

Republic of Liberia Integrated Antimicrobial Resistance Surveillance Strategy

NOVEMBER 2023

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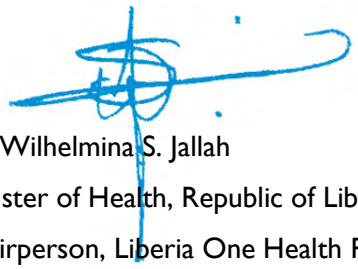
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Foreword

Antimicrobial resistance (AMR) is one of the top ten global public health threats according to World Health Organization (WHO), and it also affects animals. Since powerful antibiotics are becoming ineffective due to bacterial resistance to antimicrobials, there will be a significant loss of agricultural output that is incorporated into the food chain as well as human and animal deaths. Antimicrobials are being used more often in aquaculture and other farming systems, as well as for the health of humans and animals. The improper and excessive use of these antibiotics has a direct detrimental effect on ecosystem, health and the environment. The Government of Liberia acknowledged this issue and found that it was necessary to join international efforts to address AMR by endorsing various consensuses through the One Health approach. In close collaboration with other stakeholders at the local and global levels, the Liberian ministries in charge of human and animal health as well as the environment (Ministry of Health, Ministry of Agriculture, the Environmental Protection Agency, and the National Fisheries and Aquaculture Authority) led the development of this integrated AMR surveillance strategy. This plan will assist in streamlining AMR surveillance efforts in Liberia's environment, agricultural, and human health sectors. It is expected that this strategy will be successfully put into practice, closely monitored, and evaluated on a regular basis considering the lessons learned through its application. The integrated AMR Strategy detailed herein, is a living document, shaped by scientific advancements, evolving threats and the shared dedication of the diverse stakeholders. It represents a call to action, a roadmap for progress and a promise to ensure the sustainable and responsible use of antimicrobials. Together we can curb the rise of AMR and secure a healthier and more resilient future for all Liberians.



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Acknowledgements

The National Antimicrobial Resistance (AMR) Surveillance strategy marks an important milestone in addressing challenges associated with AMR and antimicrobial use (AMU) that are increasingly becoming a major concern within the public health, agricultural, and environmental sectors. The processes of developing the AMR surveillance strategy considered situation analysis reports regarding AMR in the public health and agricultural sectors. The National AMR Multi-sectoral Coordinating Committee (NMCC) wishes to acknowledge technical contributions from the Ministry of Health, Ministry of Agriculture, Environmental Protection Agency, the National Fisheries and Aquaculture Authority, One Health Coordination Desk, and USAID's Infectious Disease Detection and Surveillance (IDDS) project country office. In addition, the NMCC wishes to acknowledge Mr. Eddie Miaway Farngalo, the consultant whose tireless efforts led to the compilation and validation of this important document. We also acknowledge technical support from the World Health Organization (WHO) and the Food and Agriculture Organization of the United Nations (FAO).

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Abbreviations

AMR	antimicrobial resistance
AMS	antimicrobial stewardship
AMU	antimicrobial use
AST	antimicrobial susceptibility testing
ATLASS	Assessment Tool for Laboratory and AMR Surveillance System
CLSI	Clinical Laboratory Standards Institute
CMS	Central Medical Stores
CSF	cerebral spinal fluid
DHIS 2	District Health Information Software 2
DIDE	Division of Infectious Disease Epidemiology
EQA	external quality assessment
EUCAST	European Committee for Antimicrobial Susceptibility Testing
FAO	Food and Agriculture Organization of the United Nations
GLASS	Global Antimicrobial Resistance and Use Surveillance System
IHR	International Health Regulations (2005)
IQC	internal quality control
ISO	International Organization for Standardization
JEE	Joint External Evaluation
LIS	laboratory information system
LMHRA	Liberia Medicines & Health Products Regulatory Authority
MOH	Ministry of Health
NAP-AMR	National Action Plan for AMR
NMCC	National AMR Multisector Coordinating Committee
NPHRL	National Public Health Reference Laboratory
NRL	National Reference Laboratory
OIE	*Office International des Epizooties*
PT	proficiency testing
QA	quality assurance
QC	quality control
QMS	quality management system
SOP	standard operating procedure
TWG	technical working group
WHO	World Health Organization

Introduction

Antimicrobial resistance (AMR) occurs when microorganisms such as bacteria, viruses, fungi, and parasites change over time and no longer respond to treatment with medicines, making the infections harder to treat and increasing the risk of disease spread, severe illness, and death. AMR represents a formidable global challenge that transcends borders, species, and sectors. It has become one of the leading public health challenges facing the world in the twenty-first century (WHO 2021). In 2019, an estimated 4.95 million people around the world died due to AMR, while about 10 million people are expected to die annually by 2050 (Murray et al., 2019; O'Neill, 2016; O'Neill, 2014).

AMR increases health care costs and decreases agricultural productivity. Environmental management strategies can help to reduce these costs, because residues of antimicrobials used in human, veterinary and crop sectors infiltrate ecosystems, affecting wildlife and ultimately threating the well-being of humans (Peng et al., 2022; Van Boeckel et al., 2017). In addition to the spread of AMR in human and animals, the lack of clean water, poor sanitation and hygiene, and improper disposal of biological and pharmaceutical waste in the environment can lead to a proliferation of disease-causing bacteria and pathogens, leading to increased use of antimicrobials.

Liberia is among many countries that have weak or totally lacking surveillance and data collection systems for tracking and managing AMR. Despite the lack of data, researchers estimate that globally, 99,502 tons of antimicrobials were used in 2020, which will increase by 8 percent to 107,472 tons by 2030 if national and global actions are not taken (Mulchandani et al). Most antimicrobials are excreted un-metabolized from both humans and animals (O'Neill, 2015 and Dafale N.A et al, 2020) and run through municipal wastewater, animal manure and sewage sludge into the environment. Due to the complexity of AMR spread, there is an increasing need to improve policy and practices using a "One Health" approach across the human, animal, and environmental sectors. The cross-cutting nature of AMR has led to international organizations (FAO, World Organization for Animal Health, WHO, and the United Nations Environment Health Program) to form a quadripartite collaboration for working toward AMR containment (FAO *Office International des Epizooties* [OIE], 2015).

There is very limited data on drug resistance in Liberia. Drug-resistant tuberculosis (TB) provides one example of growing AMR in Liberia. According to the Global TB report (2017), there is evidence of increasing rates of resistance, with an estimated 2.6 percent of all new TB cases being multidrug-resistant TB. Among previously treated cases, 18 percent are multidrug-resistant TB, with 24 percent resistance to rifampicin, an essential TB medicine. More generally, Liberia started submitting data on AMR to WHO GLASS in 2021 and the unpublished data shows resistance to commonly used antibiotics such as fluoroquinolones and cephalosporins (Unpublished country data analysis from IDDS supported sites). Due to these increasing rates, Liberia has developed specific guidelines on how to establish, implement, monitor, and evaluate effective antimicrobial stewardship (AMS) programs at the national and health care facility levels. The roles of the AMS programs include promoting the effective and responsible use of antimicrobial agents with the main goal of protecting public health and combating antimicrobial resistance. The AMS program at facility level collaborates closely and coordinates their activities with IPC and surveillance teams guiding therapy based on laboratory results, antimicrobial consumption and utilization and other AMR interventions, such as immunizations.

1.1. Justification for the Development of an Integrated AMR Surveillance Strategy for Liberia

The 2016 Joint External Evaluation (JEE) report on the International Health Regulations (IHR) (2005) core capacities conducted in Liberia indicated that there was no capacity for the detection and surveillance of AMR that are pathogen related. The JEE report clearly indicated the country's capability to manage AMR and its associated threats was below the global recommended levels, underscoring the need to address challenges related to AMR.

In 2018, Liberia developed a National Action Plan for AMR (NAP-AMR) for 2018–2022. Except for the development of the animal health surveillance plan, most of the interventions drawn from the NAP-AMR were heavily skewed towards the human health sector. The country benefitted from the FAO Assessment Tool for Laboratory and AMR Surveillance System (ATLASS), which assists countries in assessing and improving their national AMR surveillance system in the food and agriculture sectors and the Progressive Indicator Pathway since it was first piloted in 2016. The environmental sector does not have a structured AMR surveillance strategy but has an assessment tool known as the Environmental and Social Impact Assessment. These fragmented surveillance systems were noted during Global AMR Surveillance System (GLASS) assessment, Guidance on Integrated Surveillance on Antimicrobial Resistance in Food-borne Bacteria, and the report on Surveillance of Antibiotic Consumption OIE's survey on use of antimicrobial in animals and chapters in the Terrestrial Animal Health Code on AMR assessments.

