National Strategic Action Plan on Antimicrobial Resistance

version 2.0

Singapore

Working together to combat AMR

The National Strategic Action Plan on Antimicrobial Resistance (AMR) was developed by the One Health AMR Workgroup (OH AMRWG) and is jointly published by:

- Communicable Diseases Agency (CDA)
- National Environment Agency (NEA)
- National Parks Board (NParks)
- PUB, Singapore's National Water Agency (PUB)
- Singapore Food Agency (SFA)

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National Strategic Action Plan on Antimicrobial Resistance, Singapore (version 2.0)

Date of publication: 12 November 2025

ONE HEALTH AGENCIES:

Communicable Diseases Agency Singapore
Prepare · Prevent · Protect

National Environment Agency
Safeguard · Nurture · Cherish

National Parks
Let's make Singapore a city in nature

PUB Singapore's National Water Agency

Singapore Food Agency

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FOREWORD

The **One Health Agencies** – comprising the Communicable Diseases Agency, National Environment Agency, National Parks Board, PUB Singapore's National Water Agency, and Singapore Food Agency – play a key role in shaping Singapore's response to One Health threats. These include foodborne illness, vector-borne diseases, zoonoses, and antimicrobial resistance (AMR).

AMR, in particular, has been a growing concern globally as it threatens the ability to treat infectious diseases. On the human health front, it poses risks to medical advances and patient outcomes, contributing to increased mortality and greater healthcare costs. AMR risks extend beyond human health to animal health, food systems, and potentially the environment.

To combat these threats, Singapore's first National Strategic Action Plan (NSAP) on AMR was launched in 2017. It has since delivered several meaningful outcomes. Notably, it served to formalise and structure efforts across the human, animal and environment sectors. We have embarked on public education campaigns on correct antibiotic use, expanded AMR surveillance programmes and technical capabilities across all sectors, and launched national prescribing guidelines for the primary care and veterinary sectors. On the regional and international stage, Singapore has received recognition for our strong One Health approaches and contributions to AMR research and capacity building.

Notwithstanding these successes, AMR is a long-term threat that requires sustained action. As the AMR situation continues to evolve globally and new challenges occur, Singapore must remain vigilant and adapt our national AMR strategies accordingly.

The One Health agencies are therefore pleased to share Singapore's second NSAP on AMR (NSAPv2), which represents the nation's renewed commitment to combat AMR, harnessing our strengths in One Health collaboration, research expertise, good governance and partnerships with regional and international counterparts.

The success of the NSAPv2 hinges on our collective effort. We are grateful to all stakeholders who have contributed to shaping this enhanced plan. We invite all stakeholders to continue playing their part in tackling AMR. Together, all of us can safeguard the effectiveness of antimicrobials and protect the health of current and future generations of Singaporeans.

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LIST OF ABBREVIATIONS

AAHS	Aquatic Animal Health Services
ACE	Agency for Care Effectiveness
ACG	ACE Clinical Guidelines
AHC2	ASEAN Health Cluster 2
ALD	ASEAN Leaders Declaration
AMR	Antimicrobial Resistance
AMRCO	Antimicrobial Resistance Coordinating Office
AMRWG	Antimicrobial Resistance Workgroup
AMU	Antimicrobial Utilisation
ANIMUSE	ANImal antiMicrobial USE
ARB	Antimicrobial resistant bacteria
ARG	Antimicrobial resistance genes
ASEAN	Association of Southeast Asian Nations
ASF-AMR	ASEAN Strategic Framework to Combat AMR through One Health Approach
ASWGFi	ASEAN Sectoral Working Group for Fisheries
ASWGL	ASEAN Sectoral Working Group for Livestock
ASP	Antimicrobial Stewardship Programme
ATLASS	Assessment Tool for Laboratories and AMR Surveillance Systems
CDA	Communicable Diseases Agency
CLSI	Clinical and Laboratory Standards Institute
CPE	Carbapenemase-producing Enterobacterales
CRE	Carbapenem resistant Enterobacterales
ECV	Epidemiological cut-off values
EPH	Environmental Public Health
ESBL	Extended spectrum beta-lactamase
EUCAST	European Committee on Antimicrobial Susceptibility Testing
FAO	Food and Agriculture Organization of the United Nations
GASP	Gonococcal Antimicrobial Surveillance Programme
GLASS	Global AMR Surveillance and Use Surveillance System
GP	General Practitioner
HPB	Health Promotion Board
IHL	Institute of Higher Learning

IHR JEE	International Health Regulations Joint External Evaluation
InFARM	International FAO Antimicrobial Resistance Monitoring
IPC	Infection Prevention and Control
MDR	Multidrug resistant/resistance
M&E	Monitoring and Evaluation
MOE	Ministry of Education
MOH	Ministry of Health
MRSA	Methicillin- resistant *Staphylococcus aureus*
NARCC	National Antimicrobial Resistance Control Committee
NAREP	National Antimicrobial Resistance Expert Panel
NASEP	National Antimicrobial Stewardship Expert Panel
NAIS	National Adult Immunisation Schedule
NCIS	National Childhood Immunisation Schedule
NEA	National Environment Agency
NIPC	National Infection Prevention and Control Committee
NSAP	National Strategic Action Plan
OH	One Health
OHARP	One Health AMR Research Programme
OHCC	One Health Coordinating Committee
OHMP	One Health Masterplan
WASH	Water, Sanitation and Hygiene
WOAH	World Organisation for Animal Health
PUB	Singapore's National Water Agency
QMRA	Quantitative Microbial Risk Assessment
SASTC	Singapore Antimicrobial Stewardship Training Course
SDM	Shared decision making
SFA	Singapore Food Agency
TB	Tuberculosis
TrACSS	Tracking AMR Country Self-assessment Survey
UNEP	United Nations Environment Programme
UNGA	United Nations General Assembly
WAAW	World AMR Awareness Week
WHO	World Health Organization

VISION AND MISSION

VISION

A Singapore where AMR is effectively controlled.

