The Fleming Fund

UKaid
from the British people

Strengthening AMR surveillance systems in low- and middle-income countries: A Change Story (2018–2022)

Established in 2016 by the UK government, the Fleming Fund (a grants programme) supports surveillance of antimicrobial resistance (AMR) in low and middle-income countries in Africa and Asia to monitor, track and analyse national AMR data –promoting a One Health approach spanning human, animal and environmental sectors.

This report was written by **Toby Leslie**, **Martine Donoghue**, **Jake Wildfire** and **Sheilla Onasanya at Mott MacDonald, the Fleming Fund Management Agent.**

Contents

Glossary of terms, abbreviations and acronyms

AH	Animal Health
AMC	Antimicrobial Consumption
AMR	Antimicrobial Resistance
AMRCCs	Antimicrobial Coordination Committees
AMU	Antimicrobial Use
ANIMUSE	Animal antimicrobial use collects data from veterinary services worldwide, providing insights into trends in antimicrobial consumption.
AST	Antimicrobial Susceptibility Testing – laboratory method used to determine the effectiveness of antibiotics against bacteria.
Burden (of Disease)	The impact of a health problem on a given population, and can be measured using a variety of indicators such as mortality, morbidity or financial cost.
EAR	Estimated Average Requirement
EGASP	Enhanced Gonococcal Antimicrobial Surveillance Programme
FAO	Food and Agriculture Organization
GAP	Global Action Plan
GLASS	Global Antimicrobial Resistance and Use Surveillance System
GLASS-FUNGI	Focuses on antimicrobial resistance surveillance for invasive fungal infections, particularly those caused by Candida species.
HH	Human health
IEC	Information, Education and Communication
InFarm	International FAO Antimicrobial Resistance Monitoring is an information system platform that supports countries to collect, analyse and use their AMR data from animals and food at the national level for global AMR surveillance.
IPC	Infection Prevention and Control
LMICs	Low- and Middle-Income Countries
LSHTM	London School of Tropical Medicine
NAP	National Action Plan
OIE	Office International des Epizooties - the original name of the World Organisation for Animal Health.
One Health	Integrated, unifying approach to sustainably balance and optimise the health of people, animals and ecosystems, recognising that the health of humans, domestic and wild animals, plants, and the wider environment (including ecosystems) are closely linked and interdependent.
PPS	Point Prevalence Survey
Tripartite	The collaboration between three major international organizations; World Health Organization, Food and Agriculture Organization, World Organisation for Animal Health. This Tri-partite partnership focuses on One Health – integrating human, animal, and environmental health to combat issues like zoonotic diseases, AMR, and food safety.
TWG	Technical Working Groups: National multi-disciplinary professionals who provide technical support and advice to AMRCCs.
UN	United Nations
UNEP	United Nations Environment Programme
WASH	Water, Sanitation, and Hygiene
WHO	World Health Organization
WOAH	World Organisation for Animal Health

Introduction

This report describes the development of AMR surveillance systems in 20 low- and middle-income countries (LMICs) from 2018 to 2022. Changes described relate to support provided by the UK Department of Health and Social Care's Fleming Fund programme, which consists of a portfolio of Country, Regional and Fellowship grants, overseen by the Fleming Fund Management Agent (Mott MacDonald).

The Fleming Fund provides grants to support all levels of AMR surveillance systems in supported countries. Surveillance sites (or laboratories) are primary building blocks in surveillance systems. They provide diagnostic services for human and animal health, generating quality surveillance data (or evidence) upon which higher-level decisions and actions can be based.

Without a network of high-quality diagnostic laboratories, a surveillance system for AMR does not meet the requirements of a functional system; with any data produced seen as suspect. The strengthening of a laboratory's ability to deliver high-quality bacterial cultures and perform antibiotic resistance tests is crucial for generating usable data to support improved care and the planning of AMR mitigation measures.

We describe here a 'story of change' at the surveillance site level in LMICs that received Fleming Fund support. In telling this story of change, we examine the rationale and need for AMR surveillance systems, what needed to change in LMICs for establishing and/or strengthening AMR surveillance systems, and what changes occurred over the period 2018-2022 in Fleming Fund-supported surveillance sites.

The Fleming Fund was created in late 2016 and designed throughout 2016, with 2017 dedicated to the onboarding of participating countries, grant implementers, and piloting. The period 2018 to 2022 was the first implementation phase of the Fleming Fund, moving into phase 2 from 2023. The changes reported here refer to the achievements made during phase 1. Building and strengthening quality and reliable AMR surveillance systems in LMICs takes time. This change story continues into phase 2 (2023 to the present), drawing upon lessons learnt from phase 1. Over 100 grantees, government decision-makers, and health professionals are actively engaged in delivering the programme and should be duly recognised for their energy and commitment.

The global need for AMR surveillance data

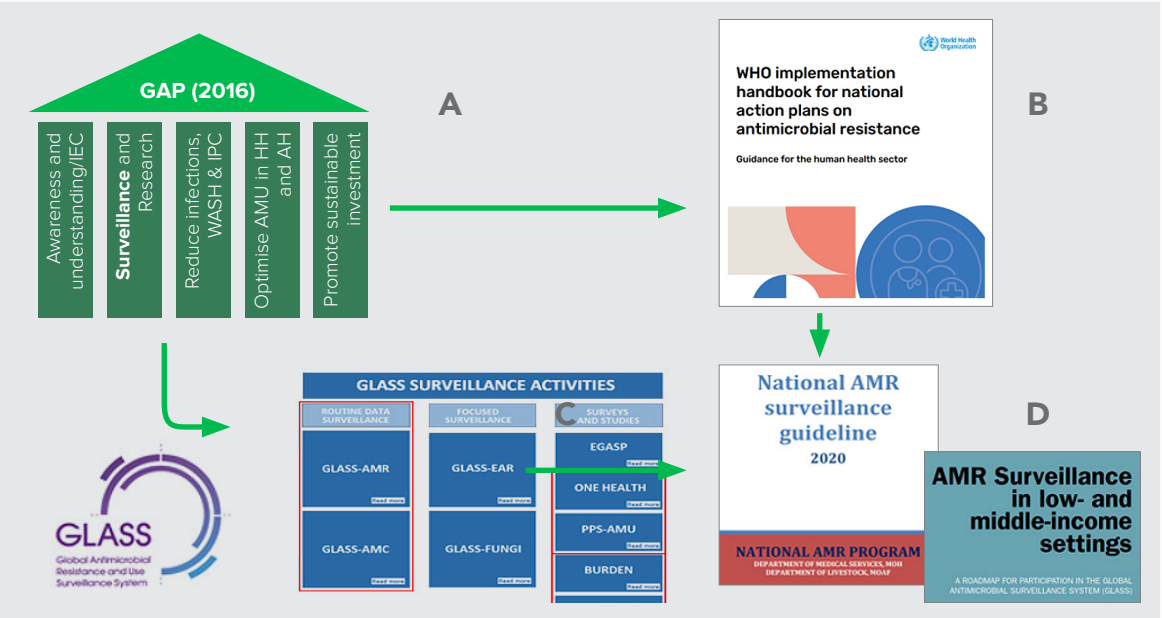
In 2015, the United Nations General Assembly approved a resolution to act against AMR. The strengthening of capacity across the world, especially in low- and middle-income countries, was central to that resolution.

The resolution highlighted the need to strengthen the capabilities of LMICs to recognise and act against the AMR threat by improving surveillance across the One Health disciplines of human, animal and environmental health. Up to this point, there was very limited usable data from public health systems in LMICs, and even less from agricultural/animal health and environment sectors.

By 2016, two important pieces of progress were made:

- The Global Action Plan (GAP) for AMR was published, which set an ambitious plan to begin to address the global issue of AMR.
- The Fleming Fund began its inception phase, planning to support the development and strengthening of AMR surveillance in up to 24 LMICs in sub-Saharan Africa, and South and South East Asia.

Figure 1: Global landmark developments for AMR surveillance



Box 1: Global landmark developments for AMR surveillance

(A) The GAP set out five pillars for global action, which act as organising principles for the development of national action plans (signified by B).

In turn, the World Health Organisation (WHO) produced a framework for the Global Antimicrobial Resistance Surveillance System – GLASS (C).

GLASS[1] provides a blueprint for countries to develop and improve surveillance of AMR in an in-patient setting, as well as undertake measurement of antimicrobial usage (i.e. GLASS-AMR and GLASS-AMC; GLASS-PPS). Subsequently, the GLASS One Health module[2] was released, alongside a module intended to improve measurement of the burden of diseases in drug-resistant infections (GLASS-Burden).

These were released alongside guidance from UN Tripartite counterparts (now a Quadripartite since 2022),[3] namely the UN Food and Agriculture Organization (FAO) [4]; the UN World Organisation for Animal Health (WOAH, formerly known as the Office International des Epizooties – OIE)[5]; WHO, and later, the UN Environment Programme (UNEP)[6].

(D): WHO member states have committed to producing and submitting data from the human health sector into GLASS to provide a higher volume of quality-assured data from a wide range of countries and clinical settings. WOAH also launched a global database of antibiotic usage in animals (ANIMUSE)[7].

1. **World Health Organization, 2016: GLASS manual for antimicrobial resistance surveillance in common bacteria causing human infection.**
2. **World Health Organization, 2016: WHO integrated global surveillance on ESBL-producing E. coli using a 'One Health' approach: implementation and opportunities.**
3. **Quadripartite Joint Secretariat on AMR.**
4. **Food and Agriculture Organization, 2016: The FAO Action Plan on Antimicrobial Resistance 2016-2020.**
5. **World Organisation for Animal Health, 2016. Strategy on antimicrobial resistance and prudent use of antimicrobials.**
6. **UN Environment Programme, 2023: Bracing for Superbugs: Strengthening environmental action in the One Health response to antimicrobial resistance.**
7. **ANIMUSE.**

The first GLASS report (2017) showed limited input from LMICs, both in terms of the number of countries reporting, and where countries did report, a limited number of sites (hospitals) producing data, with a limited repertoire of pathogens and drugs (drug/bug combinations) that they could report on.

In addition, there was a serious shortfall in the availability of blood-culture services, resulting from long-term neglect and underinvestment in laboratory services, a lack of demand for testing among practitioners, and insufficient human resource capacity to implement. These were all areas that the Fleming Fund subsequently targeted via its support to participating countries.

The Fleming Fund focuses on AMR surveillance systems strengthening i.e. one of the five pillars or thematic areas addressed by the GAP. Surveillance data is a powerful source of intelligence to inform decisions about evidence-based policy formulation and regulation, at international, national, and sub-national levels. It is most valuable in the human health sector at the level of patient-centred care, to inform clinical decisions, and save lives. This is achieved by both strengthening diagnostic services for individual patients, and by collecting data to give a broader overview of local, regional and national levels of drug resistance and use.
A similar set of advantages applies to animal care and veterinary services as well; these are more focused on animal husbandry, specifically in reducing the overreliance on antibiotics in farming.

Surveillance data serves to inform effective treatment and control guidelines by directly informing policymaking and regulation. Policymaking and regulatory decisions tend to be political in nature and influenced by many factors, not just data generated from a surveillance system. Nevertheless, surveillance data remains invaluable for patient care and for data-led decisions at all levels, including beyond national boundaries, to safeguard global health security.