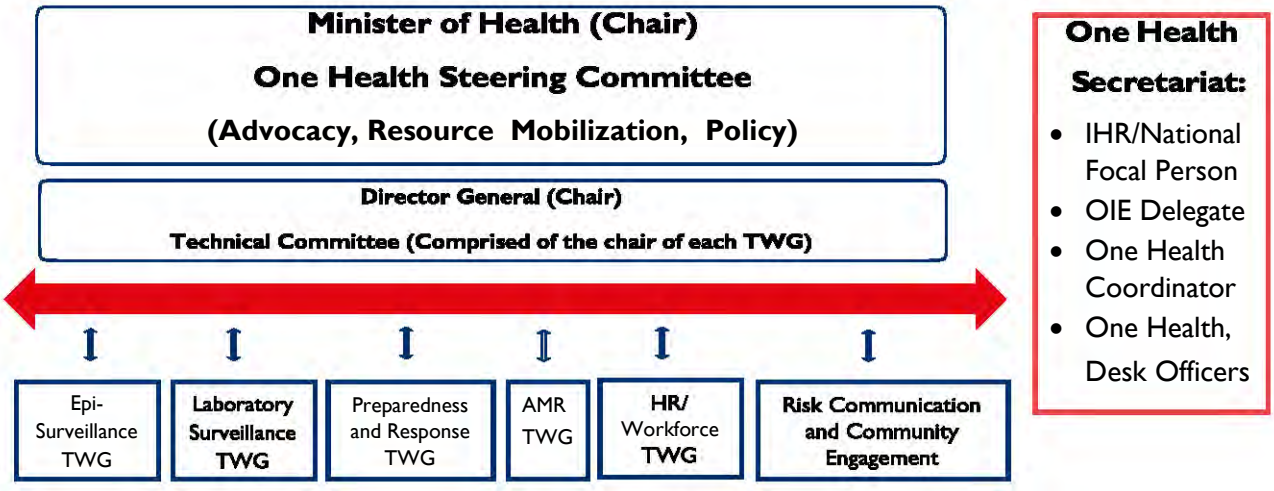
Based on the gaps identified in the country, the government of Liberia, under the One Health umbrella, has embarked on the development of an Integrated AMR Surveillance Strategy that collects information from sources including human, animal, and the environment. This information is the basis for targeted interventions and evidence-based decision making.

Previously, there was no integrated AMR surveillance strategy that governs the use of antimicrobials and their consequences in the context of One Health. Hence, the aim of this integrated AMR surveillance strategy is to guide the collection, collating, and analysis of data that will inform decision making for the reduction of AMR and antimicrobials misuse. Most importantly, the development of an Integrated AMR Surveillance Strategy will strengthen multi-sectoral collaboration in ensuring the implementation of AMR surveillance system.

1.2. AMR Surveillance Implementation Road Map

The Liberia Integrated AMR Surveillance Strategy will be implemented for the period 2023–2028.

One Health Governance Structure in Liberia



Approach to the Development of Liberia's Integrated AMR Surveillance Strategy

A desk review was conducted to establish the current AMR situation in the country. Key informant interviews were conducted in 4 of the 15 counties of Liberia in order to get expert insights pertaining to knowledge on AMR, gather diverse perspectives from key stakeholders in the human health sector, and understand barriers in the current AMR landscape. The key informants were county hospital pharmacists, laboratory technicians from AMR surveillance participating laboratories, selected wholesale and retail pharmaceutical outlets, and regulators.

2.1. Scope of Integrated AMR Surveillance Strategy

In the process of developing this Integrated AMR Surveillance Strategy, the following thematic areas were identified:

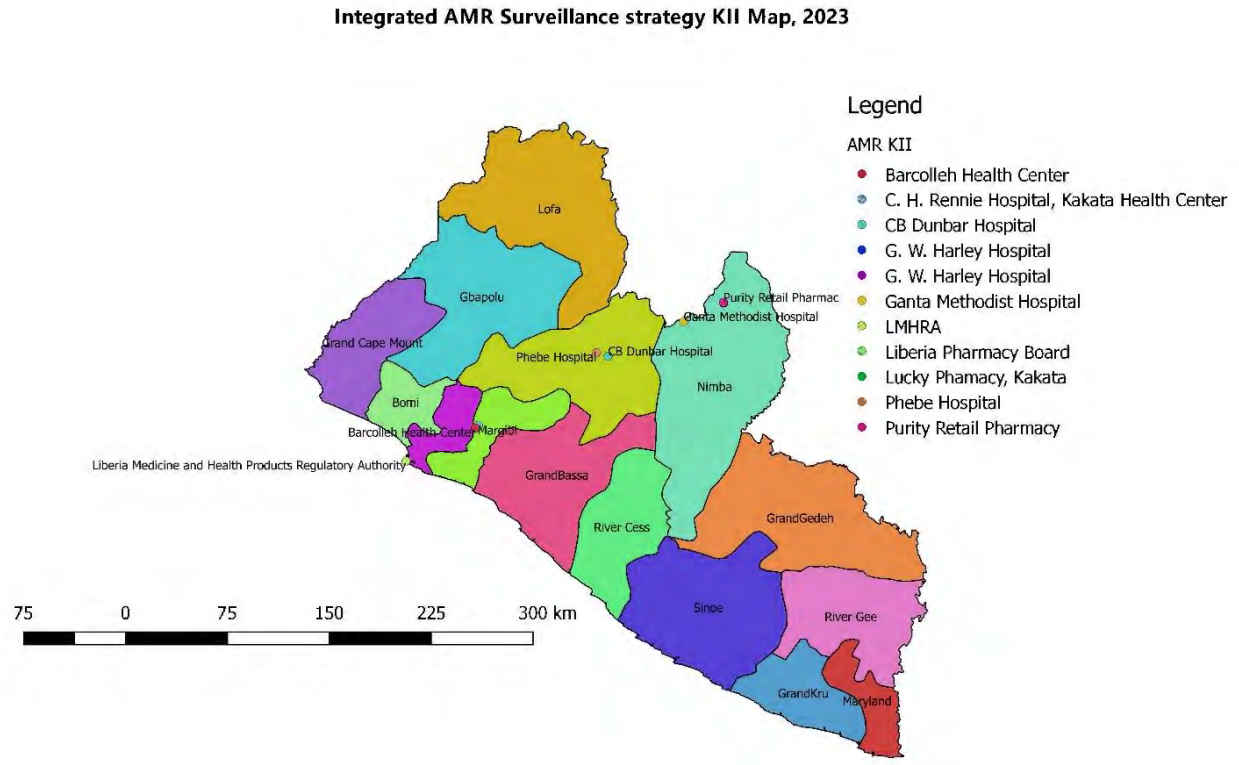
- Surveillance of antibiotic resistance in the human health sector
- Surveillance of antibiotic resistance and antibiotic residues in the food-animal sector

Surveillance of Antibiotic Resistance in the Human-Health Sector

3.1. Situational Analysis of AMR in Human

The fast emergence of AMR, which poses a danger to the efficient management and prevention of a wide range of bacterial illnesses, is the most significant issue related to infectious diseases. Against this backdrop, there are significant gains made within the human health sector when it comes to laboratory capacity. Those gains are proportional to the levels and locations of the laboratories. In the case of AMR surveillance, the human health sector is conducting antimicrobial susceptibility testing for pathogenic bacteria, tuberculosis, and malaria.

Figure 1. Map Showing Key Informant Interview Sites



The National Public Health Reference Laboratory (NPHRL) coordinates laboratories conducting culture and sensitivity testing and provides training and external quality assessment (EQA). Currently, Liberia has eight AMR sentinel sites: NPHRL, Phebe Hospital, Tellewoyan Memorial Hospital, J.J. Dossen Memorial Hospital, G.W. Harley Hospital, Jahmale Medical Solution, St. Joseph Catholic Hospital, and Duside Hospital.3.2. Goal and objectives

3.2.1 Goal of AMR surveillance in the human health sector

The goal of AMR surveillance in humans is to monitor and track the emergence, spread, and impact of AMR bacteria, viruses, fungi, and parasites in human populations. It involves the systematic collection, analysis, and interpretation of data related to AMR patterns and trends.

3.2.2 Strategic objectives

The following strategic objectives will drive the achievement of the AMR surveillance goal in the human health sector.

1. Perform regular AST across sentinel surveillance sites (inpatients and/or outpatients) on pathogens isolated from samples with clinical infections.
2. Report AST results and patient data from surveillance sites to NPHRL monthly.
3. Establish/strengthen regular communication of AST results from testing laboratories to clinicians, the health care quality management team, and stewardship committees as required.
4. Analyze, interpret, and report AMR surveillance data regularly from all surveillance sites with relevant stakeholders for public health action.
5. Participate in WHO's Global AMR and Use Surveillance System (GLASS) reporting efforts.

3.3. Surveillance Methods

Before enrollment, a facility must:

- Conduct laboratory assessment to establish their testing capacity and identify gaps.
- Scale up surveillance sites based on findings from the laboratory assessment.
- Evaluate laboratories bi-annually using a standardized process with respect to challenges.