MISSION

To prevent the emergence and reduce the spread of drug-resistant organisms, and preserve the effectiveness of antimicrobials through a One Health approach, protecting human, animal and environmental health in Singapore.

INTRODUCTION

Antimicrobial resistance (AMR) is among the top 10 public health threats to humanity. It is currently estimated that drug resistant microorganisms[1] cause 700,000 deaths worldwide each year (1). On the current trajectory, if no action is taken to control AMR, it is postulated that AMR will cause 1.9 million deaths a year and be associated with 8.2 million deaths by 2050 (2).

Antimicrobials[2], including antibiotics, are the bedrock of modern medicine. They are essential for treating many common human and animal infections. However, antimicrobials are losing their effectiveness due to AMR, which occurs when microorganisms undergo changes to resist the effect of antimicrobials. When microorganisms develop resistance to multiple drugs, it reduces treatment options against infections, leading to longer recovery times, higher risks of complications and death. It is therefore imperative that we act to slow the development of AMR and preserve the effectiveness of antimicrobial drugs.

Worldwide, AMR is driven by misuse and overuse of antimicrobials in both human and animal sectors, leading to the development of increasingly resistant microorganisms. The spread of microorganisms is facilitated by inadequate infection prevention measures, such as limited access to vaccination, poor water, sanitation and hygiene (WASH) infrastructure, poor waste management and inadequate healthcare infection control practices.

In Singapore's context, our impetus to tackle AMR is as follows: first, AMR impacts health outcomes, healthcare costs, animal health and food safety; second, Singapore is a global hub for medical services and travel and is heavily reliant on food imports, thus making us susceptible to AMR threats from external sources; third, antimicrobial residues, nonindigenous drug-resistant microorganisms and antibiotic resistance genes may contaminate our environment, which could find their way back to humans, pets and wildlife. The first National Strategic Action Plan on AMR (NSAP) (3) developed in 2017 stemmed from the need to address these challenges through a One Health approach. The first NSAP unified previously independent efforts to contain AMR, improved One Health coordination and strengthened our surveillance capacities. The second Plan (NSAPv2) builds on the groundwork laid by the first, to further advance One Health collaboration and drive more measurable and targeted action on AMR.

The NSAPv2 represents Singapore's renewed commitment to combatting the threat of AMR. *We welcome all stakeholders to work with us to help preserve the effectiveness of antimicrobials and ensure continued treatment of infectious diseases for this and future generations.*

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[1] including bacteria, fungi, viruses, and parasites.

[2] Antimicrobials are agents that act against microbes, and include antibiotics, antivirals, antifungals and antiparasitics. An antimicrobial either kills the specific microorganism it targets, or stops the microorganism from multiplying, helping the body's immune system to fight the infection caused by the microorganisms.

OVERVIEW OF AMR IN SINGAPORE

Public Health Impact of AMR

Drug-resistant infections significantly impact healthcare costs and length of hospital stays. The mean cost of a single healthcare-associated infection was estimated at SGD 1809, translating to an annual lost bed days of about 56,000 days and an economic burden of SGD 152 million (4). Hospital-acquired infections caused by carbapenem-resistant Enterobacterales (CRE) resulted in extended hospital stays and increased costs. From the hospital perspective, the economic burden of hospital-acquired CRE infections in Singapore acute hospitals was estimated to be approximately SGD 12 million annually, from both treatment costs and opportunity costs of bed days occupied by prolonged cases (5). Methicillin-resistant *Staphylococcus aureus* (MRSA) infections in Singapore increased the length of stay by nearly four days compared with patients who did not have MRSA; each MRSA infection resulted in an excess cost of SGD 3200 (6). This translates to over SGD 500,000 per 100,000 admissions. These financial impacts underscore the burden drug-resistant infections place on the healthcare system.

The US-based Institute for Health Metrics Evaluation estimated that Singapore had 502 deaths attributable to AMR and 2,300 deaths associated with AMR in 2019 (7); local studies will be needed to provide more reliable estimates of mortality in Singapore. At present, there is insufficient information to quantify the impact of AMR on animal health, food production and the environment.

AMR in healthcare settings and community

In acute care settings, the overall incidence of *Clostridioides difficile*, MRSA and multi-drug resistant[3] (MDR) *Acinetobacter baumannii* have declined since 2012. However, the incidences of ciprofloxacin-resistant *Escherichia coli* and *Klebsiella pneumoniae* have been on an increasing trend since 2017 despite a declining use of fluoroquinolones. Carbapenemase-producing Enterobacterales (CPE) are a growing concern worldwide and locally (8).

Among healthy individuals, almost one-third in one study were found to carry extended-spectrum beta lactamase (ESBL)-producing organisms (9). In primary care (polyclinic) settings, almost half of *E. coli* isolates were resistant to ampicillin, and approximately one-third were resistant to ciprofloxacin. Most isolates of *K. pneumoniae* (>80%) were found to be resistant to nitrofurantoin and one-fifth were resistant to ciprofloxacin in 2021. MRSA prevalence was low at approximately 5%, while the number of carbapenemase producers remains very low (8).

AMR in food and animals

Salmonellosis in humans is a notifiable disease and the main cause of food-borne disease

[3] Resistant to three or more classes of antibiotics.

in Singapore. While the prevalence of *Salmonella* spp in food is low, a high proportion of *Salmonella* spp isolated from raw poultry products were found to be multi-drug resistant. ESBL *E. coli* have also been widely found in retail raw chicken meat, which are entirely imported (10). ESBL *E. coli* were detected more frequently in meat products sampled at retail than at points of source, import or processing, suggesting the necessity of control measures in reducing the contamination along the food supply chain.

In local livestock farms, the prevalence of *Salmonella* spp is low due to regular monitoring and controls. However, MDR *Salmonella* spp were more frequently detected from local quail layer farms[4] than chicken layer farms. Resistance rates of indicator *E. coli* from local poultry and ruminant farms have been relatively stable since 2018.