Establishing AMR surveillance systems in LMICs

Surveillance systems strengthening and Fleming Fund programme logic

In 2017, the UK government launched the Fleming Fund programme, designed to support LMICs to improve and develop national surveillance systems to provide quality-assured data for use in policy and practice.

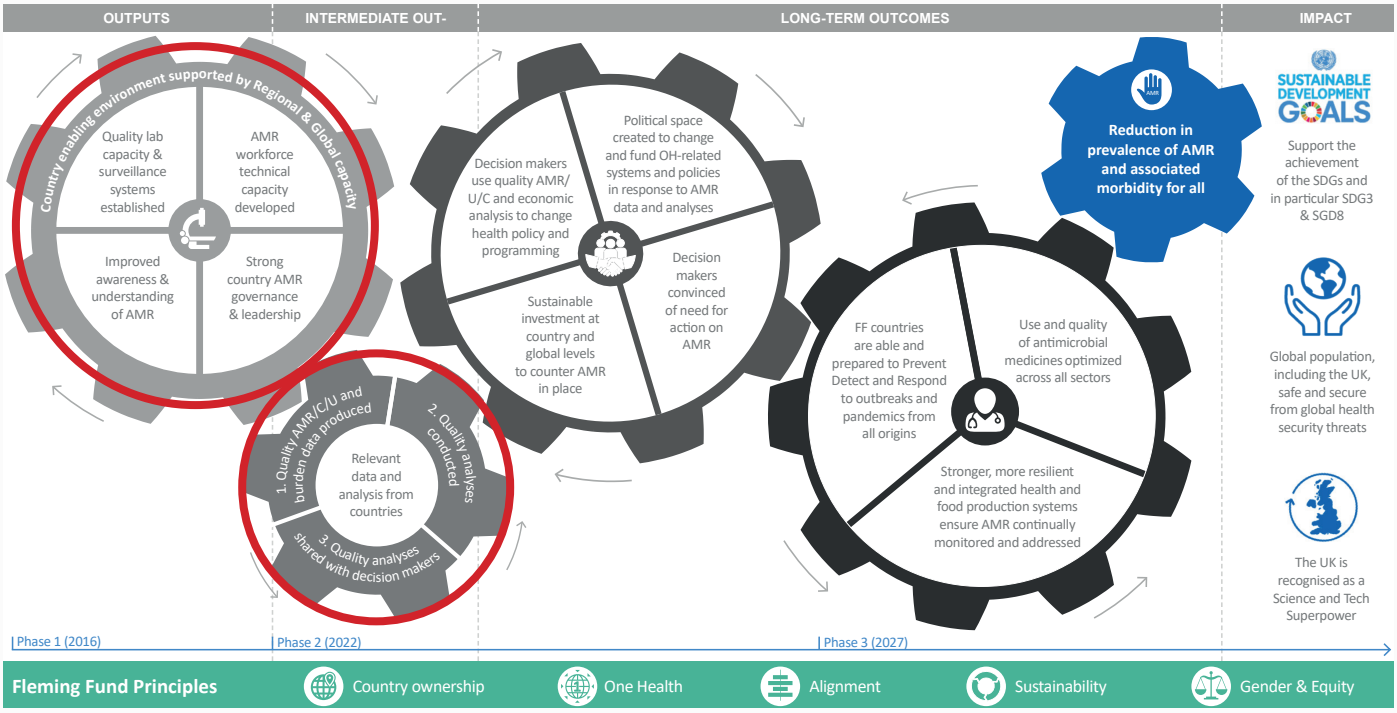
The programme design was intended to support the implementation of country-level National Action Plans (refer to Figure 1-B) related to surveillance strengthening and supporting the roll-out of the Global Action Plan in LMIC countries, which would not have been able to finance the initiative otherwise.

The programme aimed to strengthen the capabilities of countries to generate and use quality bacteriology data across sectors (i.e. human and animal health primarily, more limited for environment and food safety), and to make that data available for decision-makers at all levels – practitioners (clinicians and veterinary practitioners, etc), managers, and policymakers.

Figure 2 illustrates the Fleming Fund's Theory of Change. Programme efforts from 2018 to 2022 were focused on achieving results up to and including all sought Intermediate Outcomes. Grants (see sub-section 2.2) and programme delivery were tightly defined by and aligned with programme purpose and logic. Fleming Fund principles (see horizontal bar at the bottom of the diagram) are hallmark features underpinning programme implementation. Many of these principles are also well recognised in terms of best practice for aid effectiveness. The Theory of Change extends beyond phase 1 and situates Fleming Fund support within the broader perspective of what impact the programme seeks to achieve.

To generate **relevant AMR surveillance data (quantity and quality) and analyses from countries,** there was a need to strengthen laboratory capacity and systems; train the workforce; and empower national AMR leadership within well-supported governance structures.

Figure 2: Fleming Fund Theory of Change



*Red rings denote the focus areas for phase 1

The basic function of any surveillance system is to produce, analyse and share high-quality data for use in decision-making. The skills and infrastructure required to undertake even the least complex components of AMR surveillance are significant; a basic bacteriology laboratory requires specialist training and skills, equipment, environmental controls, biosafety and biosecurity standards, and oversight from a skilled reference laboratory. Underpinning this is the basic requirement for the availability of clean running water and steady electricity, which is often missing from LMIC laboratories.

The provision and function of AMR surveillance systems in LMICs are circumscribed by comparatively weak health systems, where multiple priorities compete for limited budgets. Within these health systems, there is widespread reliance on empirical treatment with antibiotics in the absence of a good-quality diagnosis of bacterial infections. This promotes a negative spiral, resulting in a lack of demand for laboratory services (because of weak quality), a low or absent yield of AMR data in general, with data gaps

for evidence-based policy and practice. Ultimately, the lack of data drives the emergence and spread of AMR by embedding a reliance on empirical treatment. Complementary data is also required to track the use and consumption of antibiotics in human and animal health. Providing data and evidence to support positive interventions to address and 'break' the negative spiral is core to the Fleming Fund.

Fleming Fund investments

The first phase (2017-2022) of the Fleming Fund comprised a combination of funding streams to support countries in implementing surveillance in line with their National Action Plans. The three main grant types were:

Country Grants: These grants comprised the majority (~75%) of allocated funds. Country Grants were designed with government counterparts in their national AMR Coordination Committees (AMRCC), and relevant Technical Working Groups, and aligned with the NAP, following an extensive process to assess needs. Country grantees (i.e. organisations responsible for implementing country grants) were appointed after a competitive tendering process, against Terms of Reference designed to meet country needs. Country grants supported governance structures (AMRCCs); laboratory renovation and equipping; AMR surveillance system strengthening (e.g. sample transport, waste management), training and human resource development.

Regional Grants: These grants were designed to provide specialist technical support to countries for expertise best delivered via a multi-country (regional) approach. These grants addressed inputs and services such as quality assurance support, advanced training, regional data collection exercises, gene sequencing, and working at the evidence/policy interface.

Fleming Fellowships: These were delivered by 'Host Institutions'[1] to provide medium-term professional development to a cohort of between 10-12 fellows per country. Fellows were invited to apply to the scheme and were individuals who worked within the national surveillance structure. Fellowships were typically 18 months long (although some were shorter). They covered topics across the One Health sectors, encompassing human health, animal health and environmental health. They provided training and mentorship in microbiology, surveillance and epidemiology, and antimicrobial use surveillance. 'Policy fellows' were a cadre of fellowships added mid-way through phase 1 to support the improved use of AMR data for policy purposes. The Fellowships constituted a strong component of the programme's approach to AMR human resource strengthening and sustainability. However, higher volume training and workforce strengthening were also undertaken by country and regional grantees.

The Fleming Fund grants programme also had a central procurement component, which was considered important for providing significant savings on equipment purchasing by enabling the central negotiation of pricing, maintenance contracts, and equipment delivery and installation. The purchase of maintenance and service block contracts ensured that equipment (blood culture instruments, automated antibiotic sensitivity testing, and mass-spectrometry instruments) was continually functioning.

[1] Host Institutions is a term used by the Fleming Fund programme to refer to a group of cutting edge academic and research institutions, with AMR technical expertise and institutional capacity to deliver AMR fellowships across One Health sectors.

What needed to change?

Guidance on establishing AMR surveillance systems in LMIC settings was scant. In 2015, a protocol[2] was commissioned by the UK government and developed by the London School of Hygiene and Tropical Medicine (LSHTM) to establish a standardised roadmap for developing comprehensive and quality-assured AMR surveillance systems. It addressed the guidance gap by providing a tiered framework for AMR surveillance systems and laboratory functions specifically for use in low- or middle-income country settings.

This protocol (also referred to as the LSHTM roadmap) subsequently guided Fleming Fund interventions for the strengthening of sentinel sites and reference laboratories. It recognised challenges facing LMICs and provided guidelines aligned with the WHO Global Antimicrobial Resistance and Use Surveillance System (GLASS) procedures. The Fleming Fund programme adopted this roadmap for classifying and charting the progress of supported sites over time (i.e. tracking how sites changed in features and function with investment, according to the framework's classification system).

The roadmap, when effectively implemented, provides valid comparable data on AMR and standardised approaches to laboratory features and function, and how data is used. It sets out standard laboratory capabilities or features across three tiers of development. These tiers are: 'core', 'extended' and 'advanced' levels, as applicable to providing standard diagnostic services for bloodstream infections and producing *passive*[3] surveillance data in the human health system (e.g. a hospital setting).

For the animal or environmental sectors' active surveillance[4], an equivalent roadmap was developed by Mott MacDonald during the early stages of the programme to guide investments in the animal health sector. The roadmap for animal health focused on surveillance data and collection from poultry production systems, as these are deemed common across different country settings but can be readily applied to other animal and aquatic species.

Ideally, an AMR surveillance system should be able to:

Collect and test samples: Across the One Health sectors, surveillance system laboratories should have the capacity to safely collect human, animal and environmental samples for bacterial culture, identification of species, and drug sensitivity testing against relevant antibiotics. Advanced testing should be available at national reference laboratories, for example, confirmatory testing of isolates to confirm species or resistance profile; molecular tests that identify specific antibiotic resistance genes; or whole genome sequencing, which can be used to identify similarities (and differences) between isolates collected from different places, species and/or times (e.g. for outbreak source identification).

Analyse and quality assure test results: Results of tests should be quality assured and disaggregated by type of sample (e.g. blood, urine, cloacal), gender (in humans), animal species, clinical syndrome (e.g. sepsis, urinary tract infection), and infectious agent (e.g. Staphylococcus aureus). These are outlined in the relevant international data reporting guidelines (GLASS[5], InFARM[6]).

Share and use quality surveillance data: Quality-assured results should also be made available to practitioners (e.g. doctors, veterinarians, pharmacists) promptly, supporting critical clinical decision-making. These data can also inform evidence-based interventions at local, national, and international levels by providing information on the types of circulating pathogens and resistance patterns. For the data to be useful, it needs to be tailored for the intended audience's use. Ideally, the data should be actionable – for example, identifying an outbreak of drug-resistant hospital-acquired infections, or driving changes in treatment practices and guidelines (in both animals and humans).

Phase 1 of the Fleming Fund focused specifically on building systems that could fulfil these functions safely and to an appropriate standard. The extent to which the Fleming Fund supported change in countries, and sites to produce, analyse and share quality AMR surveillance data is described in the following sections.