Table 1. List of sentinel sites and types of specimen testing

S/N	Surveillance Site	Laboratory Type	Testing Type	Specimen	County
1	Phebe Hospital	Public	AST	Blood, Urine, Pus, CSF, wound swab	Bong
2	Tellewoyan Hospital	Public	ASF	Blood, Urine, Pus, CSF, Wound swab	Lofa
3	JJ Dossen Hospital	Public	AST	Urine, CSF, Blood Pus	Maryland
4	G. W. Harley Hospital	Public	AST	Blood, Urine, Pus, CSF, Wound swab	Nimba
5	National reference Lab	Public	AST	Stool	Margibi
6	Jahmale Medical Clinic	Public	AST	Urine, Stool, Sputum, Swabs (HVs, Wounds, Urethra, Ear,	Montserrado

				Buccal, Eye, Nasa, Anal	
7	Catholic Hospital	Private	AST	Wound swab, Urine	Montserrado
8	Duside Hospital	Private	AST	Consultant to populate with samples tested	Duside Village, Firestone

3.3.1 Surveillance Roll-Out Preparation

Evaluation of laboratories requires the use of a standardized laboratory assessment tool for AMR to assess the capacity of the microbiology section to ensure the facility's participation in AMR surveillance. In addition to assessment of the NPHRL for AMR surveillance implementation and laboratory network oversight capacities, key activities include:

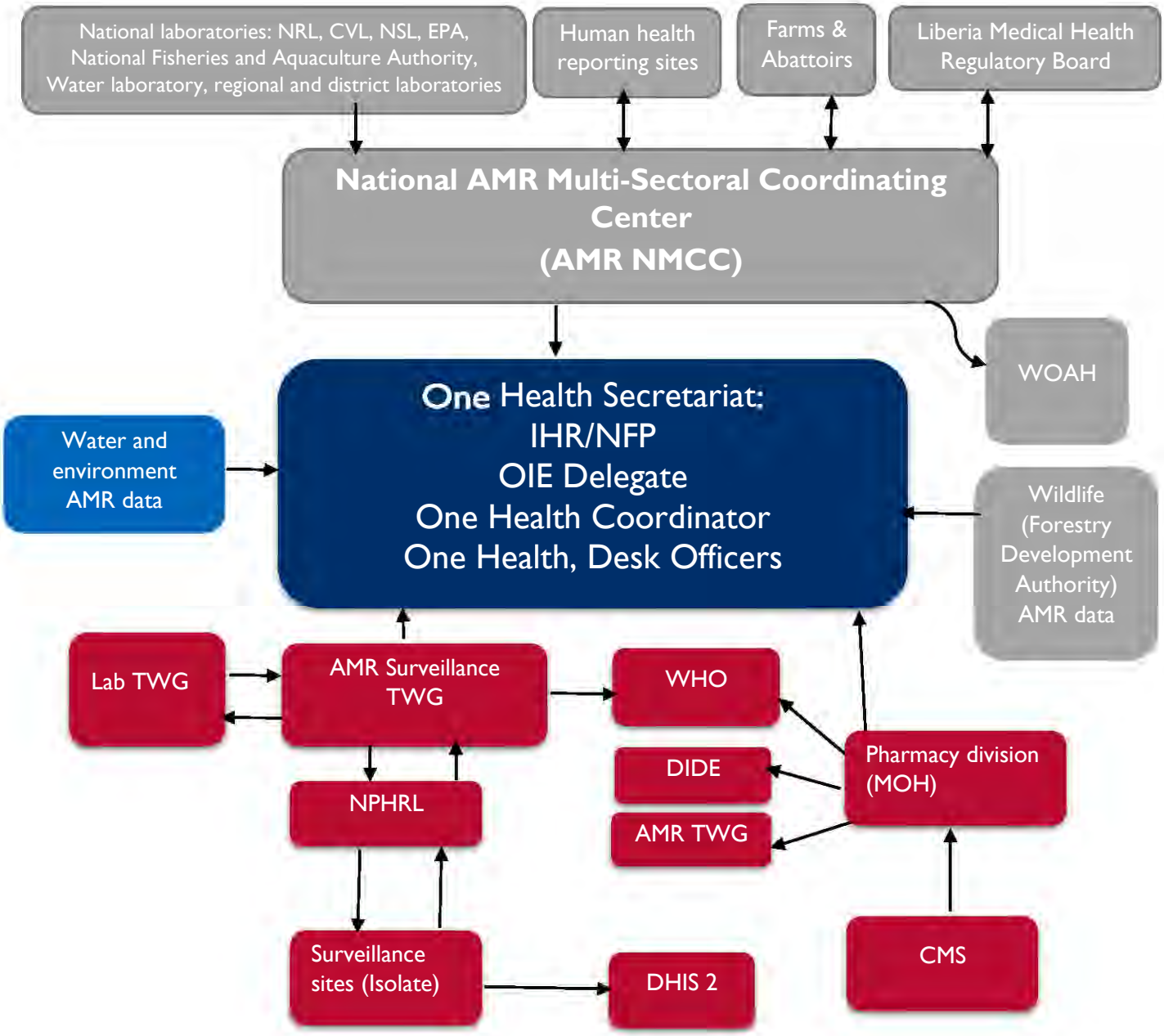
- Convene a workshop to examine and standardize AMR, evaluation instruments, standard operating procedures (SOPs), and other manuals.
- Develop standard operating procedures for AMR surveillance.
- Conduct training for approved AMR surveillance sites.
- Conduct AMR training workshop for clinicians and environmental and animal health workers.
- Disseminate the AMR surveillance, tools, SOPs, manuals, and forms.
- Establish an electronic system for AMR data repository.
- Equip NPHRL with equipment for biobank/biorepository
- On-site training for AMR surveillance sites personnel on culture, identification, and AST for priority pathogens
- Develop the master list for the materials/reagents/items, required for AMR surveillance and supply mechanism to ensure constant availability.
- Initiate implementation of AMR surveillance at site level.
- Provide mentorship and supportive supervision to facilities on the implementation of AMR surveillance.
- Train laboratory personnel on the AMR quality assurance (QA) program.
- Institute EQA for AMR testing based on the International Organization for Standardization (ISO) standards to participating laboratories.
- Support implementation of EQA AMR scheme for appointed laboratories.
- Report AMR data to national and global surveillance sites.

3.3.2 Routine Clinical Surveillance Methodology

- Routine collection of clinical specimens from patients seeking health services from sentinel sites will be employed.

- Specimens should be collected before initiating any antimicrobial agents to patient.
- Conduct AST for all identified pathogens.
- Report results through the Laboratory Information System (LIS).
- Every tenth isolate from each site must be sent to the NPHRL for QA.

Figure 2. Diagram for Reporting



3.4. Priority Specimens, Organisms and Antibiotics

The following are the priority specimens for AST: urine, blood, stool, cerebral spinal fluid (CSF), wound swaps/pus, and genital swabs (urethra and cervical) for AMR surveillance. **Note**: priority specimens to be collected may vary based on the capacity of the laboratories designated.

Even though there is a list of selected antimicrobials for surveillance purposes, it is imperative that all facilities conducting AST should test all antibiotics as required by their SOPs. The central level and the NPHRL will report the appropriate antibiotics for the GLASS report.

Table 2. Priority Surveillance Pathogens and Antibiotics for AST

Pathogen	Antibacterial Class	Antibacterial Agents that may be used for AST
E. coli	Sulfonamides and trimethoprim	Co-trimoxazole
	Fluoroquinolones	Ciprofloxacin or levofloxacin
	Third generation cephalosporins	Ceftriaxone or cefotaxime and ceftazidime
	Fourth generation cephalosporins	Cefepime
	Carbapenems	Imipenem, meropenem, ertapenem
	Polymyxins	Colistin
	Penicillins	Ampicillin
	aminoglycosides	Gentamycin
S. aureus	Penicillinase-stable beta-lactams	Cefoxitin
	Macrolides	Erythromycin
Salmonella	Fluoroquinolones	Ciprofloxacin or levofloxacin
	Third generation cephalosporins	Ceftriaxone or cefotaxime and ceftazidime
	Carbapenems	Imipenem, meropenem
Shigella spp.	Fluoroquinolones	Ciprofloxacin or levofloxacin
	Third generation cephalosporins	Ceftriaxone or cefotaxime and ceftazidime
	Macrolides	Azithromycin
Pseudomonas	Tetracyclines	Tigecycline or minocycline
	Aminoglycosides	Gentamicin and amikacin
	Carbapenems	Imipenem, meropenem
	Polymyxins	Colistin
Streptococcus	Penicillins	Oxacillin, Penicillin G
	Sulfonamides and trimethoprim	Co-trimoxazole
	Third generation cephalosporins	Ceftriaxone or cefotaxime
N. gonorrhoeae	Third generation cephalosporins	Cefixime, Ceftriaxone
	Macrolides	Azithromycin
	Aminocyclitols	Spectinomycin
	Fluoroquinolones	Ciprofloxacin
	Aminoglycoside	Gentamicin

3.5. Surveillance Standards

There are listed minimum laboratory competences ranging from technical skills required for laboratory quality control (QC) and EQA to data management. Enrollment of all laboratories should be assessed

using the standardized assessment tool. This will inform site selection and identify potential gaps that need to be addressed before AMR surveillance can begin.