In companion animals, approximately 20% of *E. coli* from sick pets in 2020 and 2021 demonstrated resistance to medically important antimicrobials such as ciprofloxacin and third generation cephalosporins such as cefotaxime. On the other hand, MRSA prevalence was found to be low in companion animals tested, including stray dogs (8).

AMR in water and environment

Antimicrobial-resistant bacteria and genes have been detected in varying degrees in urban waters. However, local treatment processes of wastewater were found to be efficient in removing antimicrobial-resistant bacteria and opportunistic pathogens. Using a risk assessment approach based on the quantitative microbial risk assessment (QMRA) framework, a study supported by PUB found no perceived recreational risks in freshwater reservoirs and no risks to our water bodies used as a source of water supply (11).

NEA's monitoring shows most recreational beach waters meet WHO recommendations of less than 200 enterococci counts per 100 mL of water. Approximately 60% of enterococci isolates from recreational beach waters, beach sand and coastal drainage sites were non-susceptible to multiple antibiotics (11). No ESBL *E. coli* was detected in recreational beach waters in a time-limited study (8). A subsequent temporal study of waterways and coastal sites corroborated the absence of *ESBL E. coli* in recreational coastal sites, while identifying ESBL *E. coli* in non-recreational coastal sites and upstream waterways. (12). This suggests the influence of anthropogenic activities on microbial and AMR pollution in aquatic environments, emphasising the need for continued monitoring and targeted interventions.

Public awareness of AMR

Since the launch of public campaigns in 2018 by HPB, public awareness that antibiotics are ineffective against viral illnesses such as influenza has maintained at approximately 50%, as of 2023 (13). A significant bottleneck may have stemmed from the nature of the AMR problem itself, often referred to as an "invisible threat". AMR is inherently difficult to tangibly define, demonstrate, and explain as a looming danger (14). Other studies identified poor knowledge and misconceptions surrounding antibiotic use and AMR,

[4] Findings were from the quail farms which ceased operations in 2023.

including the belief that resistance occurs when our bodies become resistant to antibiotics (15; 16; 17; 18; 19). Among pet (cats and dogs) owners surveyed, 33.9% used antibiotics inappropriately for their pets. Pet owners tended to have poorer knowledge of antibiotic use for their pets than for themselves. A higher proportion of pet owners used antibiotics inappropriately for their pets compared to use for themselves (20).

Figures at a glance

AMR can prolong hospitals stays by **6.1 days** (35). Hospital-acquired CRE infections could add **$12 million** annually to healthcare costs [5].

Almost **1 in 3** healthy individuals carry ESBL-producing organisms [9].

20% of E. coli from sick pets were found resistant to medically important antibiotics [8].

About **50%** unaware that antibiotics cannot treat viral illnesses [13].

60% of enterococci isolates from beaches and coastal drainage sites were not susceptible to many antibiotics [11].

51% of retail raw chicken meat found with ESBL E. coli [10].

Overview of AMR in Singapore

DEVELOPMENT OF NSAPV2

Developmental approach

The second National Strategic Action Plan (NSAPv2) was developed by the One Health AMR Workgroup (AMRWG)[5] following a review to identify the strengths and gaps of the first NSAP and chart ways forward.

We first undertook a review of the first phase of implementation from 2018 to 2023. This comprised an internal review led by the AMR Coordinating Office (AMRCO), followed by a commissioned evaluation (14) conducted by the Health Intervention and Policy Evaluation Research (HIPER) unit of National University of Singapore. Broadly, the following strengths and areas for improvement were identified:

- Areas of strengths:
  - Dedicated government funding for the implementation of AMR initiatives by One Health agencies
  - Multi-sectoral approach and a functioning One Health network
  - Central coordination through AMRCO
  - Strong technical expertise of the national laboratories of all sectors
  - Robust research network and advanced capabilities
  - Active regional engagement and capacity building
- Areas for improvement (in addition to areas in the first NSAP):
  - Coordination and integration of multi-sectoral efforts, and development of systems and structures to facilitate them
  - Communication of the national strategy to all stakeholders, emphasising the One Health approach
  - Engagement and partnering of the community and private sector
  - Attention to understanding motivations and changing behaviour
  - Translation of evidence to policy and practice
  - Articulation of clear outcomes to achieve
  - Utilisation of monitoring and evaluation to achieve outcomes

Other independent analyses had identified similar gaps and recommended improving surveillance coverage for AMR and antimicrobial utilisation (AMU) across all sectors, highlighting the need for integration, better antimicrobial stewardship and legislation in some sectors, greater innovation in approaches to bring about sustainable behaviour change, and for more open research collaborations and translation of research into policy outcomes (21). Others recommended exploring and addressing the social, economic, political, cultural, and behavioral aspects influencing AMR (22).

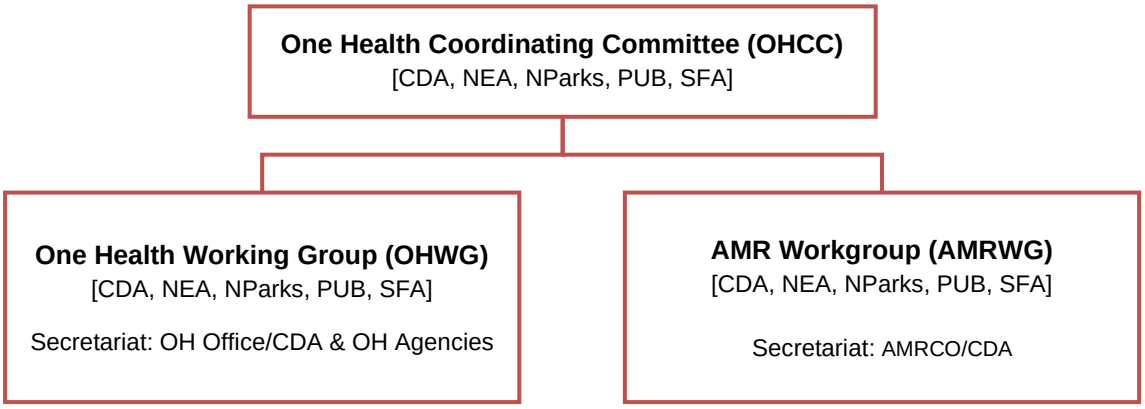
These recommendations have helped to formulate initiatives to strengthen each of the core strategies of NSAPv2.