[2] AMR Surveillance in Low – and Middle Income – Settings: A Roadmap for Participation in the Global Antimicrobial Surveillance System (GLASS); London School of Hygiene & Tropical Medicine; UK Government Fleming Fund publication. 2016.

[3] Passive surveillance occurs where patients or animals are tested based on clinical presentation at health or veterinary facilities.

[4] Active surveillance occurs where samples are actively collected from individual animals or humans using a survey design (cross-sectional survey), which is based on hypothesis testing / sample size calculations

[5] GLASS provides a framework for countries to collect, analyse, interpret, and share data on human antimicrobial resistance (AMR) surveillance.

[6] InFARM is a global information system designed to support countries in generating, collecting, collating, analysing, and effectively utilising antimicrobial resistance (AMR) surveillance and monitoring data related to animals and food

The change context

Number and type of countries

Initially, the Fleming Fund sought to support AMR surveillance in 24 priority countries. Two of these countries were discontinued due to political/security concerns. Of the remaining 22 countries, an analysis of their AMR surveillance systems was undertaken using a variety of information sources and methods, including country visits and desk-based literature reviews. Drawing upon these reviews, countries were classified by applying a scale of maturity to their AMR national action plans and surveillance systems. This guided countries' approaches to ensure proposed interventions matched the starting points for the respective countries. This typology *(Table 1)* was used to benchmark Fleming Fund-supported country progress over time and is referred to again later in this change story review.

Table 1: Fleming Fund classification for supported countries

Category	Country description: National Action Plan and AMR surveillance status
A	**Countries with no National Action Plan (NAP):** These were countries without a NAP in process, or where a NAP was underway, or not finalised. These countries also tended to lack a functional national coordination committee; may not have had a situation analysis; and some may not have been engaging with the AMR issue. These types of countries were not favoured for Fleming Fund investment.
B	**Countries with a NAP but no surveillance system in operation:** These countries had received support from the UN Tripartite (now Quadripartite) Alliance (or others) to develop a NAP or had developed a response to AMR on paper. There was national recognition that an AMR surveillance system needed to be developed, and a plan for doing so, or a plan was well advanced. Little or no progress had been made with implementation, largely due to resource constraints, rather than the absence of political will. These countries were targeted for most of the investment via Fleming Fund grants (including the Fellowship scheme).
C	**Countries where modest AMR surveillance was already established, but gaps need to be filled, and activities need to be connected:** These countries had some form of surveillance system in place, but that system was solely or predominantly in human health, small-scale, and likely to be fragmented. There were other significant constraints, such as poor-quality assurance, lack of capacity to analyse data and/or weak laboratory capacity, and/or sustainability issues. Moreover, there were weak connections between sectors for One Health approaches.
D	**Countries which were relatively more advanced and would benefit from nuanced support and/or could be supported to do more with One Health approaches:** These countries had a surveillance system (some, including animal health), which was relatively well established or likely to be well established with current donor support. Investment was likely to be additional and aligned with the actions of other donors, and/or the national government, seeking to add value.

In 2017, of the 22 countries earmarked for Fleming Fund support, one country was classified Category A; 15 countries were classified Category B; 4 countries were classified Category C; and two countries were classified Category D. Of these, a further two countries were dropped because necessary authorisation for grants to progress was not secured. This means 20 countries were supported throughout phase 1 *(Table 2)*.

Table 2: 20 countries supported by the Fleming Fund during phase 1

Phase 1 supported countries by region

	West Africa	East & Southern Africa	South Asia	South-East Asia	Total
	Ghana	Eswatini	Bhutan	Indonesia	
	Nigeria	Kenya	Nepal	Laos	
	Senegal	Malawi	India	Papua New Guinea	
	Sierra Leone	Tanzania	Pakistan	Timor Leste	
		Uganda		Vietnam	
		Zambia			
		Zimbabwe			
Total	4	7	4	5	**20**

In addition, there were gaps in country grant coverage in two out of the 20 countries during phase 1. For one country, this spanned 2021–2022; for the other country, this was from mid-2022 to the end of 2023 (*i.e. into phase 2*). These coverage gaps were due to re-programming and re-tendering of grantees. Some data is available for these two countries and is included in the analysis where available.

Surveillance sites: number and type

By the end of phase 1 (end of 2022), there were **279 laboratories** under the support of the Fleming Fund across 20 countries.

Table 3: Fleming Fund-supported sites across regions

Region (# countries)	WA(4)	ESA (7)	SA (4)	SEA (5)	All (20)	% of total
Human health	28	54	37	58	**177**	**63**
Reference laboratory	6	8	5	6	25	
Surveillance site	22	46	32	52	152	
Animal health	11	32	26	23	**92**	**33**
Reference laboratory	3	6	6	5	20	
Surveillance site	8	26	20	18	72	
Other	2	4	3	1	**10**	**4**
Aquaculture	1	0	1	1	3	
Environment	0	2	0	0	2	
Food safety	1	2	2	0	5	
Total	**41 (15%)**	**90 (32%)**	**66 (24%)**	**82 (29%)**	**279 (100%)**	**(100%)**

Key: WA = West Africa; ESA = East & Southern Africa; SA = South Asia; SEA=South-East Asia

In a typical country, there was an average of one or two human health national reference laboratories [7]; seven or eight human health surveillance sites (hospital laboratories); one animal health national reference laboratory, alongside an average of four field veterinary/animal health laboratories. Figure 3 shows the spread of sites by sector type across supported countries.

Figure 3: Geographic representation of Fleming Fund-supported sites

At the beginning of a country grant, each surveillance site was assessed in detail for renovation, improvement in utilities (water, electricity), equipment and training requirements. The process of assessing, renovating and equipping the laboratories typically took 9-15 months in most countries. Capacity strengthening of the human and animal health workforce took place in parallel.

[7] Reference Laboratories are the apex laboratories at national level and provide quality assurance and control services, reference diagnostic services and usually play a role in training and human resource development. In most instances they are officially nominated as reference laboratories by national authorities.

What changed for surveillance sites from the Fleming Fund investment?

In this section, the type and extent of change for Fleming Fund-supported sites are now examined. We describe changes at the site level over five years (2018–2022) across five areas central to strengthening AMR surveillance in countries: laboratory infrastructure; human resource strengthening; increases in the quantity and quality of AMR data; data use; and laboratory systems and processes. We conclude with an analysis of changes to the country classification at the end of the programme versus the beginning (see section 4.1).

To examine the nature and extent of change over time at the site level, a retrospective analysis was conducted using routine programme data provided by sites from 2018 up to the end of 2022.

Programme data in this context refers to routine monitoring data submitted by country grantees (including some regional grantees). For these analyses, laboratory/site data constituted the main data source. In many instances, the change or change trajectory was examined by compiling time plots for variables, indicators, scores, and/or numbers over time.

Improved laboratory infrastructure

175
Sites

Laboratory equipment supplied to **175 sentinel sites** to improve microbiology testing and diagnostics

About **50%** of all supported sentinel sites required some level of refurbishment

Following laboratory assessments, one of the first steps was to equip and refurbish laboratories to deliver microbiology services safely. Figure 4 shows a 'before' versus 'after' example of refurbishment undertaken in one laboratory. Infrastructure repair was commonly required to provide essential and safe working conditions before focusing on AMR data production.

Based upon laboratory assessment (which included understanding the type of service a laboratory needed to provide), centrally procured items of necessary equipment were provided. Items included automated blood culture capabilities (human health sites), antibiotic sensitivity testing platforms and spectrophotometry, determined by what was considered appropriate for the laboratory needs and function. A total of 175 sites were supplied with necessary equipment *(Table 5)* and service agreements. Table 5 shows essential equipment installed to strengthen the bacteriology testing capacity of supported sites.

Figure 4: An example of a microbiology lab renovation

Table 5: Number of central laboratory equipment supplied by region

	Region	ESA	SA	SEA	WA	All
Equipment	AST Platform	9	9	12	5	35
	Blood Culture	40			14	54
	Blood Culture system		16	27		43
	ID/AST	10			4	14
	MALDI-TOF MS	8	9	9	3	29
	Total	**67**	**34**	**48**	**26**	**175**

Key: WA = West Africa; ESA = East & Southern Africa; SA = South Asia; SEA=South-East Asia

Items were delivered and installed by certified suppliers. Overall, 175 sites received laboratory instruments from 2020–2022.

Aside from instruments purchased centrally, sites were also upgraded with the procurement of other standard equipment required to run a laboratory safely and effectively (e.g. freezers, incubators, biosafety cabinets). A comprehensive catalogue of reagents and media, glassware, and other laboratory items was developed. These items are required for a bacteriology laboratory to function as per the LSHTM roadmap.

Combined with the programme of renovation and infrastructure improvement, this resulted in significant improvements at the laboratory level. For example, working automated blood culture systems were

established, with the ability to store isolates on-site (Table 6).

Table 6: Proportional distribution of laboratory equipment by region

Proportion of laboratories equipped with a working automated blood culture system		
	Start (phase 1)	**End (phase 1)**
All regions	**39.2%**	**82.9%**
West Africa	50.0%	64.3%
East & Southern Africa	26.4%	90.6%
South Asia	51.4%	72.2%
South-East Asia	37.9%	91.4%
Proportion of human health sites able to store resistant isolates on-site		
All regions	**38.6%**	**72.6%**
West Africa	53.6%	85.7%
East & Southern Africa	30.2%	90.6%
South Asia	29.7%	30.6%
South-East Asia	44.8%	75.9%
Proportion of animal health sites able to store resistant isolates on-site		
All regions	**41.6%**	**80.2%**
West Africa	69.2%	92.3%
East & Southern Africa	42.9%	91.4%
South Asia	31.0%	65.5%
South-East Asia	37.5%	75.0%

A stronger AMR workforce

25,452

Training attendances completed

Over **25,000 training attendances** covering essential AMR areas were completed.

181 Fellowships were completed.

Workforce development was a core Fleming Fund contribution to countries for strengthening AMR surveillance during this period. This happened via three main modalities:

Training: AMR-related training was delivered by country and regional grants on a wide range of topics, for different cadres of staff, relevant to surveillance function and performance.

Fellowships: Fellowships provided professional development and mentorship to develop AMR leaders and champions at the country level. Fellows had dedicated mentorship from leading international institutions (Host Institutions), with proven track records and expertise in AMR.

Available online materials: An open platform of AMR learning material was developed and made globally accessible by the Management Agents partnership with the Open University.

Training and capacity strengthening

One of the key results areas outlined in the Theory of Change is the development of AMR technical workforce capacity. The programme invested extensively in training and fellowships to build the capacity of key personnel required to strengthen AMR surveillance across supported countries. Put simply, quality surveillance data cannot be produced, analysed or used without a trained workforce.

Country Grants delivered workforce training across topics, such as microbiology, surveillance and epidemiology, practitioner training (clinicians, vets, pharmacists), data management, sharing and use. Country grantees have also coordinated with suppliers of laboratory equipment to provide specific training for operating blood culture, automated AST and spectrophotometry.