3.5.1 Clinical Specimen Collection and Transportation Standards

Clinicians/laboratorians at participating hospital sentinel sites will send a sample (or samples) for culture and AST as outlined in the Integrated National Guidelines for One Health Specimen Management and Referral System – Republic of Liberia.

3.5.2 Patient Sampling Standards

A syndromic diagnosis must be established for patients before the sample is collected for AMR surveillance. This will inform the kind of decision of antimicrobials to use in case of treatment failure.

3.5.3 Laboratory Standards

Pathogen Isolation and Identification

For AMR diagnostic surveillance at a sentinel site used for culture and AST, in the case where there is identification of uncertain isolate(s) or with unusual susceptibility profiling, the NPHRL must be notified for confirmation and/or referral within 24 hours.

Pathogens prioritized by national entities and WHO will be the focus for the AMR surveillance system. Identification of these selected pathogens should be aided by using the appropriate and certified SOPs for biochemical and serological testing.

- *Escherichia coli*
- *Staphylococcus aureus*
- *Streptococcus pneumoniae*
- *Salmonella* spp
- *Shigella* spp
- *Pseudomonas aeruginosa*
- *Neisseria gonorrhoeae*
- *Haemophilus influenzae*
- *Klebsiella pneumoniae*
- *Acinetobacter* spp
- *Salmonella enterica* serovar Typhi
- *Salmonella enterica* serovar Paratyphi A

Antibiotic-resistant bacteria considered priority by WHO will also be considered for surveillance:

Priority 1: CRITICAL

- *Acinetobacter baumannii*, carbapenem-resistant
- *Pseudomonas aeruginosa*, carbapenem-resistant
- *Enterobacteriaceae*, carbapenem-resistant, ESBL-producing

Priority 2: HIGH

- *Enterococcus faecium*, vancomycin-resistant
- *Staphylococcus aureus*, methicillin-resistant, vancomycin-intermediate and resistant
- *Campylobacter spp*, fluoroquinolone-resistant
- *Salmonellae*, fluoroquinolone-resistant

- *Neisseria gonorrhoeae*, cephalosporin-resistant, fluoroquinolone-resistant

Priority 3: MEDIUM

- *Streptococcus pneumoniae*, penicillin-non-susceptible
- *Haemophilus influenzae*, ampicillin-resistant
- *Shigella spp*, fluoroquinolone-resistant
- *Pseudomonas aeruginosa*, carbapenem-resistant
- *Enterobacteriaceae*, carbapenem-resistant, ESBL-producing
- *Enterococcus faecium*, vancomycin-resistant
- *Staphylococcus aureus*, methicillin-resistant
- *Staphylococcus aureus*, vancomycin-intermediate and resistant
- *Helicobacter pylori,* clarithromycin-resistant
- *Campylobacter spp.*, fluoroquinolone-resistant
- *Salmonellae*, fluoroquinolone-resistant
- *Neisseria gonorrhoeae*, cephalosporin-resistant
- *Neisseria gonorrhoeae*, fluoroquinolone-resistant
- *Streptococcus pneumoniae*, penicillin-non-susceptible
- *Hemophilus influenzae*, ampicillin-resistant
- *Shigella spp.*, fluoroquinolone-resistant

3.5.4 Antimicrobial Susceptibility Testing

According to the GLASS guidelines, AMR surveillance must contain the following bacterial-antimicrobial medication combinations. The Clinical Laboratory Standards Institute (CLSI) standards must be followed when conducting AST for priority pathogens. Consistent with the referral guideline, all emerging or unusual/unexpected results must be reported to NPHRL for possible technical assistance.

3.5.5 Quality Control

The SOPs for QC for Microbiology will be utilized by sentinel sites. Internal Quality Control (IQC) guidelines must be reviewed by laboratory management in line with their quality management system (QMS).

IQC encompasses all phases of the diagnostic procedure, including media manufacture, equipment upkeep, and specimen collection through transmission of the results. Reference bacterial strains (American Type Culture Collection) should be used, in line with recommendations from CLSI guidelines.

3.5.6 External Quality Assessment

EQA is a system for verifying laboratory performance using a third party, impartial organization. A formal EQA program for all tests conducted must be utilized by all laboratories taking part in AMR surveillance. As EQA techniques, proficiency testing (PT), re-testing (rechecking), and on-site evaluation shall be employed when laboratories process samples/isolates. NPHRL is responsible for providing EQA to all AMR sentinel sites.

3.5.7 Isolate Repository and Confirmatory Testing

Priority AMR isolates from all sentinel sites should be referred to NPHRL once per month for repository. Isolates will be kept before and during travel at -20°C or -70°C in compliance with SOPs.

Every 10 percent of the AMR priority isolates forwarded to the repository should go through confirmatory testing once every four weeks to correct any inconsistent results.

3.5.8 Procurement of Essential Reagents, Supplies and Equipment

The proper inventory management of all materials, tools, and supplies required for the isolation, identification, and AST of priority pathogens is the responsibility of sentinel sites, as well as documenting appropriate equipment maintenance. Sentinel sites will be required to train their staff in supply chain management, inventory control, and equipment preventive maintenance. NPHRL will also keep a list of reliable vendors and supplies. To guarantee that routine operations are not disrupted, the laboratory will adopt a QMS in accordance with ISO standards. The Ministry of Health will also ensure that equipment is promptly repaired and maintained in a preventative manner.

3.5.9 Reporting Standards

Patient-based surveillance is the term used to describe this reporting requirement. When performing patient-based surveillance, AST findings from duplicate specimens or multiple specimens submitted for culture over the course of a single patient infection are not to be reported. Effective data management at both the local and national levels is necessary for reporting results. QC will be implemented at every level, with automated data validity checks and rules, as well as audits to ensure data consistency, completeness, and accuracy. Security safeguards for data should be in place, and confidentiality be preserved.

In addition to health facility data, the site coordinator makes sure that individual case-level anonymized data are supplied to the NPHRL. There are two of these: the overall number of patient episodes and the overall number of laboratory samples handled. To encourage sustained participation in AMR surveillance, the NPHRL should provide feedback on sentinel site data quarterly to health care administration, clinical, and laboratory staff.

3.5.10 Data Standards

The surveillance program's primary focus is the reliability and effectiveness of data collection, analysis, and transmission. The laboratory manager at the sentinel site should ensure that data are accurate, complete, and align with the AMR surveillance system reporting standards before sending the monthly data files to the NPHRL. In accordance with the SOP for Data Management, data files should be delivered using a standard file naming format that includes the year, month, and laboratory code that has been assigned to each laboratory.

Data management software (WHONET) must be used by sentinel sites to enter patient and laboratory information. AST findings that are specifically linked to patient infections should be reported together with relevant clinical data.

3.6. Surveillance Site Reporting

After conducting AST, laboratories will transfer the results of all priority AMR organisms from the record system into WHONET in addition to promptly entering those results into the record system (e.g., laboratory logbook, LIS) and data entry form. The laboratories are responsible for returning all routine laboratory culture and AST results to clinical teams for decision making.

3.6.1. Antibiogram Development

An antibiogram summarizes the annual cumulative proportion of pathogenic organisms that are susceptible to antimicrobials. It helps guide the human, animal, and environmental health workers in selecting the best empiric antimicrobial treatment in the event of a pending microbiology culture and susceptibility test. It is also a useful tool for detecting and monitoring trends in antimicrobial resistance. To improve the general understanding of AMR organisms in health facilities and community, the sentinel sites shall produce customized reports, such as antibiograms. Every surveillance laboratory will annually develop its own hospital antibiogram using information from its own AMR data.

3.6.2. National and Global Reporting

NPHRL and the National AMR Data Manager are responsible for managing and storing AMR data reported from sentinel sites. They oversee performing data quality checks and data analysis, producing official AMR reports, and establishing a sustainable data storage system.

The AMR One Health Technical Working Group (TWG) will review data from all sentinel sites at the AMR coordinating center and submit in consultation with national stakeholders to GLASS and the World Organization for Animal Health once a year. The TWG also releases and disseminates findings on AST results, including resistance trends, prevalence, and key recommendations at least once a year to inform policy.

3.6.3. Surveillance of Antimicrobial Use

The facility AMS program team will complete retrospective analysis of data of antimicrobials used in a specified period. The data will include prescriptions, sales records (human, animals, and environmental), records from the environmental sectors on medical waste (specifically on used antimicrobials), and chemicals used in the mining and agricultural sectors.

3.6.4. Monitoring of Antimicrobial Consumptions

WHO guidelines for monitoring antimicrobial consumptions will be implemented at both the facility and national levels. The primary purpose of the import data is to collect data on a national scale. Therefore, data on the consumption of antimicrobials will be collected at the national level intermittently by:

- Liberia Medicines & Health Products Regulatory Authority (LMHRA): a statutory arm of the government that ensures the legal importation, records, and quality of antimicrobials.
- Central Medical Stores (CMS): a government institution responsible for storage and distribution of antimicrobial agents to public and private health facilities and faith-based organizations.
- Liberia Pharmacy Board: a regulatory agency responsible to regulate the end user consumption of all essential medicines including antimicrobials at all levels.
- Supply Chain Management Unit: ensures the availability of antimicrobials and accessibility of data to inform decision making, forecasting, supply planning, distribution, and replenishing of antimicrobials at the facility level.
- Local manufacturers: provide data on the antimicrobial produced, which has been sold locally in a specified period in compliance with the LMHRA and CMS systems.