[5] Comprising CDA, NEA, NParks, PUB and SFA, under the leadership of the CDA, an agency of the MOH.

One Health, Multi-disciplinary approach

A **One Health[6] approach** will continue to be the foundation of Singapore's strategy to combat AMR across sectors. A One Health structure (Figure 1) helmed by the One Health Coordinating Committee (OHCC) has been in place in Singapore since 2011. The OHCC provides strategic direction and set priorities for One Health issues, including but not limited to, zoonoses and foodborne diseases. Reporting to the OHCC, the One Health AMR Work Group (AMRWG), led by CDA, oversees the development, implementation and monitoring of the NSAP on AMR. The OH AMRWG is supported by the AMRCO, which serves as the national AMR secretariat.

Figure 1. Singapore's One Health Structure



To further strengthen multisectoral collaboration, Singapore's **One Health Masterplan** was developed in 2025 as a framework to present a shared mission for implementing the One Health approach in Singapore to address public health threats. One Health for Singapore pursues actions "to anticipate, prevent, prepare against, respond to and recover from shared One Health threats across the human-animal-environment interface, with a goal to build health resilience". The NSAP implements Singapore's One Health approach to address AMR, in alignment with the guidance provided by the Quadripartite One Health Joint Plan of Action, Action Track 5: "Curbing the Silent Pandemic of Antimicrobial Resistance".

The NSAP also complements other national programmes that monitor drug-resistant infections, such as drug-resistant tuberculosis (TB) and sexually transmitted infections. To avoid duplication, strategies for managing drug-resistant TB and sexually transmitted infections are not described in this document. More information on these programmes may be found at https://www.cda.gov.sg/professionals/national-hiv-hepatitis-c-and-sti-programmes/ and https://www.cda.gov.sg/professionals/national-tuberculosis-programme/ .

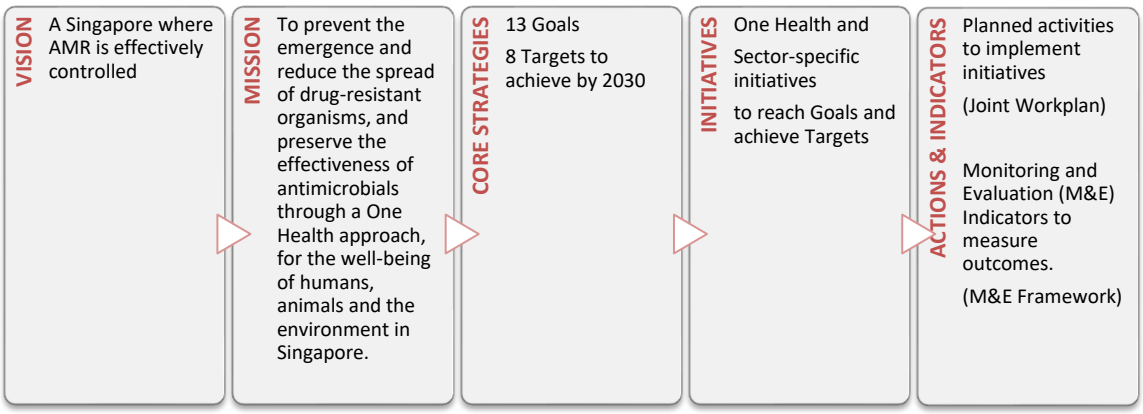
[6] One Health is described as an integrated, unifying approach that aims to sustainably balance and optimise the health of people, animals and ecosystems. It recognises that the health of humans, domestic and wild animals, plants, and the wider environment (including ecosystems) are closely linked and interdependent (34).

STRUCTURE OF NSAPV2

The NSAPv2 is driven by its **Vision** and **Mission**. The Vision and Mission are achieved through various initiatives under five **Core Strategies**:

1. Communication and Education,
2. Surveillance and Risk Assessment,
3. Research and Evidence,
4. Prevention and Control of Infection, and
5. Optimisation and Stewardship of antimicrobials.

Thirteen **Goals** describe the desired outcomes of each Core Strategy, while a set of **Targets** serve to drive more specific, focused and measurable actions. This document lays out the broad initiatives to be undertaken collectively and by each sector, in order to achieve the Goals of the Core Strategies and the Targets set.



Monitoring and Evaluation

The implementation of these initiatives is monitored via an **NSAP Joint Workplan**. This multi-sectoral Workplan details the planned activities, expected timelines, budget and responsible parties. It is designed on a five-year timeline and reviewed at least yearly.