Regional Grants provided more technically advanced training, working across multiple countries, but with smaller numbers trained in each country for more specialist topics. For example, not everyone in the system needs to learn about developing and managing a quality assurance system, which is a role of National Reference Laboratories. The approach was tailored to target and address needs for more advanced levels of training across specialist technical topics, including quality assurance: whole genome sequencing and other molecular methods, policy and policy analysis, epidemiology, and further specialist subjects.

Overall, more than 25,000 training attendances were completed across a range of subject areas *(Table 7)*. About two-thirds were in the human health sector, with the remainder in the animal health sector (and other One Health sectors). Most training attendances have been for microbiology (including a range of sub-category topics) and practitioner engagement.

The West Africa region had the lowest number of training attendances, reflecting both the lower number of supported countries, size of the programme in those countries, and the baseline capabilities in the region, i.e. training tended to focus on elemental subjects like basic bacteriology, rather than more advanced methods. In addition, there were significant breaks in grant coverage in two countries (mentioned previously) in this region.

Table 5: Number of central laboratory equipment supplied by region

Region	WA	ESA	SA	SEA	Total
Sector					
Human health	1,323	4,122	5,700	5,482	**16,627**
Animal health	496	2,958	2,392	2,979	**8,825**
Subject					
Microbiology and laboratory	942	2,997	2,454	3,798	**10,191**
Surveillance and epidemiology	62	263	101	327	**753**
AMR training for practitioners (e.g. clinicians, vets)	228	1,255	3,892	1,957	**7,332**
Data collection, management and analysis	274	1,696	1,211	1,387	**4,568**
Data sharing and use*	7	752	211	488	**1,458**
Other**	306	117	223	504	**1,150**
Total	**1,819**	**7,080**	**8,092**	**8,461**	**25,452**

Key: WA = West Africa; ESA=East & Southern Africa; SA = South Asia; SEA = South-East Asia.
Note:
* This number is low because training occurred in only one country. As mentioned, grants were interrupted in two countries for a significant time.
**Others include ISO training, field workshops for farmers, import of antibiotics, bioinformatics, etc.
Training attendances refer to instances of individuals attending training; it does not refer to the number of people trained. The same individual may have attended several different trainings

Fleming Fellowship Scheme

In 2018, the Fleming Fund introduced a Fellowship Scheme targeting professionals within key institutions across the human, animal, and environmental health sectors. This initiative sought to strengthen human resources and foster workforce development by enhancing the professional growth of practitioners and influencers within the antimicrobial resistance workforce.

The scheme encouraged peer-to-peer learning, strong One Health Communities of Practice, and communication within the highest levels of government to influence AMR policies. Fellows were selected via a competitive process from within public government institutions (termed Beneficiary Institutions) to build national capacity in response to AMR. Funding was allocated to Host Institutions to work with a cohort of fellows (up to 14) in each country. A total of 212 applications were received for fellowships, out of which **181** completed the programme *(Table 8)*.

Table 8: Breakdown of available versus completed Fleming Fellowships

Fellowships completed	181
Fellowships advertised but not appointed*	23
Fellowships postponed	2
Resignations	6
Total	**212**
Fellowships available	**214**

The Fellowship Scheme was tailored to individual needs, county-focused, and part-time, with long-term mentorship provided to support the professional development of practitioners and policy makers. Fellowships were typically 18 months in duration (though some were shorter), and Fellows continued to work in their routine jobs alongside their fellowship participation. This was a demanding formula, and fellows demonstrated huge commitment to learning and growth, both at the personal and institutional levels.

There were two categories of fellowships, with individual learning objectives captured in workplans:

Professional Fellows (87% of completed fellowships): These were the bigger group in terms of numbers and sub-type of professional fellows. These fellows were expected to develop core skills required to generate, disseminate, and use country-level data on AMR and antimicrobial use.

Policy Fellows (13% of completed fellowships): These were expected to provide leadership and champion AMR data use, i.e. building institutional and political awareness and demand for evidence for use in policy and decision making. They were often already established senior leaders at the country level.

Table 9 provides a breakdown of fellowships with more details on the nature and distribution of professional fellows by type.

Table 9: Fellowship speciality areas

		Number of Fellows
Advocacy/Advisory/Policy	AMR	23
Antimicrobial Stewardship	AMS	2
Clinician/Practitioner	AMR	4
Health Economics/Informatics	AMR	3
Laboratory/LQMS/Bioinformatics/WGS	AMR	55
Surveillance	AMR	45
Surveillance	AMU/C	49
Total		**181**

Key: AMU = Antimicrobial Use; AMC = Antimicrobial Consumption

The Fleming Fellowships contribute to building sustainable AMR systems in LMICs. Fellows are supported by Host Institutions to lead and cascade training for peers and colleagues; actively participating in professional networks, conferences, and Communities of Practice.

It was reported that 67% of fellows reported an improvement in 80% or more of their competency areas compared to their baseline. For the remaining fellows, the majority were close to the 80% level of competency improvement. This is a personal competency change of notable proportions.

A **Legacy Review** of the phase 1 fellowship programme was completed and provides further insights into the longer-term reported benefits from participating in Fellowships. This includes strengthened technical capacity and leadership within the AMR One Health workforce; a contribution to quality standards within sentinel sites; national awareness and understanding of AMR; and strong country AMR governance and leadership.

The global AMR curriculum

In 2018, the Open University was commissioned to develop and implement a publicly available and free web-based curriculum on AMR. This training material was developed as a global public good to support practitioners in adapting, building expertise, and applying new skills and knowledge to change work practices and improve AMR data surveillance. The curriculum material is available in English and is available to the AMR global community. It will remain available beyond the Fleming Fund programme and continue to be a high-quality resource on AMR for all.

The curriculum consists of 25 modules, enabling the training of relevant professionals across a broad range of surveillance topics. There is also a toolkit that supports users in applying knowledge and skills to their workplaces.

From 2021 to the end of 2022, 9,506 users visited the website, with 2,352 enrolled across all modules. During this period and since then, there have been web visitors to the Open University resources from every Fleming Fund focus country, and almost every country in the world[10].

[10] Beyond phases 1, a recent Fleming Fund programme news article provides more recent information and statistics on curriculum access and use - https://www.flemingfund.org/publications/global-online-professional-development-programme-on-tackling-antimicrobial-resistance-relaunched/

Box 2: Examples of regional grants contribution to country-level progress during phase 1

Qualifying the Workforce for AMR Surveillance in Africa and Asia (QWArS):

The Qualifying the Workforce for AMR Surveillance grant, funded by the Fleming Fund and implemented by the African Society of Laboratory Medicine, has achieved significant milestones in enhancing antimicrobial resistance (AMR) surveillance in Fleming Fund countries in Africa and Asia.

The grant has trained over 330 laboratory and epidemiology professionals. The grant has also collaborated with professionals from 73 health institutions and 67 agriculture ministries across 17 countries, including engagement of experts from veterinary/animal health universities, government environmental health laboratories, and private sector laboratories.

Of the 330 professionals trained, a smaller cohort underwent advanced training and became master trainers/mentors and supervisors. Domestic subject matter experts were also drawn upon to facilitate and deliver training, too.

The grant is providing ongoing support to establish a framework for the continuous development of AMR professionals, ensuring sustainable practices beyond the project's timeframe.

Increased AMR data production

around **2M**

Samples processed

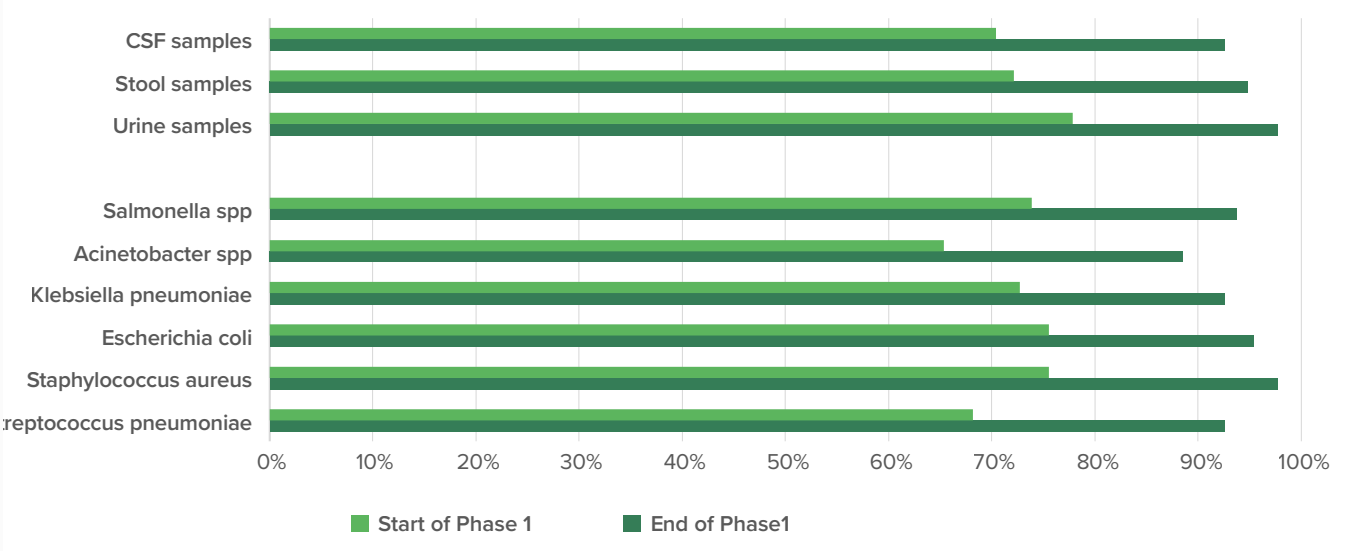
1,831,711 clinical samples from patients

178,454 samples from animals

AMR data production: sample types

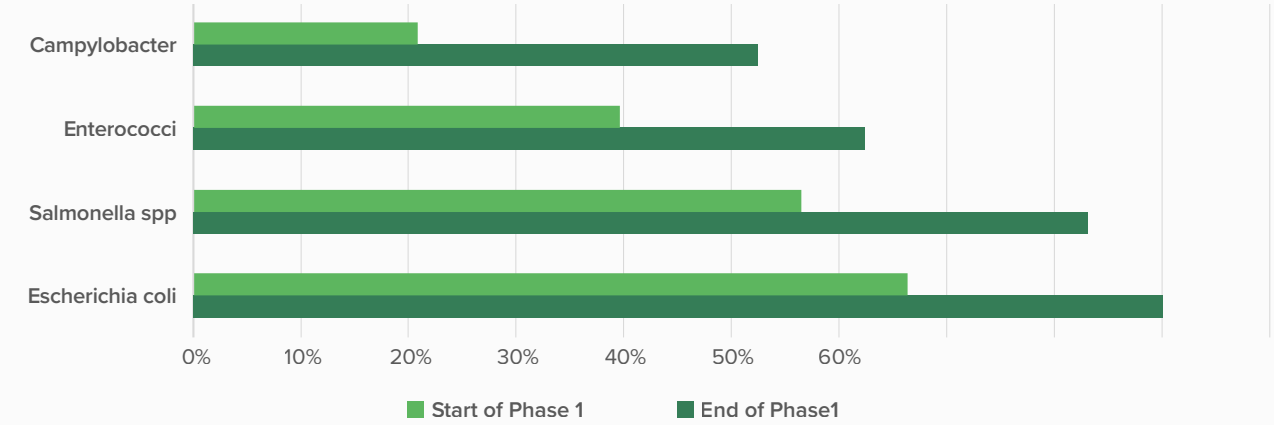
In phase 1, surveillance sites demonstrated incremental improvements in their ability to process different sample types, such as stool, urine and cerebrospinal fluid (CSF); and to undertake culture and drug sensitivity testing on a wider range of WHO-GLASS priority pathogens. Figure 5 shows a phase 1 baseline versus endline comparison of GLASS pathogen types tested by sentinel sites.