3.6.5. Core Set of Antimicrobials Under Surveillance

Only antimicrobials intended for systemic use are the subject of the Liberia Integrated AMR surveillance Strategy, which is based on the WHO surveillance program.

3.6.6. Monitoring Antimicrobial Use in Hospitals

For monitoring antimicrobial consumptions in hospitals, Liberia will adopt the GLASS guide for national surveillance systems.

3.6.7. Monitoring and Evaluation of AMR Surveillance

The Liberia Integrated AMR Surveillance System will be monitored and evaluated annually under the supervision of the One Health platform.

3.6.8. Key Performance Indicators

The following indicators will be used to monitor the performance of the AMR surveillance system:

- Proportion (%) of all patients admitted with infectious conditions correctly sampled
- Proportion (%) of all samples sent for investigation with the physician's clinical diagnosis
- Proportion (%) of priority pathogens correctly identified by the sentinel site laboratory (tested against the gold standard of the coordinating AMR laboratory or by EQA assessment)
- Proportion (%) of the resistance profiles correctly identified by the sentinel site laboratory (tested against the gold standard of the coordinating AMR laboratory or by EQA assessment)
- Number of reports (timely and complete) sent to the central laboratory by surveillance sentinel sites
- Number of reports on antimicrobials consumption data reported to central level by facilities (human, animal, and environmental health)
- Proportion (%) of animal products sampled and tested for antimicrobial residues
- Proportion (%) of animals sampled and tested for antimicrobial residues
- Proportion (%) of all patients admitted with infectious conditions correctly sampled
- Proportion (%) of all samples sent for investigation with the physician's clinical diagnosis.
- Proportion (%) of priority pathogens are correctly identified by the sentinel site laboratory (tested against the gold-standard of the coordinating AMR laboratory or by EQA assessment)
- Proportion (%) of the resistance profiles are correctly identified by the sentinel site laboratory (tested against the gold-standard of the coordinating AMR laboratory or by EQA assessment)
- Number of reports sent to the central laboratory by surveillance sentinel sites timely
- Number of antimicrobials consumption data reported to central by facilities (Human, Animal, and environment)

- Proportion (%) of animal products sampled and tested antimicrobials residues
- Proportion (%) of animals sampled and tested for antimicrobials residues

Surveillance of Antibiotic Resistance and Antibiotic Residues in the Animals, Food, and Plant and Environmental Sectors

Like humans, domestic animals suffer a high burden of infectious diseases that are caused by pathogens (bacterial, protozoan, virus, fungi). The most prevalent bacterial diseases worldwide (*Contagious Bovine Pleuropneumonia* in cattle, contagious *Caprine Pleuropneumonia* in goats and sheep, and two important tick-borne protozoan infections in cattle, East Coast Fever and Anaplasmosis) are curable with antibiotics.

In chickens, antimicrobials are used as broader preventive care in *Coccidiosis*, *Mycoplasmosis*, *Infectious Coryza*, and *Salmonellosis* (Mdegela, 2015). Studies by Mdegela et. al (2013), Kemera et.al, (2015), Mdegela et. al, (2003), and Mmbando (2004) found residues of antimicrobials in beef, milk, and eggs. Timely mass medication/metaphylactic, prophylactic as well as growth promotion are the main uses of antimicrobials within animal agriculture and the veterinary health sector. Also, antimicrobials are sometimes given to animals by farmers to make up for poor farm management techniques, a lack of professional veterinary services, and the prevalence of animal diseases. The lack of regulatory capacity contributes to this challenge as there are no guidelines on importation of antimicrobials. Farmers may not be aware of the consequences of animal antibiotic misuse if these techniques are followed (Mdegela et.al (2013); Kemera et.al, (2015); Mdegela et.al, (2003); Mmbando (2004). Even though there is a lack of research data on type of antimicrobials in Liberia, other countries like Tanzania have recorded oxytetracycline, amprolium, sulphonamides, flumequine, penicillins, chlortetracyclines, doxycyclines, trimazine, and tylosin as the most frequently used antimicrobials in the production of commercial poultry and cattle. These countries have also reported resistance to tetracycline, trimethoprim, amoxicillin, streptomycin, chloramphenicol, and erythromycin within the aquaculture sector.

A Knowledge Attitudes and Practice survey conducted by Eddie M. Farngalo in Nimba County, Liberia revealed the use of human-related chloraphenicol, doxycyline, griseofulvin, tetracycline, metronidazole, penicillin, and co-trimoxazole to treat livestock diseases (Farngalo, 2019). With the weakness in AMR research in country, there are potential risks for a higher burden of AMR among the citizenry, especially when over 80 percent of animals and animal products consumed in country being produced domestically. Also, an extremely limited number of veterinarians within the public sector rationally prescribe antimicrobials for the treatment of animals' diseases, further exacerbating the potential threats to AMR. Consequently, livestock owners are left with no alternative but to treat symptomatic animal diseases with human antibiotics. These are documented in the biosafety and biosecurity assessment among poultry farmers, which uncovered that those drugs are used by farmers without prior knowledge of their impacts on both animals and humans (FAO and Central Agricultural Research Institute, 1989). It is also imperative to know that farmers are less likely to be concerned about the adverse effects of antimicrobials on humans; their key focus is the prevention of economic losses that will affect their livelihood as well as nutrition intake.

4.1. Situational Analysis in Plants

Globally, viruses, fungi, and other microorganisms cause more illnesses in plants than bacteria. Even when detected in rare cases, the effectiveness of antimicrobials for the prevention of plant-related bacterial diseases is extremely limited. However, other antimicrobials (tetracycline and streptomycin) are often utilized in the form of spray as a trial.

4.2. Situational Analysis in Environment

There is increasing evidence that suggests that environmental organisms serve as repositories for AMR genes (Costa et al., 2011; Bhullar et al., 2012). This confirmed the information that the environment might contain genes of resistant bacteria. Wastewater, medical waste, damaged sewage systems, improper waste disposal, as well as some agriculture practices are among several ways animals, crops, and humans can contaminate the environment with antimicrobials.

The effectiveness of antimicrobial disposal within the environment is predicated upon the available climate condition, types of soil including other environmental factors as well as the physiochemical properties of the antimicrobials. To minimize AMR in the environment that hosts the potential resistant bacteria population, antimicrobials need to be disposed of or destroyed appropriately. Unfortunately, several studies that have described AMR in the environment have mostly examined high-income nations, with little understanding of low- and middle-income nations.

Over 70 percent of resistance that is recorded in aquaculture derives from availability of human and animal waste (e.g., urine) within an environment that already has anthropogenic AMR genes. This process is a potential exposure factor for aquaculture to AMR. The percentage of resistance to tetracycline, trimethoprim, amoxicillin, streptomycin, chloramphenicol, and erythromycin in aquaculture is even higher among co-operative fish farmers.

4.3. Goal and Objectives

4.3.1. Goal

The goal of AMR surveillance in the context of animals, plants, and the environment is to monitor and understand the emergence, spread, and impact of antimicrobial resistance in these domains.

4.3.2. Strategic Objectives

- Establish profiles of priority resistant pathogens against antimicrobial agents for animals, plants, and the environment
- Monitor AMU and AMR in food producing animals and their products to inform control interventions.
- Establish AMR baseline data from wastewaters, soil, and other water sources in the environment.
- Generate AMR data from animals, food, crops, and environment for policy, control, and future research guidance.

- Develop an early warning notification system for emergence of novel resistant strains/ pathogens and aid in rapid identification and control of outbreaks.

4.4. Methods of Surveillance

The type of surveillance system to be employed for collecting desired information to trace AMR infections and resistant strains will be active and passive. Like any other surveillance system, this technique aims at early identification of resistant strains and sharing of required information for effective intervention. The surveillance techniques in this framework will primarily concentrate on tracking trends and patterns, monitoring resistant pathogens, and monitoring antimicrobial consumption and usage in animals, plants, and the environment.

This surveillance strategy will use a variety of surveillance techniques to gather appropriate and trustworthy AMR data that will enable the implementation of actions to lower the burden of antimicrobial resistance in the food, agricultural, and environmental sectors across the country.

To obtain reliable and accurate AMR data, both epidemiological and microbiological data will be collected and analyzed. To stop the spread of antibiotic resistance and improve the selection and use of antibiotics, antimicrobial resistance will be monitored regularly by surveillance of resistant microorganisms of animal, food, environmental, and human origin.

4.4.1. Target Surveillance Systems for Food and Agriculture

AMR surveillance will focus on land and aquatic animals and plants. The table below shows the environments of focus for surveillance for the different animals and products in the food and agriculture sectors.

