp., *Klebsiella* spp., *Citrobacter* spp., *Serratia* spp., *Proteus* spp., *Staphylococcus* spp., *Pseudomonas* spp., mixed bacterial infections), respiratory infections (*Mycoplasma* spp., *E.coli*), salmonellosis—fowl typhoid, bacillary white diarrhea (*Salmonella pullorum*, *Salmonella gallinarum*)
Pig	Brucellosis (*Brucella suis*), colibacillosis (*Escherichia coli*), enzootic pneumonia (*Pasteurella multocida, Mycoplasma* spp.), erysipelas (*Erysipelothrix rhusiopathiae*), greasy pig disease (*Staphylococcus hyicus*), leptospirosis (*Leptospira* spp.), mycoplasma infections (*Mycoplasma suis*), necrotic enteritis (*Clostridium perfringes* type A, B or C), pasterollosis (*Pasteurella multocida*)
Fish	Diseases caused by *Aeromonas* spp., *Lactococcus* spp., *Staphylococcus* spp., *Streptococcus* spp.

Viral diseases	
Cattle	Bovine viral diarrhoea (Bovine Viral Diarrhoea virus), foot-and-mouth disease (Foot-and-mouth disease virus), lumpy skin disease (Lumpy Skin Disease virus), rift valley fever (Rift Valley Fever virus)
Chicken	Egg drop syndrome (Egg Drop Syndrome virus), fowl pox (Avipox virus), infectious bronchitis (Infectious Bronchitis virus), infectious bursal disease (IBD virus), Marek's disease (Marek's disease virus), Newcastle disease (Newcastle disease virus)
Pig	African swine fever (African Swine Fever virus), gastrointestinal infection (Rotavirus), disease caused by Porcine circovirus
Fish	–
Fungal diseases	
Cattle	Dermatophytosis (dermatophytes)
Chicken	Aspergillosis (*Aspergillus fumigatus*), mycotoxicosis
Pig	Candidiasis (*Candida* spp.)
Fish	Aflatoxicosis (*Aspergillus flavus*)
Protozoan diseases	
Cattle	Babesiosis (*Babesia bigemina*, *Babesia bovis*), bovine coccidiosis (*Eimeria* spp.), cryptosporidiosis (*Cryptosporidium* spp.), theileriosis (*Theileria parva*, *Theileria annulata*), trypanosomiasis (*Trypanosoma congolense*, *Trypanosoma vivax*, *Trypanosoma brucei brucei*)
Chicken	Coccidiosis (*Eimeria* spp.), histomoniasis (*Histomonas* spp.)
Pig	Coccidiosis (*Eimeria* spp.)
Fish	–
Helminthic diseases	
Cattle	Filariasis (*Mansonella perstans*, *Parafilaria bovicola/ Filarioidea*), fascioliasis (*Fasciola gigantica*), amphistomosis (*Amphistoma* spp.), nematod infections (*Cooperia* spp., *Haemonchus* spp., *Trichostrongylus* spp.), hydatidosis (*Echinococcus granulosus*)
Chicken	Helminthiasis (*Allodapa suctoria*, *Ascaris* spp., *Ascaridia galli, Taenia solium*)
Pig	Cysticercosis (*Taenia solium*)
Antibiotics used	
Cattle • Aminoglycosides: Gentamicin, streptomycin • Fluoroquinolones: Enrofloxacin • Macrolides: Tulathromycin, tylosin • Penicillins: Amoxicillin, benzopenicillin, penicillin • Sulfonamides: Sulfathiazole, sulfamethazine, sulfamerazine, sulfadiazine, sulfadimidine sodium • Tetracyclines: Doxycycline, oxytetracycline, tetracycline Chicken • Aminoglycosides: Gentamicin, neomycin, streptomycin • Tetracyclines: Doxycycline, tetracycline • Fluoroquinolones: Enrofloxacin, flumequine • Macrolides: Tylosin • Penicillins: Amoxicillin, ampicillin • Sulfonamides: Sulfadiazine, trimethoprim/sulfamethoxazole • Polymyxins: Colistin • Cephalosporins: Ceftiofur • Amphenicols: Chloramphenicol • AGPs: Avilamycin, flavomycin, olaquindox, virginiamycin, zinc bacitracin Pig • Aminoglycosides: Gentamicin, streptomycin • Tetracyclines: Tetracycline • Fluoroquinolones: Enrofloxacin • Macrolides: Tulathromycin, tylosin • Penicillins: Amoxicillin, benzopenicillin • Sulfonamides: Sulfadimidine, sulfathiazole	