Figure 5: Percent of sites able to process human sample types and GLASS pathogens tested by sentinel sites



In the animal health sector, samples are taken predominantly from healthy animals using an active surveillance approach. Laboratories processed samples and identified a range of priority bacterial species which are zoonotic (i.e. can be found in both humans and animals) – see Figure 6.

Figure 6: GLASS pathogens tested by animal health sentinel sites

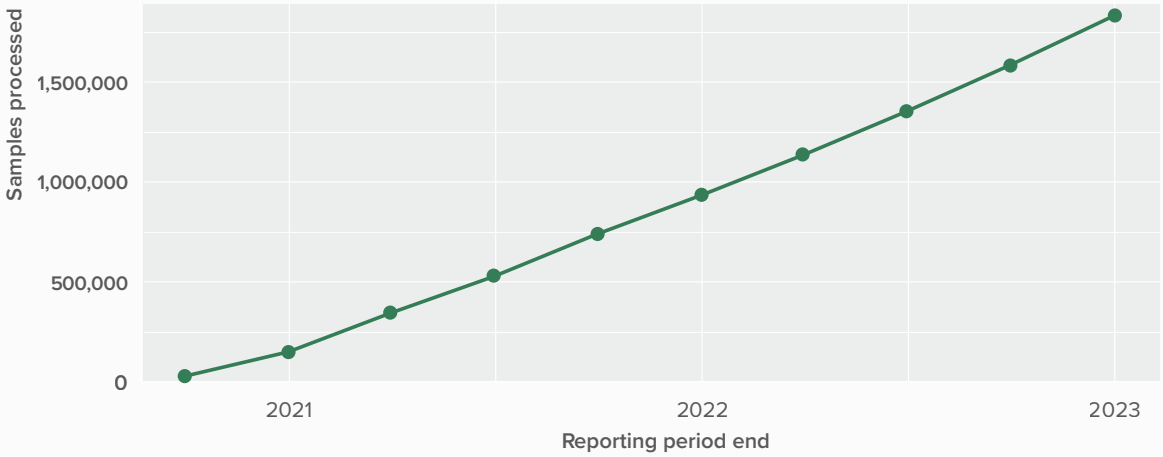


Both human and animal sectors significantly broadened the range of pathogen types being tested at the surveillance site level during phase 1.

AMR data production: sample volume

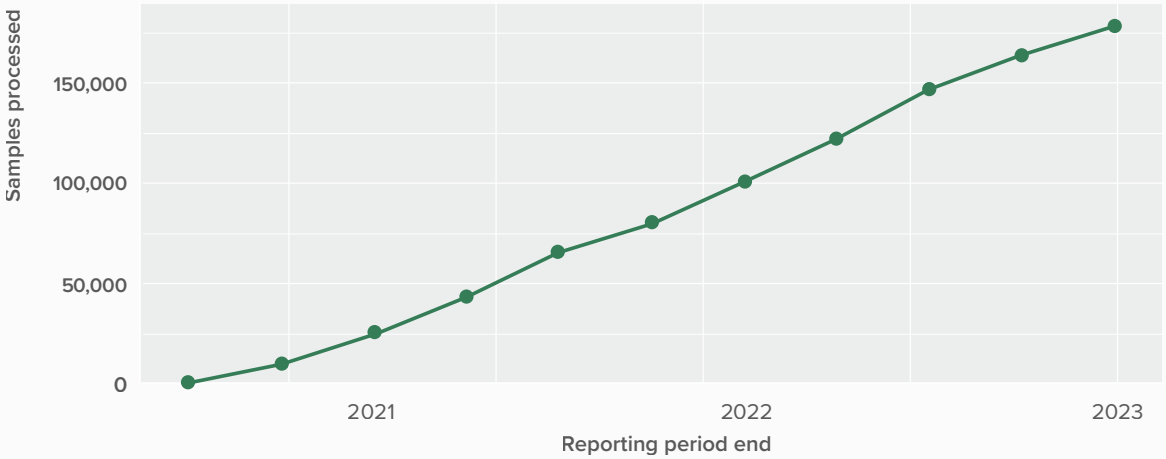
The number of samples collected and processed across Fleming Fund-supported sites has been tracked, indicating the scale-up of testing for bacterial infections (Figures 7 and 8).

Figure 7: Human health cumulative AMR samples plotted by quarterly intervals during phase 1 (and into phase 2) for surveillance and reference sites.



There has been a significant increase in the testing of biological samples, with a cumulative total of ~1.8 million tests undertaken during phase 1 from mid-2020 to the end of 2022. This is partly accounted for by: an increase in the number of supported sites, i.e. there was a rolling timetable of sites onboarding throughout phase 1; improvements in laboratory infrastructure (e.g. installation of blood culture instruments); improvements in the use of laboratory services, i.e. with samples taken by clinical staff and sent to the laboratory; and improving AMR related skills in the workforce.

Figure 8: Animal Health cumulative AMR samples plotted by quarterly intervals during phase 1 (and into phase 2) for surveillance and reference sites



In the animal health sector laboratories, similar increases were observed, primarily driven by the programme's approach to promoting active surveillance in animal species. Successive rounds of surveillance generated data on AMR in poultry, pigs, small ruminants and in aquatic species (e.g. tilapia and shrimp) in the aquaculture sector.

AMR data was also produced and made available in various ways by regional grants during phase 1 (Box 3).

Box 3: An example of regional grants' contribution to AMR data production during phase 1

Whole genome sequencing (WGS) is an essential tool for AMR surveillance, seeking to identify the genetic makeup of resistant organisms and to see how they are related to each other. When the Fleming Fund started, there was no WGS programme for AMR in Africa, and only 2 laboratories (in Africa) with the capability to undertake such work.

The **Whole Genome Sequencing and Bioinformatics Capacity Building in Africa (SeqAfrica)** grant, led by the Technical University of Denmark, established four additional sites in Africa; supported training in gene sequencing and bioinformatics; and provided 22 countries with access to a genome sequencing service. This grant has contributed to a better understanding of the nature and spread of AMR in Africa, providing insights into the spread of resistant bacteria. More than 30,000 sequences have been generated, and the programme also contributed to genomic surveillance of COVID-19.

So far, most of the genomes (73%) have been uploaded to public (i.e. National Centre for Biotechnology Information database; European Nucleotide Archive; and EnteroBase) or semi-public (e.g. Global Initiative on Sharing Avian Influenza Data) databases. Thereby, making a global public good data contribution.

Improving AMR data quality

53%

Sites improved data quality

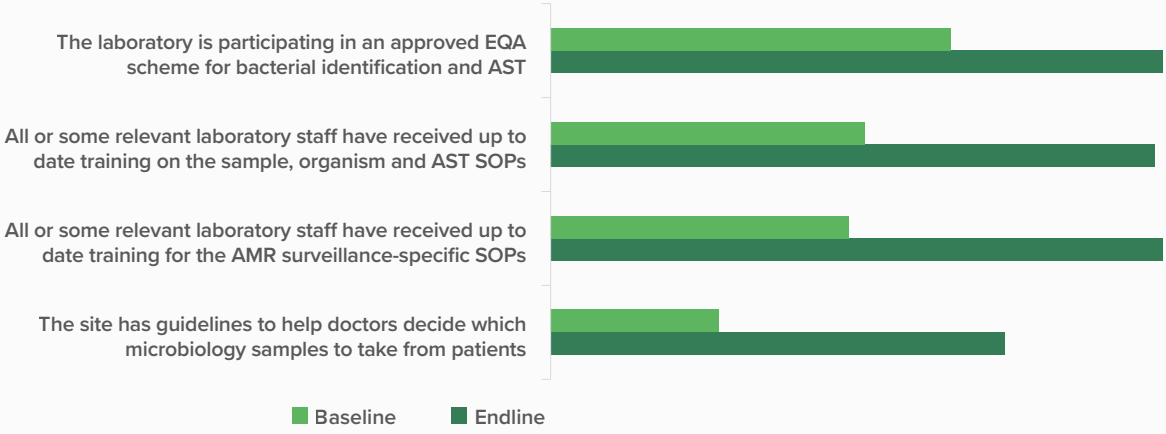
82/154* sites (human and animal health) achieved an acceptable** EQA score by 2022

*154 refers to sites participating in EQA (not all sites participated or participated in all EQA rounds). ** An 'acceptable' EQA score is a high benchmark and is defined as >=80.

Human resource strengthening efforts, supported by the Fleming Fund, contributed to improved capacity of laboratory staff across supported sentinel sites. This yielded AMR data quality improvements over time.

Figures 9 and 10 show a selection of variables (e.g. key guidelines, training, practice) important for driving AMR data quality improvements in laboratories. Comparisons of phase 1 baseline data versus end point data demonstrate improvements for all 'markers' for both human and animal health sites.

Figure 9: Baseline versus end point (phase 1) comparison of selected indicators (by proportion of sites) for driving quality improvement in human health sentinel sites

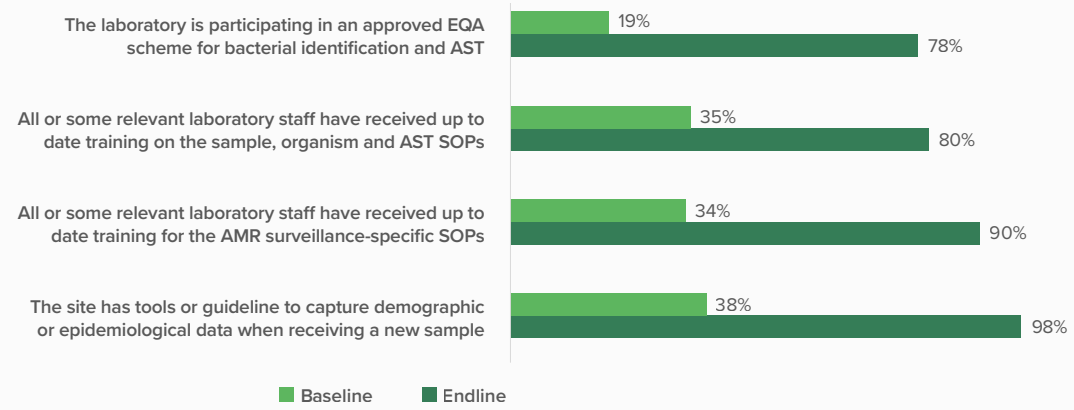


Key: EQA = External Quality Assurance; AST = Antimicrobial Sustainability Testing; SOPs = Standard Operating Procedures

There was a large and positive swing over phase 1, to more sites engaging in an external quality assurance scheme (i.e. independent verification /validation of laboratory standards, and good practice). 89% of human health sites were participating in an EQA scheme by the end of phase 1, compared to 58% at the start. With a bigger change for animal health sites, 78% of sites participated in an EQA scheme by

the end of phase 1 compared to 19% at the start.