Table 3. Areas targeted for surveillance in food and agriculture sectors

Production System	Environment of Focus	Species	Products
Extensive and intensive ruminant production	Grazing (pastoral and agro-pastoral), feedlots	Cattle, goats, sheep	Meat, milk, manure
	Pasture based and semi/zero-grazing	Cattle (graded/ improved)	Milk, meat, and manure
Commercial, semi-intensive and extensive Poultry production	cages, poultry houses and backyard	Indigenous (chicken, ducks, guinea fowls), broilers and layers	Meat, eggs, manure
Extensive (free range) and intensive pig production	Pig houses and backyard	Local and Improved breeds of pigs	Meat, manure
Companions' animals (Stray and housed)	Houses and backyard	Dogs, cats	Fecal
Aquaculture and mariculture	Cages, Recirculation Aquaculture System, pond and Happas	Finfish and Crustaceans	Freshwater and marine foods
Intensive and extensive crop production	Farmland	Vegetables, Fruit trees, Sunflower, cashew-nuts	Fresh fruits and vegetables
Honey production	Beehives	Bee	Honey

Processed/ semi processed food/ environment	Processing plants, transportation, and storage facilities	Meat, milk, fish, canned food	Swabs, wall, effluent, workers

4.4.2 Target Bacteria for AMR Surveillance

In the context of food, agriculture, and environmental health, different species of bacteria are mainstreamed. Before a bacterium is considered as a pathogen for surveillance, it should be linked to a zoonotic disease, prone to cause food-borne disease, have a high incidence or prevalence, or relatively high pathogenicity. Moreover, those organisms (e.g., *E. coli. Enterococcus spp, Salmonella spp, Streptococcus, Staphylococcus aureus*, and *Pseudomonas aeruginosa*) must have a known history of developing resistance in animals, crops, and the environment (Almuzaini et al., 2013).

4.4.3 Antimicrobial Agent for Surveillance

The antimicrobials below are included based on their ease of access to farmers, the likelihood that they can be abused or misused, their range and efficacy, and the opinions of experts. Antimicrobials' significance to public health is a further selection criterion.

Table 4. Antimicrobials and their use in humans and animals

Classes	Principal Use in Humans	Principle Uses in Animals
Tetracycline's (Chlortetracycline, oxytetracycline, tetracycline, doxycycline)	Used for treatment of infections of the urinary tract, respiratory tract, and the intestines and are also used in the treatment of chlamydia, especially in patients allergic to lactams and macrolides	Major broad-spectrum primary agent for systemic infections in animals
Cephalosporins	Treatment of infections in penicillin allergic patients. Prophylaxis in orthopedic and other surgery and respiratory infections	intramammary treatment of mastitis due to staphylococci and streptococci in dairy cattle/ intrauterine treatment for metritis in cattle
Aminoglycosides (Gentamycin and Neomycin	Topical agent for skin infection and gut suppression	Primary agent for enteric infections in livestock (oral form); broad spectrum primary agent for a range of systemic infections in livestock. Primary agent for E. coli and Salmonella infections in calves, pigs and broilers
Sulfonamides (Trimethoprim/ sulphonamide, Sulfadiazine, Sulfadoxine	Broad spectrum antibiotics use for the treatment of UTI, conjunctivitis, otitis media, chronic bronchitis, Traveler's diarrhea, etc.	Primary agents for broad-spectrum infections in livestock, horses and dogs including enteritis and pneumonia (oral and injectable), Oral sulfonamides (without Trimethoprim) are also used for coccidiosis in poultry and aquatic Used for treating and preventing powdery mildew in cashew-nut
Macrolides (Erythromycin, and	Treatment of minor Gram-positive, Chlamydia and Mycoplasma	Livestock for respiratory infections and other serious systemic

Azithromycin, Tylosin)	infections.	infections including mastitis. Respiratory disease in poultry

*(Source: modified from surveillance and reporting of AMR and AMU in animals and Agriculture in Australia, 2014.

4.4.4 Surveillance Categories

According to the Terrestrial Animal Health Code (OIE, 2013c) and Aquatic Animal Code (OIE, 2013b) of the World Organization for Animal Health, the following important questions should be addressed for AMR surveillance.

- How do you sample?
- Which sample origin/animal species?
- Which bacterial species?
- Which antibiotics are tested?
- How do you interpret the data?

When monitoring AMR in aquatic and animals, the OIE code recommends the following:

- establishes baseline data on the prevalence of antimicrobial resistant microorganisms and determinants.
- assesses and determines the trends and sources of antimicrobial resistance in bacteria.
- detects the emergence of new antimicrobial resistance mechanisms.
- provides the data necessary for conducting risk analyses as relevant to animal and human health.
- provides a basis for policy recommendations for animal and human health.
- provides information for evaluating and guiding antimicrobial prescribing practices and for prudent use recommendations; and
- Explore the potential relationship between antimicrobial resistance in aquatic animal microorganisms and the use of antimicrobial agents.

Participatory, active, and passive AMR surveillance systems (as described in the sub-sections below) may be deployed in accordance with needs and resource availability.

4.4.5 Active Surveillance

The goal of active surveillance will be to acquire data to support the responsible use of antibiotics. To determine how the prevalence of resistance has changed over time and whether resistant priority pathogens have emerged, longitudinal, cross-sectional, or purposive surveillance will be used. Sites for surveillance will be chosen based on the prioritized species and the recognized production systems as shown above.

4.4.6 Passive Surveillance

During normal activities, a passive surveillance system will focus on gathering information and samples that have been sent to diagnostic laboratories for clinical use. When necessary, private laboratories,

academic/research institutions, wildlife centers, and zonal centers will participate in diagnostic testing. Data will be gathered using an electronic system (event mobile application).

4.4.7 Participatory Based Surveillance

During Participatory Rural Appraisal, epidemiological data is collected to guide decision-makers on action to take towards information that was collected using knowledge, attitudes, practices, and perceptions of AMR and AMU.

Focus group discussions, semi-structured questionnaires, checklists, scoring, ranking, proportional piling, and matrix scoring should be used as tools in the participatory surveillance to characterize how consumers and suppliers perceive relative preferences and risk factors (drivers) for AMU and AMR.

4.5. Sampling Protocols for Human and Animal Sampling

The sample protocol provides information on the sampling's purpose, design, and operational method.

4.5.1 Purpose

To ensure accurate laboratory test results and laboratory analyses, the purpose of this surveillance protocol is to describe sampling design, types of data to be collected, procedures for collecting, handling, transporting, and storing samples (quality specimens) for AMR laboratory analysis.

4.5.2 Users and Responsibility

This procedure is meant to be followed by all institutions and persons involved in Liberia's AMR surveillance program. The sample collectors and analysts must adhere to the SOPs when gathering and handling samples from the field to laboratories. Laboratories should ensure that samples submitted for testing meet the sample acceptance requirements.

4.5.3 Sampling Design

To determine variations in trends of the prevalence of resistance overtime and the occurrence of new resistant strains of important pathogens, probability and non-probability sampling design should be employed.

4.5.4 Sample Size

Depending on different statistical methods, the level of accuracy, the number of samples to be gathered for human and animals may vary. The sample size should be determined using a desired alpha level of confidence, margin of error, and an assumed minimum illness prevalence of 1 percent, with the population in each sampling area taken to be infinite. The sample size will be determined via the common formula for proportion estimation as below:

$$n = Z^2 \times P \times (1-P)\ e^2$$

n is the necessary sample size, P is the estimated prevalence, z is the alpha level of confidence, and e is the desired precision level.

4.5.5 Sample Size Estimation at Predefined Level of Precision Level

Individual Study Sample Size Estimation

Sample size collection as per WHO AMR surveillance standards will be used to guide the process. The correlation between sample sizes and the sensitivity of a monitoring system to identify rises in resistance is provided by this standard guide.

Estimated Sample Size Needed for Documenting Increasing AMR Frequencies in The Environment

Environmental Sampling

To choose the sampling frame, the subset of the sample population to be taken into consideration, and the locations, an abstract transect can be utilized for environmental (soil, water, and plant) samples. When there is insufficient data on the sample population, the sample size will be decided using randomization to choose a predetermined number of sites. From a few chosen places, active sampling will occur bi-annually.

4.6. Laboratory Standards

Minimum requirements for laboratory participation as a surveillance site in the AMR Surveillance System are required.

4.6.1 Sample Collection

For priority organisms to be identified, SOPs for sample collection, preservation, transportation, and storage must be adhered to accordingly.

Table 5. Samples from Humans

Priority organisms for screening	Type of Samples
Salmonella spp	Stool, blood, tissue
Staphylococcus spp	Blood, pus, wound swab
E. coli	Urine, blood, pus,
Shigella spp	Stool
Klebsiella pneumoniae	Pus, wound swab
Vibrio Cholerae	Stool

Table 6. Samples from Animals

Priority organisms for screening	Type of Samples
Salmonella spp	GIT specimens: Swabs, Fecal sample, etc.
Staphylococcus spp	swab samples from food producing animals (Fecal, nasal, choanal, cloacal and septic wound)
E. coli	Fecal sample, GIT specimen, body swab, water
Enterococcus spp	Fecal sample

Campylobacter spp	Fecal sample

Table 7. Foods of animal origin, crop, and environmental samples

Priority organisms	Type of Samples
Streptococcus spp	. Milk from cows with mastitis · Animal tissue samples, Plant tissue · Water sample
Staphylococcus spp	. Milk from cows with mastitis · Eggs, Plant tissue · Animal tissue samples, Plant tissue · Water sample
Salmonella spp	Eggs, meat, Plant tissue · Water sample
E. coli	Eggs, meat, fish, milk, Plant tissue · Water sample

4.6.2 Sample Submission and Coding

As outlined on the sample submission form, all samples must be submitted to the participating laboratories for AMR surveillance along with completed sample submission form as per the standard variables and coding for each sector and sentinel site.