Historical AMR trends

(Data from available research papers; text in black: ≤50% resistance, text in red: >50% resistance)

Cattle (beef)	
E.coli[32]	Ampicillin (88%), augmentin (83%), co-trimoxazole (91%)
E.coli[33]	Ampicillin (2.4%), kanamycin (1.2%), streptomycin (1.8%), sulfadimethoxine (3%), tetracycline (3%) — AST
Cattle (dairy)	
E coli[34]	Ampicillin (6.02%), cefpodoxime (1.91%), gentamicin (0.8%), trimethoprim/sulfamethoxazole (4.49%), tetracycline (10.61%) — AST (CLSI) and genomic methods
Cattle (pastoral)	
E.coli[35]	Amoxicillin (14.5%), ampicillin (8.43%), co-trimoxazole (71.1%), erythromycin (83.1%), gentamicin (2.41%), nitrofurantoin (22.9%), tetracycline (3.6%) — AST
Enterococci faecalis[36]	Amoxicillin (62.9%), ampicillin (75.8%), co-trimoxazole (85.5%), erythromycin (56.5%), gentamicin (85.5%), nitrofurantoin (50%), penicillin (80.6%), tetracycline (41.9%) — AST
Enterococci faecium[37]	Amoxicillin (65.5%), ampicillin (51.7%), co-trimoxazole (89.7%), erythromycin (72.4%), gentamicin (96.6%), nitrofurantoin (65.5%), penicillin (79.3%), tetracycline (51.7%) — AST
Poultry	
ESBL *E.coli*[38]	Ampicillin (100%), cefotaxime/ceftazidime (100%), chloramphenicol (57.1%), ciprofloxacin (48.1%), gentamicin (37.7%), nalidixic acid (48.1%), norfloxacin (54.5%), streptomycin (20.8%), trimethoprim/sulfamethoxazole (41.6%), tetracycline (59.7%) — AST (CLSI) and genomic methods
Pig	
E.coli[39]	Ampicillin (10.8%), colistin (0.6%), kanamycin (0.6%), streptomycin (11.5%), sulfadimethoxine (9.6%), tetracycline (18.5%) — AST

Antibiotic residues in food-animal products

Milk*	Aminoglycosides (gentamicin, neomycin, streptomycin), amphenicols (chloramphenicol), beta-lactams (ampicillin), macrolides, sulfa drugs (sulfamethoxazole, sulfadiazine, sulfamethizole, sulfamonomethoxine, sulfapyridine, sulfadimethoxypyrimidine), tetracyclines (oxytetracycline, tetracycline)
Animal tissue*	Aminoglycosides (gentamicin, neomycin, streptomycin), amphenicols (chloramphenicol), beta-lactams (ampicillin, penicillin), fluoroquinolones (enrofloxacin), macrolides, sulfa drugs (sulfamethoxazole, sulfadiazine, sulfamethizole, sulfamonomethoxine, sulfapyridine, sulfadimethoxypyrimidine), tetracycline
Honey**	Amphenicols (chloramphenicol), diaminopyrimidines (trimethoprim), fluoroquinolones (cinoxacin, ciprofloxacin, danofloxacin, difloxacin, enoxacin, enrofloxacin, fleroxacin, flumequine, lomefloxacin, marbofloxacin, nadifloxacin, nalidixic acid, norfloxacin, levofloxacin, orbifloxacin, oxolinic acid, pazufloxacin, pefloxacin, pipemidic acid, sarafloxacin, sparfloxacin), macrolides (tylosin A, sum erythromycin A, clindamycin, josamycin, leucomycin, oleandomycin), nitroimidazoles (metronidazole, ronidazole, dimetridazole), tetracyclines (oxytetracycline, tetracycline, chlortetracycline, doxycycline, demeclocycline, methacycline, minocycline), sulfa drugs (sulfamethoxazole, sulfadiazine, sulfamethizole, sulfamonomethoxine, sulfapyridine, sulfadimethoxypyrimidine)