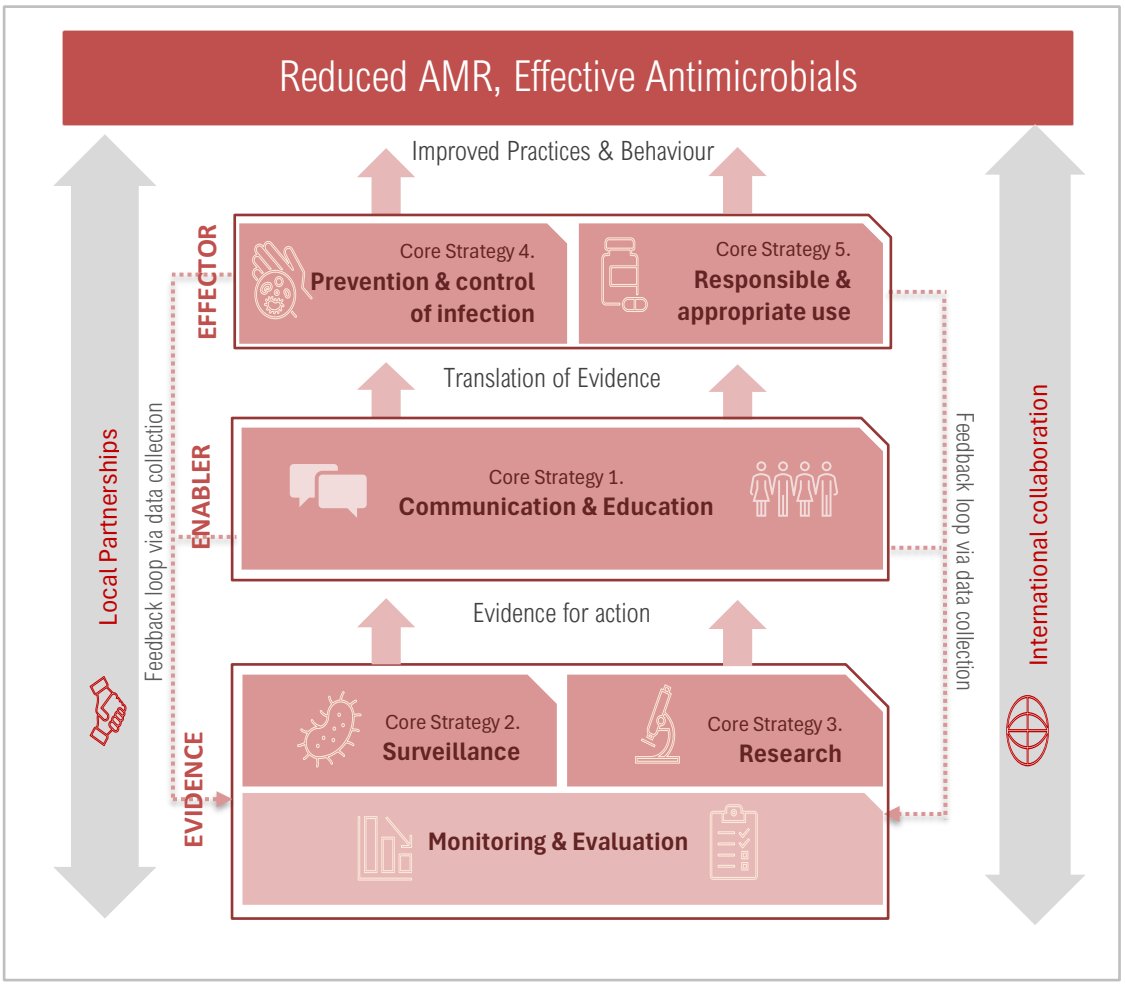
The **NSAPv2 Monitoring and Evaluation (M&E) Framework** monitors outcomes and outputs using selected indicators. The Framework is developed as a supplementary document to the NSAP and describes the indicators to be measured, and processes for data collection, reporting and evaluation. The Framework is reviewed every three to five years to ensure indicators monitored stay relevant.

Reduced AMR and the preservation of antimicrobial effectiveness are primarily brought about by **Prevention and Control of Infection** and **Optimisation and Stewardship** of antimicrobials (the effector strategies).

Evidence generated through **Surveillance and Risk Assessment**, and **Research and Evidence** (the evidence-generating strategies), as well as the **Monitoring** of key indicators, is translated into action via the enabler strategy, **Communication and Education.** This involves the education and engagement of stakeholders, and the communication of evidence, policy and best practices.

These **Effector, Evidence and Enabling strategies,** considered as the NSAP's five core strategies**,** work synergistically to achieve the Vision and Mission, and are underpinned by the principles of local partnerships and international collaborations (Figure 2).

Figure 2. Interaction of the five NSAP core strategies.



GOALS & TARGETS

Goals

Overarching goals

- **1**. Reduced impact of AMR on health and well-being.
- **2**. Reduced resistance and incidence of drug-resistant organisms.

Core Strategy 1: Communication and Education

- **3**. Improved awareness and behaviours concerning appropriate antimicrobial use and preventing the spread of infections.
- **4**. Evidence-based, up-to-date and practice-oriented professional education across sectors.

Core Strategy 2: Surveillance and Risk Assessment

- **5**. Timely and comprehensive picture of AMR and AMU within and across sectors.
- **6**. Data from surveillance guides policy, practice and behaviour change approaches.

Core Strategy 3: Research and Evidence

- **7**. Increased AMR research relevant to local policy and practices.
- **8**. Research evidence aids the formulation of national AMR strategies.

Core Strategy 4: Prevention and Control of Infection

- **9**. Strengthened and effective infection prevention and biosecurity practices.
- **10**. Increased uptake of vaccination and alternatives to reduce reliance on antimicrobials.
- **11**. Contamination of waters and environment by antimicrobials and AMR organisms and genes is minimised and mitigated.

Core Strategy 5: Optimisation and Stewardship

- **12**. Sustained access to essential, safe and effective antimicrobials to treat infections.
- **13.** Evidence-based and prudent use of antimicrobials is supported by regulatory controls and professional oversight.

Targets

The 2024 UNGA Political Declaration on AMR called on countries to update and implement multisectoral national action plans on AMR with national targets informed by analysis of existing capacities and priorities.[7] Targets give focus to our strategy and serve to provide clear direction and drive concrete action.

Singapore has set the following targets to achieve by 2030:

- Reliable estimates of deaths associated with AMR in sentinel healthcare facilities are obtained and reported.
- Antimicrobial stewardship programmes are implemented in all acute hospitals.
- Antibiotic prescribing guidelines for at least seven common primary care infectious disease conditions are developed and disseminated.
- The quantity (kg) of sales of fluoroquinolones to farms is reduced.
- A regulatory framework for antimicrobial use in the animal sector is established, including regulatory levers to ensure that antimicrobials used are safe, effective, and only supplied through prescription.
- Baseline levels of relevant antimicrobial resistant bacteria (ARBs) and antimicrobial resistance genes (ARGs) in sentinel environmental sites and water bodies are established.
- Levels of relevant ARBs and ARGs in the sentinel environmental sites and water bodies are reported at least yearly.
- Data from surveillance of priority drug-resistant organisms in the human, animal, food and environment sectors are integrated and correlated.