Figure 10: Baseline versus end point (phase 1) comparison of selected indicators (by proportion of sites) for driving quality improvement in animal health sentinel sites

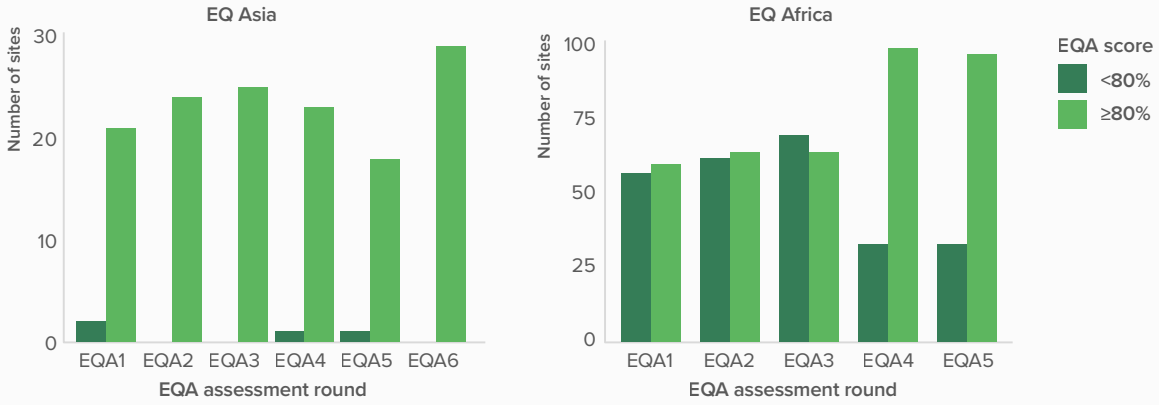


Key: EQA = External Quality Assurance; AST = Antimicrobial Sustainability Testing; SOPs = Standard Operating Procedures.

The Fleming Fund has supported successive rounds of External Quality Assurance (EQA) testing. This involves the use of standardised 'panels', which are sent to participating laboratories that are blinded to the species and types of bacteria in the panel. They undertake to culture, identify and ascertain the AMR status of the samples using their normal laboratory processes. These analyses are then returned to the EQA provider, who reviews them for standards of accuracy and quality. These reviews are in successive rounds, and each round focuses on and provides a different batch of bacterial species.

Figure 11 is an example of the successive rounds of EQA undertaken by the Fleming Fund regional grantee, Technical University of Denmark, at supported sites. A strong trend of increased EQA scores above 80% is shown for an increasing number of sites over time. For Asia, participating laboratories were reference laboratories only; in Africa, a mix of sentinel and reference laboratories was involved, i.e. explaining the lower number of sites shown in the graph for Asia compared to Africa.

Figure 11: EQA scores over successive rounds of EQA in Asia and Africa in phase 1



Note: Rounds EQA6 (for Asia) plus EQA4 and EQA5 for Africa were conducted beyond the end of Phase 1.

Box 4: Examples of regional grants contribution to AMR data quality during phase 1

When the Fleming Fund started, it was clear that there was almost a total lack of access to external quality assurance services across the countries. External Quality Assurance is essential in maintaining laboratory service quality and supporting National Reference Laboratories for consistent quality, improving training and capabilities, and providing reference services for laboratories in the surveillance system.

Two regional grants provided external quality assurance services to participating Fleming Fund-supported sites during phase 1.

In Africa, this grant was referred to as **External Quality Assessment of Laboratory Data Africa (EQuAfrica)**; in Asia, the grant was called **External Quality Assessment of Laboratory Data Asia (EQuAsia)**.

The grants initiated rounds of proficiency testing (i.e with participating laboratories identifying and testing pre-prepared samples), with successive rounds focusing on identifying and testing different bacterial species.

Participating sites were both sentinel and reference laboratories in nature, with the compositional mix of laboratory types varying by grant. The grant covering Asia focused on reference laboratories in phase 1 (n = 49), while the grant in Africa covered a mix of sentinel and reference laboratories (n=151). The overall number of participating sites increased during phase 1, and not all sites participated in all rounds.

Improving AMR data sharing

AMR data sharing

Domestic and International

16 out of 18* countries submitted AMR data to WHO GLASS in 2022 compared to 6 out of 20 countries in 2017-2018.

171 sites (66%)** were regularly sharing data with a National Reference Laboratory in 2022 compared to 40 sites (15%) at baseline during phase 1

*Information for two countries unavailable.**Sites for which FF support was discontinued before 2022 were excluded from this calculation

Better domestic sharing of AMR data: Within countries, there was an increase in the number of surveillance sites submitting AMR data to their respective National Laboratories (i.e. for compiling national analyses). National AMR committees also increasingly received an AMR report (human or animal health) at least once a year.

Better international sharing of AMR data: A key pillar of global efforts to improve surveillance is the **WHO's GLASS platform**. The platform is used to collect data from WHO member states into a large global database. Throughout the programme, we have tracked country participation in GLASS. This includes country enrolment in GLASS (an important pre-cursor to data sharing /submission with GLASS). In 2017-2018, 11 Fleming Fund-supported countries were enrolled in GLASS compared to 18 countries in 2022 *(Figure 12)*. Major progress was also made with data submission to GLASS (see headline box), including an over-doubling of the number of sites within countries providing data for sharing with GLASS (i.e. thus signifying the strengthening and broadening of AMR surveillance networks within countries) – Figure 12.

Figure 12: Number of countries by GLASS enrolment status, with the number of sites providing data for GLASS

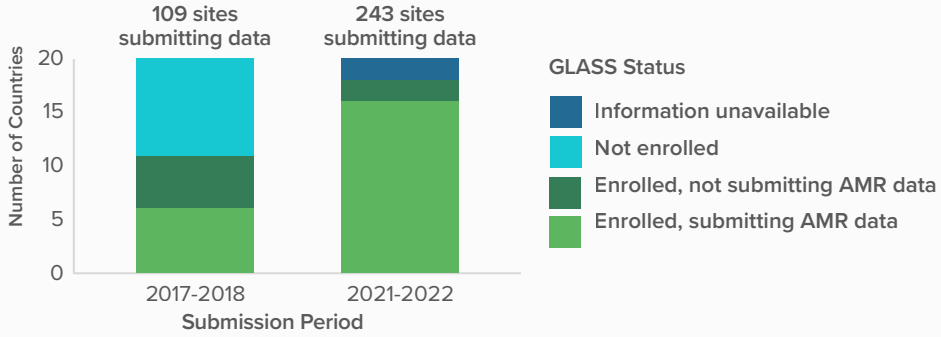
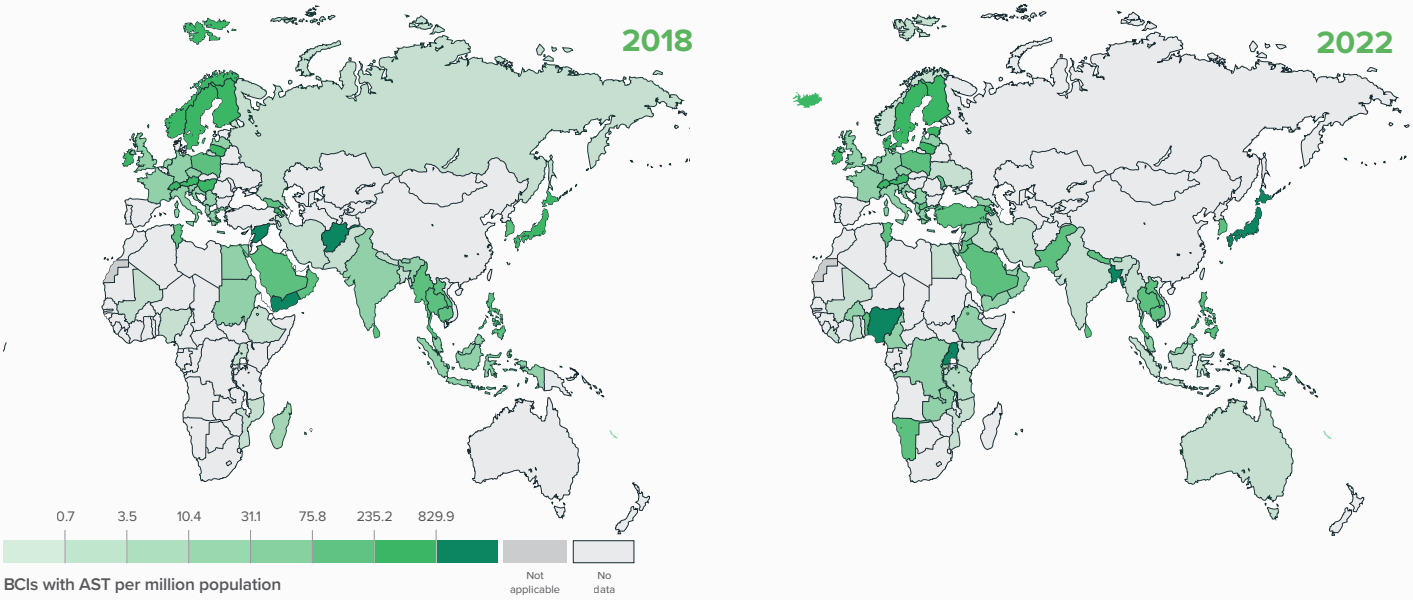


Figure 13: WHO-GLASS dashboard

The number of sites submitting data has more than tripled. This means increases in both the number of countries and in the number of sites per country.

AMR data use was also promoted and enabled by regional grants in different ways during phase 1 *(Box 5)*.



Box 5: Examples of regional grants contributing to AMR surveillance data use for evidence-based policy

Regional Antimicrobial Resistance Data Analysis for Advocacy, Response and Policy (RADAAR) is a regional grant led by the International Vaccine Institute (IVI) and focused on improving data-sharing at the country and regional level, to support evidence-based policymaking for AMR. This grantee examined how AMR data is being used, the barriers and enablers to data sharing at a regional level by Fleming Fund-supported countries, and how that data can be better shared, analysed, and used to develop and implement policies to fight AMR. Through its work, the grant has contributed to improving the collection and analysis of AMR data across regions, enabling more accurate tracking and reporting.

In 2017/2018, work began via the Fleming Fund to identify 'hidden' AMR data sources from laboratory records, with a view to analyse and learn from available data sources that may not have been previously analysed or analysed in-depth.

Two regional grants undertook this work. In Africa, this grant was called the **Mapping Antimicrobial Resistance and Antimicrobial Use Partnership (MAAP)** and was led by the African Society of Laboratory Medicine. While in Asia, the grant was **Capturing Data on Antimicrobial Resistance Patterns and Trends in Use in Regions of Asia (CAPTURA)** led by the International Vaccine Institute.

In Africa, the grant examined data records from thousands of laboratories and provided detailed strategic advice on past patterns of AMR, gaps and needs in the system, and support for improving national surveillance data quality. Significant gaps in diagnostic coverage in Africa were identified, with only five out of 15 priority pathogens consistently tested, and less than 1% of laboratories able to conduct bacterial testing.

Similar insights were provided by the grant in Asia into national-level data quality and quantity. Gaps in data quality and data sharing were highlighted, with support provided to countries for improving data quality and quantity. Country-specific reports were produced, providing high-level data for planning, policy and advocacy at the national level.