Laboratory capacity

- National laboratory—CVRI
- Regional laboratories—Chipata RDL (Eastern), Isoka RDL (Muchinga), Mazabuka RDL (Southern), Mongu RDL (Western), Ndola RDL (Copperbelt), Zambezi RDL (North Western)
- Provincial laboratories—Choma provincial laboratory (Southern), Kasama provincial laboratory (Northern), Solwezi provincial laboratory (North Western)
- Laboratories with capacity for AST
  - CVRI
  - Food and Drugs laboratory (FDCL)#
  - UNZAVET microbiology laboratory
  - UNZAVET public health laboratory
  - VETLAB

*Antibiotics were tested for the presence of their residues but not necessarily found

**In case of honey, there is a residue monitoring plan wherein testing is still done based on the demand from the client in order to get an export permit. The tests are done in collaborations with external laboratories

#AST not routinely performed but capacity available

• Laboratories with capacity for gene level surveillance—CVRI, UNZAVET • Laboratories with capacity for veterinary drug residue monitoring—CVRI, FDCL • Referral laboratory—FDCL	
Agrovet shops[40] *(data as of 2019)*	
22 Agrovet shops in Zambia Central (1), Copperbelt (1), Eastern (2), Lusaka (13), Muchinga (1), Southern (3), Western (1)	
Antibiotics imported *(data as of 2017)*	
Antibiotics	**Quantities (kg)**
Tetracyclines	4,600
Fluoroquinolones	2,000
Sulfonamides (including trimethoprim)	1,896
Penicillins	1,579
Pleuromutilins	900
Aminoglycosides	259
Macrolides	110
Other quinolones	106
Cephalosporins (all generations)	100
1st and 2nd generation cephalosporins	100
Total quantities	**11,650**
Sources of funding	
• A public-private partnership between the Department of Veterinary Services and industry for antimicrobial residue monitoring • FAO Fleming Fund (Zambia AMR regional project) for piloting of AMR surveillance in broiler chickens in five districts of Zambia • Mott Macdonald Fleming Fund for supporting the AMR surveillance system targeted towards broiler chickens • Foundation for Innovative New Diagnostics (FIND) for capturing and sharing AMR data focused on a multi-sector integrated surveillance platform	

Notes:

1. The following areas of information could be considered for collection in the future:
   - Population data on cattle for beef and cattle for dairy separately; provincial break-up of establishments for all animal species; number of chicken (broiler and layer) households and establishments
   - Information on total meat, meat from goat and sheep, cattle milk production
   - Number and location of veterinary hospitals with capacity for AST
   - Veterinary antimicrobial retailers, wholesaler and feed manufacturers in Zambia
2. Additional baseline information can be obtained from other stakeholders such as CSO, PACRA, feed manufacturers, and distributors of veterinary medicinal products

5. Baseline information: Plant sector

Information collected from Zambia Agriculture Research Institute (ZARI) is presented in *Table 3: Baseline information in the plant sector*. Presently, information on historical antibiotic resistance trends or key antibiotics used in the plant sector is not available. These could be considered for collection going forward. Similarly, data on provincial distribution of agricultural households, or provincial break up of key crops produced could also be collected.