[7] The 2024 UNGA Political Declaration on AMR, para 24: "Ensure, by 2030, that all countries have developed or updated and are implementing multisectoral national action plans on antimicrobial resistance with national targets informed by analysis of existing capacities and priorities, with inclusive and effective national functioning multisectoral coordination mechanisms, and appropriate and sustainable human and financial resources, according to national contexts and priorities."

Core Strategy 01.

COMMUNICATION & EDUCATION

CORE STRATEGY 01. COMMUNICATION & EDUCATION

Our professionals, policy makers, industry and the public need to be informed of the AMR situation and best practices for its control. Outreach and training to increase awareness need to be delivered in ways appropriate for each target audience. Through effective communication, education and adopting behaviour change approaches, we aim to raise awareness and narrow the knowledge-practice gaps with respect to appropriate antimicrobial use and preventing the spread of drug-resistant organisms. In addition, we aim to ensure that professional education across sectors is evidence-based, up-to-date and practice-oriented.

Measures in place

In the public space, HPB has conducted annual campaigns since 2018 to raise awareness of AMR through education on appropriate antibiotic use, the consequences of misuse, as well as the importance of consulting and following the doctor's advice. Various activities have also been held to create awareness among children and youths (23). AMR is a component of local undergraduate and graduate healthcare professional programmes, as well as in the curricula of veterinary degree programmes recognised by Singapore. Since 2015, events to commemorate World AMR Awareness Week (WAAW) have been held at various hospitals, institutions and public forums, and participation is increasing. NParks regularly organises activities to raise awareness of AMR among local veterinarians, leveraging international events such as World Veterinary Day and WAAW. As veterinarians play a critical role in the control of animal diseases and in prescribing veterinary medicines, the active engagement of veterinary professionals is essential for a successful education campaign. In addition, SFA engages farmers on the importance of responsible usage of antimicrobials and educates them on good biosecurity, animal husbandry and farm management practices to reduce the need for antimicrobials.

Areas for further action

While we have made significant strides in raising awareness of AMR, there are still gaps to be addressed. These include insufficient knowledge beyond healthcare settings, insufficient awareness of AMR transmissibility across sectors, gaps in workforce training in some sectors, and limited community engagement and behavioural change strategies. Education efforts in the first phase of implementation were largely siloed by sectors, while healthcare and veterinary professionals had expressed the need for guidelines and patient education tools (14). In addition, we aim to improve health literacy and shared decision-making with respect to antibiotic use, as well as sustain infection prevention practices among the general population.

Goals

- **3.** Improved awareness of AMR and behaviours concerning appropriate antimicrobial use and preventing the spread of infections.
- **4.** Evidence-based, up-to-date and practice-oriented professional education across sectors

Initiatives

One Health

1.1 Develop a One Health AMR communication and education plan that includes tailored behavioural interventions addressing sector-specific contexts and motivations. This will ensure consistent AMR messaging across the One Health sectors, highlighting the interconnectedness of human, animal, and environmental health, and the transmissibility of AMR across sectors. A clear and coherent communication strategy on AMR is essential. Communication and education efforts will be synchronised and sustained, rather than ad hoc or confined to the WAAW. Educational initiatives that address both personal antibiotic usage and use for pets will be developed. Our education strategies will continue to leverage research to better understand the knowledge, attitudes and practices within the local context.

1.2 Sustain the awareness of infection prevention and good hygiene among the public through a multi-faceted approach that integrates education, infrastructure and community engagement. Post-COVID-19, it is important to continue to promote and reinforce infection prevention and good hygiene practices, such as hand hygiene and mask-wearing. Educating children on these practices will help to ensure that the next generation retains good hygiene habits *(linked to 4.2, Prevention and Control of Infection).*

1.3 Adopt behaviour change approaches. Education will extend beyond awareness-raising and incorporate behavioural science interventions. Community-based and participatory engagement methods will also be explored to increase interventions for AMR behaviour change.

1.4 Measure the effectiveness of communication and education efforts. Relevant behavioural indicators will be monitored through national surveys and studies to determine the knowledge, attitudes and practices towards AMR within and across sectors. The survey findings will guide improvements needed in future communications.

Professionals

1.5 Deliver up-to-date knowledge of AMR issues among healthcare and veterinary professionals. Topics on AMR and antimicrobial prescribing in existing undergraduate,

postgraduate and continuing education programmes should be kept up-to-date as new evidence emerges. Initiatives to improve the understanding of antimicrobial stewardship will also be introduced to primary care, veterinary health and agricultural sectors *(linked to 5.4 and 5.9, Optimisation and Stewardship).* Initiatives aimed at improving antibiotic prescribing in primary care will also be explored (24). We will also partner professional bodies and societies to educate professionals on good clinical practices in antimicrobial usage.

Industry

1.6 Increase awareness of AMR, prudent antimicrobial use and preventive measures among stakeholders in the animal and agriculture sector. Awareness campaigns will be expanded beyond veterinarians and farmers to include all relevant stakeholders in the sector, including the pet industry, feed manufacturers, and distributors of veterinary drugs. Education efforts will also promote prudent and responsible use of antimicrobials in animals, emphasising good animal husbandry and health management, prevention of infection via vaccination and biosecurity as essential tools to prevent and reduce the spread of disease.

1.7 Strengthen the knowledge and skills of the food-production industry, especially livestock farms, with respect to improved farming practices, biosecurity, antimicrobial use and increased awareness on disease management and prevention.

Public

1.8 Increase public awareness and understanding of AMR, including the importance of infection prevention practices, and using antibiotics appropriately for themselves and their pets. Ways in which to increase public awareness will include:

- **Embedding AMR-related messaging into relevant public campaigns** for greater reach where appropriate, such as for preventing respiratory disease, responsible pet ownership and food safety.