4.6.3 Laboratory Testing Standards

Liberia-recognized standards will be used as primary guideline for AMR testing. However, pathogen-specific SOPs will be used for the detection and isolation of bacteria (*Salmonella, E. coli, Staphylococcus aureus, Aeromonas, Enterococcus,* and *Klebsiella*). In an extreme case where the national standard is not available, the ISO standards will be utilized. For instance, in the case where isolate susceptibility is to be ascertained, ISO 20776 is required. The antimicrobial groups tetracycline, penicillin, sulfonamides, cephalosporins, aminoglycosides, and macrolides will be subjected to AST.

In compliance with CLSI standards, quantitative results (disc diffusion, zone diameters, or minimum inhibitory concentration values) will be produced. Serotyping (for *Salmonella spp.*), polymerase chain reaction (for *E. coli* and *S. aureus*), E kits specific for ESBL Chromogenic medium, and other biochemical tests are advised for the confirmation of isolates. It will be important to identify pathogens at the type of level (such as serotypes) for some species.

4.6.4 Antimicrobial Susceptibility Testing

Clinical Laboratory Standards Institute (CLSI) and European Committee for Antimicrobial Susceptibility Testing (EUCAST) guidelines should be referenced while testing priority pathogens for antimicrobial susceptibility. Standard interpretation of AST result must be based on "Susceptible, Intermediate, and Resistant" categorization by participating laboratories in determining at what level the isolates are susceptible based on the zone sizes (mm) and clinical breakpoints established by CLSI and EUCAST.

4.6.5 Laboratory Reagents, Consumables, and Equipment

The laboratory management for each sector shall ensure the availability of quality assured equipment, reagents, and consumables for AMR detection.

4.6.6 Quality Assurance

Laboratories shall ensure the implementation of the QMS is required to make sure that results generated in the laboratories are of quality. Each participating laboratory shall include internal and external quality audits as well as execution of the non-conformances found during audits.

4.6.7 Internal Quality Control

Proficiency testing for laboratories will be conducted by participating laboratories using a test panel that is supervised by the designated reference laboratories with specifics to IQC. This should evaluate preanalytical, analytic and post-analytic (diagnostic cycle) steps involved with the testing of pathogens. As a standard, IQC must be conducted with each AST testing while regularly conducting preventative maintenance on equipment.

The monitoring of the accuracy of the results will be aided using reference bacterial strains in accordance with CLSI/EUCAST standard recommendations. The American Type Culture Collection or the National Collection of Type Cultures will be used as the control strains for the laboratories.

4.6.8 EQA

International as well as reference AMR laboratories will institute a re-testing, on-site evaluation, and PT for participating laboratories as part of the external QC process. An agreed turnaround time will be used in sharing results from the PT with institutions of concern for EQA.

4.6.9 Isolate Repository

National reference laboratories (animal, human and environment) must have a repository for all stored cultures. AMR samples will be sent by the participating laboratories. SOPs for transportation, storage (-20°C or -80°C) will be referenced. Laboratory manager shall ensure that there is uninterrupted power supply, requisite freezers, specimen tracking system, and personnel trained in biorepository management to maintain integrity of isolates.

5. Data Management and Information Sharing

Across all sectors, data from sentinel sites at the districts or counties levels should be provided to a centralized database housed at a designated location. Designated reference laboratories across each sector may compare trends of antibiotic resistance or antibiotic residue surveillance. An annual report integrating analyzed surveillance data should be made available in the public domain. In addition, a quarterly online system for reporting of surveillance data should be developed. There should also be quarterly reporting through appropriate software such as WHO-NET, District Health Information Software (DHIS 2) and LIMS. To share biological materials, biosafety and biosecurity protocol must be observed.

5.1. Antimicrobial Use Surveillance

AMU surveillance will include monitoring microorganisms and antibiotic residue from animal products meant for human consumption that are gathered at various food chain stages, including processing, packaging, and retailing. This monitoring process will involve quantitative information data collection base on variables such as: user (farmers), animal species, and antimicrobial agent or class agents,

perception in terms of access, storage, use, animal handling, type of use whether for therapeutic or non-therapeutic purposes, and route of administration. The category of variables listed are pivotal for conducting risk analysis. This will inform what kind of intervention will have high impact and corrective measures.

1. Identify the antimicrobial agents in commercial circulation.
2. Identify potential points of data collection.
3. Assess what each data source represents.
4. Set parameters for precision and completeness of the surveillance system.

5.2. Sources of Data for AMU

Data for AMU can be collected from import and export data, manufacturing and sales data, customs, wholesalers, retailers, pharmacists, veterinarians, feed stores, farms, feed mills as well as from the pharmaceutical industries and associations or regulatory authorities. At certain intervals, a variety of methods, such as comprehensively prepared data gathering forms (e.g., consumers' survey) will be used.

5.3. Data Collection Procedures

Various data types and collection techniques will be used to monitor the usage of antimicrobial agents, as outlined below:

1. Collect appropriate information of the pharmaceutical manufacturers and the regulatory authority (LMHRA) targeting types of drugs, importers, volumes, labelling and packaging and distribution channels.
2. Non-conventional sources including Internet sales data related to antimicrobial agents could be collected where available.
3. Collect information from the end user (veterinarians and food animal producers): Collection, storage, and processing of data from end-use sources should be carefully designed, well managed, and have the capability to produce accurate and targeted information.

5.4. Types of Data to be Collected

- Number of the active antimicrobial's ingredients in the food-producing animals annually
- Estimate of total consumption in the form of sales data, prescribing data, manufacturing information, and clients' treatment records (data on both export and import).
- Channels through which the drugs were imported, category of drugs, packaging, labelling, and importers information are also needed.
- The number of food-producing animals by species, production types and weight measure in kilogram annually

6. Monitoring and Evaluation of AMR Surveillance

The goal of the integrated AMR surveillance strategy plan is to conduct a robust, comprehensive, and multi-sectorial impact evaluation of the overall performance of the system covering food, agriculture, and environment sectors. The objective of the AMR strategy plan monitoring and evaluation (M&E) is to provide a framework for tracking progress and demonstrating results of the AMR surveillance system over the short and medium terms.

7. Performance Indicators

- Proportion (%) of institutions incorporated AMR surveillance into their work plans
- Proportion (%) of targeted resistant pathogens profiles established annually
- Proportion (%) of surveillance sites covered in AMR surveillance annually
- Proportion (%) of surveillance reports generated and shared quarterly, bi-annually, and annually
- Number of sites participating in inter-laboratory comparison and EQA
- Number of policy documents developed, e.g., Proportion (%) of early warning notifications resulting from emergency of novel resistant pathogen
- Number of laboratories with basic equipment to conduct AMR surveillance (baseline, target, frequency, and data sources)
- Number of laboratories with reagents and consumables
- Number of laboratories trained/mentored in AMR testing
- Number of AMR surveillance sites reporting priority pathogens (timely)
- Number of laboratories with AMR active surveillance protocol (for poultry, beef, pork, fish, and milk)
- Number AMR surveillance sites accredited (internationally)
- Number of AMR surveillance sites fully implementing QMS
- Number of sentinel sites producing customized reports (e.g. antibiograms).
- Terms of reference and MoU developed and approved (where appropriate)

8. Roles and Responsibilities of Key Players

The following roles and responsibilities are proposed for key stakeholders in the implementation of the integrated AMR surveillance strategy plan.

8.1. Coordinator, Focal Points, National AMR Coordinating Center (AMRCC or NCC)

- Coordinate monitoring and evaluation of the national AMR/AMU surveillance system.
- Define and communicate to the relevant stakeholders the timeline for data submission from surveillance sites to the national level in consideration of the annual GLASS data call schedules.
- Coordinate surveillance sites (clinical and laboratory).
- Coordinate cross-sector protocols and reporting mechanisms.
- Report AMR data to key county, national, and international stakeholders.
- Provide interpreted data for use in guiding policies, guidelines, and informed decision making.
- Monitor and evaluate the AMR and AMU surveillance system on an ongoing basis.
- Coordinate surveillance, stewardship and policy implementation, and advocacy and training activities of the AMR national plan.
- Report annual aggregate AMR and AMU data to WHO and other relevant actors.