5.6 Strengthened AMR surveillance sites

97%

of sites strengthened

95% human health sites strengthened* against baseline

99% animal health sites strengthened* against Baseline

*Strengthened is defined as made progress towards achieving laboratory 'core' AMR performance/function as defined by the LSHTM road map

The Fleming Fund programme tracked AMR capacity and function of individual human health sites (over time) against the LSHTM roadmap, with a customised version of the tool used for animal health sites. This was described earlier *(Section 3)*.

Data gathered from grantee routine site reports from 2019 to 2022 was used to generate heatmaps, a visual representation of change across time, for supported sentinel sites. Figures 14 to 15 show a colour chart of progress for supported human health and animal health sites in Africa and Asia.

Figure 14: Heatmap of LSHTM roadmap progress across human health sites

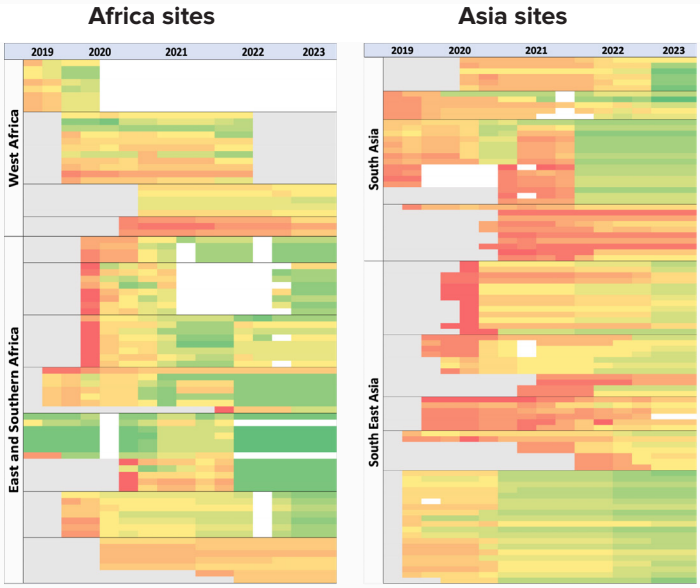
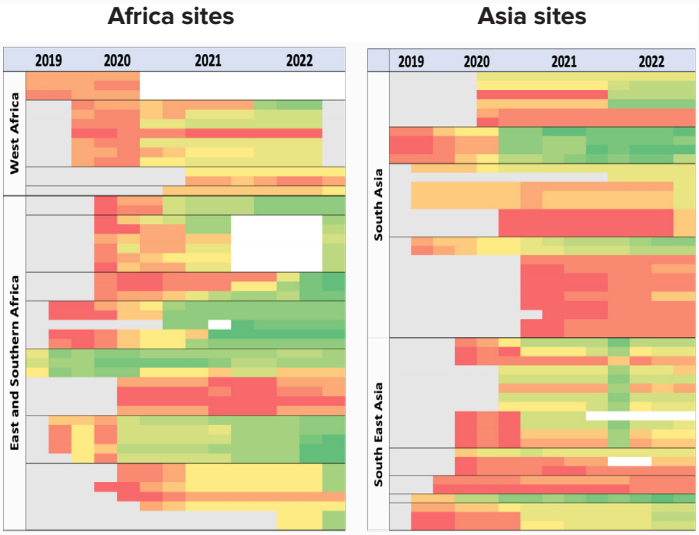


Figure 15: Heatmap of LSHTM progress indicators across animal health sites



Changes in site function and performance capacity are represented by changes in colour, with higher performance and function lower when 'red'; highest when 'green'; and middling when 'amber'. Sites are organised by country (anonymised) and region.

Each row in the heatmaps (above) represents a supported sentinel site; each cell per line represents a reporting quarter. The colour shades for each site demonstrate the proportion of LSHTM roadmap sub-components (Annex I) that are performed by that site to at least at core standard, each reporting quarter. 'Extended' and 'advanced' LSHTM road map functions are not shown here. Therefore, for a selection of sites, the full scale of progress is not shown.

The heat maps show how some countries demonstrate more consistent change over time, while others show more irregular and variable patterns. Nevertheless, almost all laboratories demonstrated a positive increase in functional capacity compared to their baseline, with improvements in at least one core sub-component of the LSHTM road map.

For instance:

- In human health sites, only 8 of 174 sites did not demonstrate an increase against their baseline *(Figure 14)*. A further 6 appeared not to show progress; however, this was due to a relatively high functional capacity at baseline (i.e. a ceiling effect).
- In animal health sites, only 1 of 105 sites did not demonstrate an increase compared to their baseline (Figure 15).
- In broad terms, the baseline status of human health sites was higher compared to their animal health site counterparts.

Within regions and across continents (Asia and Africa), variation can be observed, with some contexts more challenging for facilitating progress to the core level compared to others. Where progress was made, the time taken to make progress was highly variable (some much quicker than others). This variation is explained by many, and these explanations vary from country to country. The range of possible reasons includes:

Grant implementation time: This varied by country. For example, in West Africa, several countries joined later or terminated early, which hindered progress. Implementation time is a critical factor in making change and progress.

Extent of refurbishment needed: While sites commonly required refurbishment (approximately half of the sites), some sites needed more than others. Refurbishment took time and impacted the implementation of other laboratory function /systems changes.

Level of investment: This varied by country, including the number of supported sites within a given country

Starting point: Countries and sites (within countries) had different starting points or baselines. Even within a 'grading band' (e.g. 'red'), sites will have different profiles. Some LSHTM sub-components for attaining 'core' site status are easier than others.

COVID-19 pandemic: A large proportion of Fleming Fund phase 1 implementation time coincided with the worldwide COVID-19 pandemic. The WHO declared an associated public health emergency of international proportions from the end of January 2020, officially ending in May 2023. The impact of this on phase 1 implementation progress and results should not be underestimated. These were unprecedented times, with population sickness, widespread lockdown, and movement /travel enforcement restrictions. Given the global nature of the Fleming Fund, the impact of the pandemic and pattern of restrictions varied from place to place and over time. The programme adjusted and adapted flexibly depending upon the pandemic's 'on the ground' conditions and requirements. Depending on the pandemic phase, access to work/sites varied; the feasibility of installing and/or repairing laboratory equipment varied; access to technical assistance was largely online for a substantial period.

Procurement: Procurement systems and processes were smoother in some countries versus others, i.e. this influenced the timeliness with which essential equipment and supplies were in place for use. In turn, this impacted the site's data production capacity.

Country systems: Surveillance sites are part of country health systems, which differ very significantly from one another. For example, in some systems, staff rotate very regularly, with a constant cycle of training and re-training, including orientation to equipment and procedures required. Other systems are more stable but have very decentralised approaches to planning and resource allocation.

Other events: Natural events impacted some sites and their pace of change. For example, natural disasters (e.g. floods) caused damage and required repair and 're-start', other events impacted upon progress, such as laboratory staff shortages, labour strikes, and widespread fuel shortages/price increases, which impacted widely upon the movement of people and supplies.

Political context: The political context is important at different levels and in a multitude of ways. Elections in many of our countries represent elevated risks of social disorder – this was often transient, with consequences for travel and government decisions impacted, but can last for a considerable time (e.g. months in some cases). Government change, following elections, heralds a change in administration and leadership at all levels. During this period, government decisions and approvals are commonly

suspended, which has a major impact on planning. Government change may take months as it filters through layers of government. Subsequently, new appointees require orientation and briefing before 'business' can resume. Government and leadership priority, concerning AMR, is an important determinant of change and the speed of change. This varies depending on competing priorities and the degree of political will at cabinet levels of government.

Sector: In general terms, animal health sites started from a lower baseline compared to human health counterpart sites. Several reasons explain this, and they are considered in Section 6 (Conclusion). The lower baseline, the pace of change for some animal health sites was greater than for human health sites in terms of progress made.

While the Fleming Fund site change focuses on AMR surveillance strengthening, some changes and improvements brought about by the Fleming Fund are likely to yield wider laboratory systems and beneficiary benefits. For instance:

- Improvements in clinical admissions procedures (e.g. clinical data included with referral to the laboratory; use of unique identifiers; use of demographic data, etc) are likely to benefit all laboratory referrals in terms of enhanced practice – not just microbiology-related referrals.
- Improvements in the transport of samples according to standard operating procedures and /or correct storage of isolates are likely to impact how other sample types are managed.
- AMR-related sample quality control measures and efforts to reduce contamination rates are likely to positively impact the taking and management of other samples.

Box 6: An example of regional grants contribution to AMR systems strengthening

WHONET is a standard piece of software (free to use) which allows laboratories to process, analyse and manage data in laboratories. It is used also to issue alerts for potential outbreaks of infections. Data in WHONET can easily be transferred to central level for analysis of country resistance profiles and used at laboratory level to highlight new or important pathogens and types of resistance. WHONET has become an industry standard in LMICs because it is easy to use and there is a strong user base to provide support.

The Fleming Fund supported a regional grant to expand and install WHONET in all Fleming Fund-supported countries. The grant called **WHONET: Management and Analysis of Microbiology Laboratory Data**, led by Brigham and Women's Hospital, installed and trained users in almost all laboratories. This work improved data management and supported laboratories to provide services to healthcare settings and public health services.

Changes in country-level capabilities

Up to now, phase 1 changes *(Section 5)* have been presented at the site level. This section concludes by considering phase 1 change in relation to the country classification at the beginning of the programme. Earlier (Section 4.1), Fleming Fund supported countries were classified according to a typology system that considered features such as the presence/absence of a National Action Plan and the broad status of AMR surveillance within countries.

At the end of phase 1, countries were assessed against the same categories – 'A-D' scale (Table 10). Of 20 countries in the initial phase of the Fleming Fund, **18 (90%) countries moved up or improved by one or more categories**. The biggest movement/change was countries moving from a Category B to Category C classification, with countries changing from having no AMR surveillance system to having an AMR surveillance system that undertakes quality-assured surveillance and generates national-level data.

Table 10: Change in country classification of Fleming Fund-supported sites

Country Category:	Description	Start (Phase 1), 2018	End (Phase 1), 2022
A	Countries which have no National Action Plan (NAP)	1	0
B	Countries which have a NAP but no surveillance system in operation	14	2
C	Countries where most surveillance is established, gaps need to be filled, and activities need to be connected	3	13
D	Countries which are relatively more advanced and would benefit from nuanced support and/or could be supported to do more in One Health	2	5
Category Change	**18 out of 20 countries moved / improved by >=1 categories**		

This is a significant positive change and encompasses the achievement of the programme's overall aims.

At the end of phase 1:

- Most Fleming Fund-supported countries (n=13) were now 'Category C' (not Category B). Now with modest surveillance systems established, and major gaps filled.
- These countries now have a better picture of the spectrum of resistance from more patients, more animal species, more clinical syndromes, more sample types, and analyse a higher number of GLASS priority pathogens, compared to the beginning of the programme.
- This has made an impact on the ability to track, review and analyse AMR data at local, country, regional and international level.

Phase 2 of the Fleming Fund continues this work by: ensuring and maintaining sustained change over time; continuing to fill in some gaps in surveillance systems; and, where sensible and affordable, modestly extending the scale of Fleming Fund support to include some new surveillance sites across a limited number of countries. In addition, a focus of phase 2 investments is to embed these systems more fully within their respective country context and architecture, promote sustainability, and ensure the use of investments to generate actionable evidence and data.