- **Increasing engagement of youths and young adults** as a priority audience for education efforts as the impact of AMR will be felt most acutely by future generations. We will continue to engage and partner the Ministry of Education (MOE) on outreach to students, so as to introduce concepts relevant to combatting AMR into their education journey. Innovative channels will be explored to deliver educational messages to younger adults who are less likely to be active seekers of health information (17).

- **Co-designing and implementing solutions through community engagement.** We aim to partner the community on education to improve public knowledge, awareness and practices related to AMR, infection prevention and appropriate antimicrobial use.

- **Improve health literacy of patients concerning antibiotic use** through targeted outreach and educational tools**.** Health literacy refers to the ability to

understand health information to make informed decisions. For example, in Singapore, over two-thirds of adults above 65 years old face challenges in reading, understanding and using health information resources (25).

- **Outreach to animal owners** to help them better understand their obligations and responsibilities as licensees with respect to vaccinations, welfare and seeking veterinary consult for treatment. Licensees include pet owners (cats and dogs), pet shops, pet animal breeding farms, and ornamental fish farms.

Core Strategy 02.

SURVEILLANCE & RISK ASSESSMENT

CORE STRATEGY 02. SURVEILLANCE & RISK ASSESSMENT

Strong surveillance and analytics capabilities are essential for generating reliable data that can be effectively used to guide the formulation of policy and practices, drive behaviour changes and measure the impact of interventions. To do so, surveillance data needs to be shared and communicated in a timely fashion. Synchronising One Health surveillance data will further facilitate cross-sector risk assessment and action. We thus aim to obtain a timely and comprehensive picture of AMR and AMU within and across sectors to improve our understanding of trends, linkages and risks. AMR surveillance will also include relevant behaviour and impact indicators; correlating surveillance information with behavioural indicators will help identify those behaviours that make an impact in reducing AMR.

Measures in place

In the human health sector, the National Antimicrobial Resistance Control Committee (NARCC) monitors trends of priority drug-resistant organisms and antimicrobial utilisation in acute care hospitals. NARCC is supported by two panels: the National Antimicrobial Resistance Expert Panel (NAREP) and the National Antimicrobial Stewardship Expert Panel (NASEP). The National Infection Prevention and Control Committee (NIPC) monitors healthcare-associated infections, including infections by drug-resistant organisms.

In the animal and food sectors, NParks collates and reports data on the sales of antimicrobials to farms and veterinary establishments to WOAH annually. NParks also monitors priority animal pathogens and indicator bacteria for AMR. Bacterial pathogens are also screened for drug resistance on request, to guide the treatment of pet animals. Food safety in Singapore is overseen by the SFA, which conducts monitoring of foodborne pathogens and indicator bacteria for AMR. The monitoring programme routinely tests food products collected from various points of the food chain for the presence of foodborne pathogens, AMR and antibiotic residues. Food products exceeding the maximum residue limits are prohibited for sale. Local farms are jointly monitored by SFA and NParks for production diseases and pathogens of public health concern, such as *Salmonella enterica* serovar Enteritidis in poultry.

NEA and PUB conduct studies to determine the baseline microorganism community and the diversity of environmental gene reservoirs of ubiquitous microorganisms in urban water bodies, water and used-water treatment processes. NEA's Environmental Health Institute and PUB's Water Quality Department are the national laboratories for environment and water testing, respectively. They monitor the trend and dynamics of gene reservoirs in the environment to guide risk assessment and mitigation measures.

Key findings from national surveillance programmes are reported in the One Health Report on AMR and AMU[8].

Areas for further action

Significant advances have been made in AMR surveillance across all sectors, while the collection of comprehensive AMU data remains a challenge. While there is joint reporting, surveillance is currently conducted separately and data analysed independently by each sector. The main gaps to fill lie in the expansion and integration of these capacities in a manner that supports timely joint analyses and risk assessment, in conjunction with the collection of behavioural and impact indicators, and making better use of data for policy and action.

Goals

- **5.** Timely and comprehensive picture of AMR and AMU within and across sectors is obtained.
- **6**. Data from surveillance guides policy, practice and behaviour change approaches.

Initiatives

One Health

2.1 Integrate surveillance for antimicrobial resistance and antimicrobial utilisation across human, animal, food and environmental sectors. This will help map the prevalence of AMR across all sectors and shed light on how specific resistance develops and spreads across sectors. Resistance data on drug-resistant organisms of interest across sectors will be integrated for joint analyses and risk assessment. Relevant AMR data will also be integrated with AMU data to determine impacts of use on resistance. Research will inform the design of integrated surveillance, such as identifying new targets for surveillance, and advanced methods of surveillance (including genomic analysis).

2.2. Establish a data-sharing governance framework and common database to facilitate timely collection and effective integration, analysis, sharing and use of data for action, leveraging existing national databases where available.

2.3 Improve timeliness of communication of surveillance findings to stakeholders. A public facing dashboard will be developed to improve access and frequency of communication.

[8] Available on CDA's website at www.cda.gov

2.4 Conduct risk assessments regularly according to national priorities. Results will be communicated to all relevant parties, such as decision makers and key field actors, for awareness-raising and action as needed.

2.5 Harmonise analytical methods across sectors. To enable joint analysis, methods for antimicrobial susceptibility testing and interpretation will be harmonised.

2.6 Identify relevant behaviour indicators for monitoring. Surveillance will extend beyond AMR and AMU to include monitoring relevant behavioural indicators. Suitable indicators will be identified through behavioural change research and monitored to determine the prevalence of undesirable behaviours and their associated factors. Examples of such behaviours could include patients requesting prophylactic antibiotics for future use, or the administering of antibiotics for prophylaxis in healthy puppies when they are sold as pets. Baseline levels of hygiene and infection prevention practices could also be established for comparison with behavioural change interventions.