8.2. National AMR Surveillance Technical Working Group

- Advocate and support awareness and understanding of AMR through effective communication, education, and training.
- Facilitate, coordinate, and monitor the implementation of national action and operational plans for containment of AMR.
- Ensure regular data collection and information sharing by instituting effective communication and coordination among all stakeholders, the members of AMR and their constituencies, sectors, and disciplines.
- Coordinate national and sub-national activities for establishment of AMR surveillance systems.
- Conduct surveillance and detection for foodborne pathogens containment and diseases.
- Coordinate monthly TWG meeting every third Wednesday of the month.

8.3. National Public Health Reference Laboratory (NPHRL)

- Adapt and disseminate microbiological methods, standards, and protocols.
- Promote good laboratory practice and provide guidance and technical support for quality management, pathogen isolation and identification, and AST methodology.
- Support capacity building of laboratories serving AMR surveillance sites through oversight and training.
- Organize or facilitate participation in EQA schemes for laboratories serving AMR surveillance sites, review EQA performance of participating laboratories, and provide feedback on EQA results to laboratories.
- Perform confirmatory testing, e.g., isolates with rare and unusual resistance patterns and resistance mechanisms.

- Collaborate and conduct research in the field of microbiology.
- Ensure compliance to SOPs via initial training programs and mentorship visits.
- Coordinate and ensure that reporting of aggregate AST results meets AMR surveillance system requirements.
- Act as the national repository of bacterial strains or cultures from all participating laboratories

8.4. County Diagnostic Officer (CDO)

- Support development of an action plan to address gaps identified during AMR baseline data collection.
- Monitor and supervise county-level implementation of GLASS within the AMR-NAP.
- Compile regular county AMR GLASS reports and timely submit to AMRCC/NCC.
- Communicate with the national laboratory as necessary.
- Ensure that existing confirmation procedures for laboratories at the national level are known and implemented at the facility, district, and county levels.

8.5. Logistics and Procurement and Supply Chain

- Procure supplies and reagents for laboratories participating in national surveillance.
- Coordinate distribution of standardized reagents and supplies across participating laboratories.
- Manage stock to prevent interruptions in testing and provide accountability for items procured.

8.6. Data management /IT and M&E (Data Warehouse)

Data manager

- Facilitate laboratory staff training on data collection and transmission.
- Conduct periodic data verification visits, which will compare source data and system data.
- Coordinate biannual review of the system with regards to data available, timeliness of reports, and challenges faced.
- Provide data entry of paper-based data collection tools as well as data cleaning.

M&E personnel and data analysts/statisticians

- Analyze data and prepare aggregate county and national AMR reports.
- Prepare and update reporting tools for the sites.
- Provide feedback data to NPHRL to feed back to the testing laboratories.
- Conduct quarterly data entry checks comparing archived paper-based records and data entries logged.
- Conduct routine data quality checks.

- Provide monthly QC reports to participating laboratories.
- Maintain data warehouse infrastructure and transmission platforms.
- Interface with other data platforms e.g., DHIS2.
- Integrate different LIS platforms for optimal data collection.

8.7. Hospitals/ Clinics and laboratories

Hospital administration

- Ensure that there are adequate staff and physical infrastructure in place to perform surveillance activities.
- Review and disseminate surveillance reports at the facility level.
- Establish Antimicrobial Stewardship Committee (ASC) or its equivalent consisting of clinicians, laboratory technologists, pharmacists, and nurses to meet at least quarterly.

Quality management team/AMS team (should include drug therapeutic team)

- Address challenges associated with specimen collection, transport, results, and reporting.
- Provide feedback on system and individual performance to the members of the surveillance system at the hospital.
- Review reports and make recommendations to the hospital administration.

Clinicians (doctors, clinical officers, and nurses)

- Collaborate with the laboratory team for collection and submission of priority specimens per approved specimen collection SOP.
- Consistently and correctly complete laboratory requisition forms including required clinical data.

Laboratory technologists/technicians

- Collect and package clinical samples for transportation to reference laboratories, as per SOPs.
- Conduct ID and AST of isolates as per SOP, where capacity is available.

Laboratory manager or designee

- Prepare aggregated monthly reports to the hospitals.
- Ensure clinical reports are returned to requesting hospital/clinicians on a timely basis.
- Review all reports prior to release.
- Ensure employees meet all required standards and are following SOPs.
- Regularly report to the NPHRL.
- Promptly communicate priority patient-level AST results to clinical providers.
- Ensure ID/AST results are not duplicated when reporting.
- Report aggregate AST data as described in this document.
- Act as a liaison between hospital clinical and laboratory teams.
- Promote diagnostic stewardship activities on site.

The microbiology laboratory providing support to the surveillance site should:

- Isolate and identify pathogens, perform AST according to standards and report microbiological information derived from the tested clinical specimen.
- Participate in External Quality Assessment scheme.
- Provide feedback/discuss locally generated surveillance data to inform local treatment guidelines and AMR control strategies.
- Report quality-assured AST results and relevant core patient data to NCC.
- Compile facility GLASS report and submit timely to the CDO.

8.8. Political leaders at national, district and county levels

- Encourage residence or community members to seek care from professional health care workers and advocate for use of medications prescribed by trained HCWs.
- Play an active role in sensitizing community members on how to promote, maintain, and sustain positive behavior change to reduce risks for AMR.
- Secure funds for active surveillance activities.
- Advocate for community-based planning, implementation, and evaluation of health programs to promote IPC, AMR awareness, and education.
- Play an active role in committees on One Health.
- Mobilize and allocate resources to address AMR and emerging diseases.
- Advocate for AMR and AMU surveillance and medication safety in different forums.

8.9. Health development partners and international stakeholders

- Contribute to setting standards and developing guidelines.
- Provide technical assistance (including surge capacity), expertise, and other material support in strengthening Liberia's disease surveillance and laboratory and health information systems.
- Support MoH, MOA, EPA, surveillance sites and local authorities in mobilizing resources for surveillance and response activities.
- Support the monitoring and evaluation of AMR and AMU surveillance systems.
- Provide logistical support for annual international AMR reporting.
- Support capacity building (training, equipment, etc.).

9. Legal Framework and Resource Mobilization

To implement the integrated AMR surveillance strategy effectively and efficiently, political will, supportive legislation, and coordination are required. The existing regulatory framework on antimicrobials must be strengthened. In this light, this integrated AMR surveillance strategy is one of the activities outlined within the National Action Plan on AMR). In addition, there are other existing laws within the food, agriculture, and environment sectors that are current while others are obsolete.

1. Legislation for regulation of quality, safety, and efficacy of antimicrobials (LMHRA 2010 Acts; NSTG, EML, NF 2017; Liberia Public Health Law 2019)

2. Existence of regulatory bodies for medical products and professional conduct (LPB, LMHRA, LDMC)

3. System in place for QC of antimicrobial agents and supply chain (LMHRA ACTS 2010, Supply Chain Master Plan 2015)
4. Existence of policy guidelines for management and optimal use of antimicrobial agents (NSTG, EML NF)
5. Establishment of multi-disciplinary structure for Antimicrobial Resistance (AMR TWG) and existence of the One Health Governance Manual, 2021, National Action Plan for Health Security (NAPHS), 2021 and AMR National Action Plan (NAP), 2018

Validation Participants

Table 8. Participants involved in the validation of the Integrated AMR Surveillance Strategy

	Name	Position	Institution
1	Eddie Miaway Farngalo	Consultant	Consultant
2	William Walker	Laboratory Technician/AMR Focal Person	Phebe Hospital
3	Esther N. Woiwor	Head Pharmacist	C. H. Rennie Hospital
4	Emmanuel Sonkarlay	Laboratory Technician	G. W. Harley Hospital
5	Menom P. Z. Dunah	CEO	Liberia Pharmacy Board
6	Flomoku Miller	Technical Advisor	LMHRA
7	Saybah Manyango	AMR Focal Person	MOH/Pharmacy Unit
9	Timothy S. Kollie	Hospital Pharmacist	Phebe Hospital
10	Diana Gahn-Smith	One Health/AMR Specialist	UNFAO
11	Oliver Jeh	Communication Specialist	PIU
12	Watta Anthony	Director, Central Veterinary Laboratory	MOA
13	Levi Piah	One Health Focal Person	EPA
15	Patrick Stepney	AMR Data Manager	MOA
16	Ralph Jetoh	Director, Division of Infectious Disease Epidemiology (DIDE)	DIDE/NPHIL
17	Godwina Williams	Epidemiologist	DIDE/NPHIL
18	T. Henry Kohar, Sr.	Director	MOH/NDD
19	Dr. Jonathan N. Kpaka	Deputy Director	MOH/NDD
20	Romel Fahnbulleh	Inspector	EPA
	Partners		
21	Moses Bolongei	Health Systems Strengthening Officer	WHO
22	Vera Weah	SBCC Specialist	AFROHUN
23	Ellen Munemo	Country Team Lead	USAID/IDDS
24	Augustin Koryon	Technical Advisor	GIZ
25	Mohamed Jawara	Finance and Operations Manager	USAID/IDDS
26	Musu Goll	Administration Assistant	USAID/IDDS

27	Jeremiah Kyne	Programme Officer	Breakthrough Action

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