Conclusions

The Fleming Fund has made significant contributions to AMR surveillance at both national and global levels during its first phase. Much has been learnt in addition to – and beyond – the generation and analysis of AMR data:

Change is feasible: The Fleming Fund has demonstrated it is feasible to build AMR surveillance systems in LMICs – and relatively quickly from a very low baseline. We have come far in a short time. Core objectives have been achieved – quality AMR data produced, analysed, and shared at domestic and international levels.

Power of partnerships: Close partnership and co-planning with country governments from the outset, and throughout, has been critically important. Change at the 'grass roots' (surveillance sites) is determined by leadership support from all levels of the system.

Detailed co-planning and relationship building enabled high-level government ownership in countries. This empowered national bodies in charge of AMR, national AMR focal points, and associated Technical Working Groups, and gave momentum to planning and awareness. An enabling environment has been created for the evolutionary path to AMR data use, and associated practice and policy change, over time.

Change is not a simple or linear process: Evidence considered in Section 5.6 demonstrated the differential rate of progress of site development both within and across country contexts.

Determinants of progress and change were discussed, and it is important to acknowledge:

- Change takes time, and pace will differ within and across contexts.
- Change is often not stable (i.e. changing behaviour and systems go forwards and backwards) before stabilising, implying that support over time *(e.g. phase 2)*, and active planning for sustainable change is vital.
- Change requires ambition but a readiness to adjust ambition and approach in the face of challenge and adversity.

Arguably, changes in human health sites have been comparatively easier to achieve than some animal health sites/contexts when adjusting for a lower baseline position that many animal health sites started from, compared to many human health sites. Reasons for this are complex but include:

Funding: For good reason (i.e. AMR is a human health threat), there was generally higher programme investment in human sites compared to animal sites.

Core business – virology: Due to the nature of animal health, notifiable diseases and outbreaks (e.g. foot and mouth disease, African swine fever, Avian flu), means animal health laboratories are focused on a different set of animal pathogens related to transboundary animal diseases – most of which are viral. 'AMR' is relatively new to the animal health sector, whose 'core business' is virology.

Boom and bust: Active surveillance has been used for building AMR surveillance via the Fleming Fund. Given the wide lack of data /evidence and knowledge about AMR in the animal sector, at the start of phase 1, active surveillance was the quickest and most effective way of establishing standardised and robust sampling for AMR surveillance data. However, active surveillance approaches are episodic in frequency (i.e. surveys and sample collection are not frequent), meaning there is a more intermittent use of bacteriology testing skills/experience in laboratories. AMR testing and analyses come in volumes and 'waves' – unlike in the human health sector, where passive surveillance is used.

Phase 1 achieved AMR data produced, analysed and shared for target animal health species. As part of the Fleming Fund's sustainability in Phase 2 (and beyond), options for additional or different models for animal health surveillance (e.g. 'piggybacking' on virology studies, waste or abattoir sampling approaches) need to be considered. A focus on AMU and consumption surveillance can support reductions in antibiotic use in animal production systems without the need for active AMR surveillance. In addition, the use of laboratory services in the animal health sector needs to provide an incentive for practitioners by addressing key areas of animal health that impact economic viability. For AMR surveillance in the animal health sector, using active surveillance has proved comparatively expensive. New modalities are being explored to link AMR surveillance with surveillance of other animal diseases and provide linkages to passive surveillance approaches, which will promote efficiency and sustainability.

Country views: Key government stakeholders have valued the investment, support and change brought by the Fleming Fund to building their AMR surveillance systems.

Theory of Change: Evidence examined in this paper demonstrates that the Fleming Fund programme's Theory of Change (tested to date) is valid and robust. Namely, the type and combination of identified programme outputs yielded identified and sought intermediate outcomes.

Using a blend of multiple grant streams brought improvements at the country level, down to the individual site level. The implementation of country, fellowship and regional grants in parallel allowed critical improvements in infrastructure, technical capabilities and human resources capacity. These, in turn, have led to improvements in diagnostic services, surveillance data, awareness and practice.

> The government of the Republic of Zambia has been privileged to work with the Fleming Fund for the last six years. The Fleming Fund support has been invaluable to our laboratory systems, microbiology systems and services. As the head of the Zambia National Public Health Institute, and Chairperson for the Antimicrobial Resistance Coordinating Committee, I'm proud of the partnership that we have had, which has immensely contributed to our One Health surveillance work".
>
> **Director General,**
> **Zambia National Public Health Institute**

> The Fleming Fund has played a transformative role in strengthening Nepal's ability to combat AMR. From modernising laboratories and supporting surveillance systems to catalysing evidence-based policy reforms, their contributions have elevated our national response across human, animal, and environmental health sectors. We deeply value this partnership, which continues to empower our institutions and professionals to protect public health through a One Health approach".
>
> **Ministry of Health and Population,**
> **Government of Nepal**

Considerations for future programming

When moving forward to test and deliver more advanced results sought, there are several considerations to be mindful of:

Surveillance data is useful but has limitations: AMR surveillance data has immense value both at the practice and policy levels for informing and making improved decisions. National policymaking is a political process, influenced by many factors – not only evidence from surveillance systems. Expectations related to the time required for change and the changes required need to be better understood because national-level changes in policy do happen, but not always. There is also the obvious risk of unintended consequences because the interpretation of AMR surveillance data can be challenging and could conceivably lead to negative unintended consequences. For example, a change of treatment guidelines was inappropriately applied based on a misinterpretation of data from passive surveillance or impacts on food production systems.

The Fleming Fund has improved health systems: Improving access to diagnostics for bacterial diseases has emerged as a major issue[11]. At the patient level, diagnosis saves lives. There is significant qualitative evidence that the Fleming Fund has contributed to change in practice at the clinical level – whether reinforcing antibiotic prescribing practice or contributing to the identification of outbreaks of drug-resistant infections.

Providing continuity in the medium term: As the programme moves forward into phase 2, and possible subsequent phases, higher-level results are sought within the Theory of Change – these are more complex and difficult to achieve, though they are all underpinned by solid foundations in good quality surveillance and improved access to diagnosis. It will be important to actively support the foundations established in phase 1 over the next five to ten years, so newly established systems become established and indispensable parts of national systems. This consideration should be part of discussions on the scale, scope and timescale of programme delivery in the future.

Guiding change

The use of WHO and FAO guidance as the blueprint for the programme provided important standard guidance, and a basis of common understanding between the Fleming Fund's approach, the countries, and the multilateral partners (the Tripartite – latterly the Quadripartite). The LSHTM roadmap for participation in GLASS was applied to countries, as this supported the incremental approach for surveillance system development. This was used to mirror into the animal health sector, allowing the ability to plan, monitor, and undertake activities to provide usable data.

[11] Bacterial antimicrobial resistance burden in Africa: accuracy, action, and alternatives', The Lancet, Feb 2024.

Wider change and benefits: The Fleming Fund programme is a launching point for wider benefits to broader health systems change. AMR is in danger of becoming a 'vertical' programme. Extensive efforts have been made throughout implementation to ensure programme relevance to country health systems, and to be faithful to the needs of National Action Plans, systems and other relevant AMR development action. Site changes (e.g. laboratory working conditions and some AMR-related practices) have wider benefits for the quality of site performance beyond AMR. As the programme matures, evolves and continues with its committed focus on sustainable systems building, AMR systems integration for greater 'horizontal' laboratory and wider system function is imperative. Part of this is to see AMR for what it is – a cross-cutting issue that requires sustained improvement in bacteriology services in human and animal health.

A change story has been described here, showing that improvements in AMR capacity and capabilities can be achieved. This story is only half-told and continues and develops with changes currently being achieved in phase 2 of the programme. The Fleming Fund programme is broad and supports different levels of AMR systems development within countries. There is strong evidence of change happening throughout health systems and into the political arena.

In a fast-changing landscape of international development, continued donor support to LMICs to maintain, sustain and drive forward changes already made has never been more important. The second High-Level Meeting on AMR took place in September 2024, where UN member states agreed on a **political declaration** on AMR, including a priority to strengthen and sustain surveillance systems. This is not a small undertaking. Measuring success for other targets, such as the target to reduce deaths associated with bacterial AMR by 10% by 2030, is neither measurable nor achievable without strong surveillance systems.

ANNEX I: Sentinel site functions for AMR surveillance (core, extended, advanced) in the LSHTM Roadmap

AMR surveillance component		Requirements and standards for core level	Extended level activities	Advanced level activities
Overall aim		Surveillance data inform individual care	Surveillance data drive local and national policy (e.g. empiric treatment guidelines, drug procurement) and public health activities	
Clinical admission assessment and investigation	**Clinical admission assessment**	Clinical history and examination and investigation based on physician (syndromic) diagnosis.	Systematic clinical hisory and examination according to clinical algorithms in all patients presenting with suspected infection.	Standardised admission proforma documenting clinical signs and symptoms used to guide diagnosis
	Clinical data	Clinical data included in (paper) request for laboratory investigation, with unique alphanumeric identifier	Clinical data included in (electronic) request for laboratory investigation, with unique alphanumeric identifier	Linkage of extended clinical data (e.g. vital signs, blood results, outcomes) with laboratory data
	Clinical investigation	Systematic investigation based on physician syndromic diagnosis	Systematic investigation based on clinical findings	
	Training and quality assurance	Routine training for surveillance SOPs, quality control and Internal Quality Assessment	External Quality Assessment	Functions as a regional training centre
Isolate identification and susceptibility testing	**Sample transport**	Samples transported according to local SOPS	Samples transported according to international biosafety standards	
	Sample registration	Local laboratory paper-based data system	Electronic laboratory data system	
	Culture and identification	Automated blood culture system and capacity to identify the relevant priority pathogens according to SOPs	Automated blood culture; CSF, urine, stool and swab culture, identifying all isolates according to SOPs for all priority pathogens	Automated identification (e.g. MALDI-TOF)
	Susceptibility testing	Use of disc diffusion for blood culture priority pathogens according to SOPS	Use of disc diffusion methods according to SOPs fo all species; may include e-tests or broth dilutior methods.	Automated identification (e.g. VITEK)
	Training and QA	Routine training for SOPs, quality control and internal QA	External quality assessment	Functions as a regional training centre
Isolate storage (local) and referral to AMR laboratory	**Storage of isolates**	Freezer storage (-20°C) or resistant isolates with linkage to paper or electronic database	Reliable (generator back-up) freezer storage (-80°C) of resistant isolates with linkage to electronic database	
	Transport to AMR laboratory	Invasive isolates are transferred to AMR laboratory annually according to SOPs	Invasive isolates are transferred to AMR laboratory quarterly according to international standards for biosafety	
	Training and QA	Routine training for isolate storage, SOPs, quality control and internal quality assessment	External quality assessment	
Data review	**Data use**	Anonymised individual data submitted to national co-ordinating centre and shared regionally and internationally		Automated real-time submission of data to national network
	Data linkage	Clinical and laboratory data linked by recording them on the same lab request form	Automated linkage between clinical request data and laboratory data	Automated linkage between clinical and laboratory databases
	Data governance	Data sharing policy and agreements in place in collaboration with Ministry of Health and/or national public health institute		