Table 3: Baseline information in the plant sector

Agricultural households
Total number of agricultural households growing crops: 2,052,379
Crop production *(Data as of 2017–18)*
Food crops • Barley: 2,294 MT (key producer – Southern province) • Maize: 466,877 MT (key producer – Central province) • Rice: 12,723 MT (key producer – Northern province) • Soyabean: 139,623 MT (key producer – Central province) • Wheat: 83,949 MT (key producer – Central province)
Key crops where antimicrobials are used
Bean, citrus, cowpea, okra, onion, potato, soybean, tomato
Key infectious diseases and causative organisms
Bacterial • Bacterial wilt Fungal • Ear rot diseases[41, 42]: Fusarium ear rot (*Fusarium verticillioides*), Stenocarpella ear rot (*Stenocarpella maydis*), Aspergillus ear rot (*Aspergillus flavus*) • Kernel rot diseases • Fusarium wilt of bananas Viral • Banana Bunchy Top virus (outbreak in 2009) • Cassava Brown Streak virus (outbreak in 2018)
Key antimicrobials used in plants*
For disease treatment Apron, Benlate, Benomyl, Bravo, Capta, Copper oxychloride, Mancozeb, Maneb, Metalaxyl, Punch xtra, Ridomil, Shavit, Thiram, Zineb For disease prevention Apron, Dithane M45, Zineb
Laboratory capacity
General information • Four laboratories at Mt Makulu Research Station • No referral laboratories • No laboratory networks established AMR and residue monitoring capacity • Two laboratories at Mt Makulu Research Station • One plant virology laboratory at Lusaka (capacity for PCR-based detection of AMR) • Soil Microbiology laboratory at Mt Makulu Research Station (capacity for residue monitoring)

*Most of these brands are antifungals.

6. Baseline information: Environment

Information collected from stakeholders such as the Zambia Environmental Management Agency (ZEMA), Ministry of Water Development, Sanitation and Environmental Protection (MWDSEP), and the Ministry of Local Government is presented in *Table 4: Baseline information for the environment sector*. Currently, not much information w.r.t the environment is available with the stakeholders. The information gaps include number and distribution of point sources; volume of waste generated across each point source; volume of unused drugs generated from healthcare, domestic and market settings, number of waste disposal facilities, etc., which could be collected in subsequent years.

Table 4: Baseline information for the environment sector

Point sources of waste generation
• Pharmaceutical manufacturing companies • Human and veterinary healthcare settings • Animal establishments • Abattoirs/slaughter houses • Animal feed manufacturing plants • Dairy and meat processing units • Effluent treatment plants • Sewage treatment plants
Waste disposal methods
• <u>Pharmaceutical manufacturing companies, human and veterinary healthcare settings:</u> – Incineration; ash is treated as non-hazardous waste – Inertisation for injectables, and dilution for liquids • <u>Animal establishments, abattoirs/slaughter houses, animal feed manufacturing plants, dairy and processing units</u> – Liquid waste is treated and discharged into the aquatic environment – Solid waste is disposed of at the general waste disposal sites (landfills) – Condemned meat at slaughter houses and processing units is incinerated • <u>Effluent treatment plants</u> – Effluent from industrial process such as food processing companies is discharged into the aquatic environment • <u>Sewage treatment plants</u> – Trickling filter systems, activated sludge system • <u>Unused/expired antimicrobials</u> – Incineration in hospitals
Laboratory capacity
No laboratories with ZEMA. However, ZEMA collaborates with the following laboratories/ institutions*: – Alfred H Knight Industrial Laboratory – National Institute for Scientific and Industrial Research – UNZA – Zambia Bureau of Standards – Toxicology laboratory commissioned at UNZA

*These collaborating laboratories do not perform AMR testing in the environmental samples in particular, but with some capacity they could adapt or include AMR

Notes: Additional baseline information can be obtained from other stakeholders such as CSO, Dairy/Beef Association of Zambia, HPCZ, local municipality, MoH, MoHE, MFL,VCZ and ZAMRA

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This report presents the baseline information which would contribute to integrated surveillance of antimicrobial resistance in Zambia. It brings together presently available data across human-health, animal, plant sectors and the environment.

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