Human

2.7 Expand surveillance to all relevant healthcare and community settings. Current surveillance programmes target the acute care hospitals: AMR, AMU and infection prevention and control (IPC) indicators are reported by public and private acute care hospitals to the MOH. Healthcare-associated infection and AMU point-prevalence surveys are also routinely conducted in public hospitals. We aim to expand surveillance in stepwise fashion to include all relevant hospital settings, including community hospitals. Community surveillance could be conducted through research studies or point prevalence surveys for feasibility. Sentinel primary care clinics have been enrolled in a pilot programme on antimicrobial use surveillance since 2019; we aim to increase the number of surveillance sites to improve representativeness of the data. There is also a need to correlate data obtained from hospitals with those from the community.

2.8 Enhance environmental AMR surveillance in healthcare facilities and community. Current surveillance in hospitals focuses on patient samples. However, the hospital environment plays a role in the transmission of drug-resistant microorganisms. Ways to enhance environmental surveillance to identify risk areas and develop viable solutions to reduce transmission in hospital settings will be explored. In collaboration with NEA and PUB, wastewater surveillance will also be explored to estimate AMR trends and patterns (*see 2.17 under Environment).*

2.9 Improve the comprehensiveness of national human antimicrobial consumption estimates. Reliance on market research sales data alone may be insufficient to reliably estimate the total national consumption due to incomplete coverage and poor correlation with actual utilisation. Other sources of antimicrobial consumption or utilisation data will be explored to obtain more comprehensive data to complement sales data. This will enable a clearer understanding of national consumption trends as well as support Singapore's participation in global AMU surveillance.

2.10 Develop appropriate methodology and mechanisms to measure and report on the number of deaths associated with AMR. Methodologies published by

international organisations and those used by countries reporting such data will firstly be examined. Thereafter, resources will be obtained to conduct the necessary studies in Singapore, with the aim to include this metric as a key health indicator for regular monitoring in the future. This initiative is vital to understanding the impact of AMR and providing baseline data for setting appropriate reduction targets in the next phase of implementation. This initiative supports the goal of the UNGA Political Declaration on AMR to reduce global deaths associated with AMR.[9]

2.11 Leverage technology to automate data extraction, analyses and reporting from central databases and information systems where available. Current data collection relies on manual processes. Available software and systems that have been developed and trialled in other countries will be explored for feasibility and adaptability.

Animal and Food

2.12 Expand AMR surveillance programmes to include all relevant food-production and animal sectors, according to national priorities. Surveillance of resistance will include key pathogens and indicator microorganisms. Surveillance priorities will use a risk-based approach, considering antimicrobials of veterinary and human health importance in the WOAH List of Antimicrobials of Veterinary Importance and the WHO List of Medically Important Antimicrobials respectively.

2.13 Improve AMU data collection from farms and veterinary industries to understand how antimicrobials are used in these establishments. This will identify trends, inform antimicrobial stewardship programs, and guide targeted interventions in the farms and veterinary industries. Understanding baseline usage will potentially inform the creation of benchmarks for AMU across the different types of farms and production systems. AMU data reported from local farms are useful for analyses and comparison with the AMR data to identify trends over time, to assess how antibiotic use correlates with patterns of resistance.

2.14 Improve the capability of national food chain AMR risk assessment through new techniques such as molecular epidemiology and quantitative risk modelling to estimate the health risks from antibiotic-resistant bacteria in specific foods for optimisation of risk management measures along the food chain.

2.15 Collaborate with international experts to develop, advance or improve AMR testing and result interpretation through harmonised methods for the animal health sector. This will help fill gaps in the availability of standards and methods to guide AMR testing and result interpretation in sectors with limited data or underdeveloped surveillance systems, such as aquaculture and animal health. This will include establishing and/or updating antimicrobial quality control values and epidemiological cut-

[9] UNGA Political Declaration on AMR, para 16. 'Commit to scale up action to be commensurate with the present burden of antimicrobial resistance, with the aim of reducing the global deaths associated with bacterial antimicrobial resistance by 10 per cent by 2030 against the 2019 baseline of 4.95 million deaths, and undertake to address the multifaceted and cross-cutting nature of antimicrobial resistance.'

off values (ECVs) for target bacteria species, as well as incorporating next-generation sequencing technologies for pathogen identification and understanding the transmission dynamics of antimicrobial resistant bacteria and genes (ARBs and ARGs) across sectors. Harmonised methods will enable AMR data and result interpretations to be compared between laboratories within and across borders for monitoring of global AMR trends. This also facilitates the production of quality data which can support antimicrobial stewardship.

Water and Environment

2.16 Develop an environmental surveillance system to gain a better understanding of the dynamics and prevalence of AMR in the environment and urban waters, including water bodies, waterways, recreational waters, and wastewater. Baseline prevalence of relevant ARBs and ARGs in priority water and environment surveillance sites will be established. This will enable trends and dynamics of gene reservoirs in the environment to be monitored over time.

2.17 Leverage wastewater surveillance to monitor ARB, ARG and other microbial indicators in the community. Wastewater surveillance for AMR will be explored by detecting and monitoring resistant bacteria, genes and other microbial indictors in local sewage systems. Monitoring wastewater over time may provide insights into the prevalence and spread of AMR in the community.

2.18 Conduct studies of residues in water and the environment to provide insights into antibiotic usage, which can potentially identify residue "hotspots". These studies will be further guided by the international development of science- and risk-based systems to analyse antimicrobial residues and resistance in the environment.[10]

[10] UNGA Political Declaration on AMR, para 101, 'Invite the Quadripartite organizations to consider, within existing resources, the development of a science- and risk-based system to analyse antimicrobial residues and resistance in the environment, complementary to, and, where appropriate, interacting with existing global surveillance systems'.

Core Strategy 03.

RESEARCH & EVIDENCE

CORE STRATEGY 03. RESEARCH & EVIDENCE

Research provides evidence to increase our understanding of AMR, including its emergence, spread, drivers and risk factors. Research also supports other Core Strategies by identifying the evidence gaps for control, the areas of innovation needed, and the decisions we need to make. Globally, a One Health priority research agenda for AMR has been developed (26), highlighting the areas where research is needed to fill the knowledge and evidence gaps. Locally, we need increased sectoral and cross-sectoral AMR research that are relevant to local policy and practices, including novel prevention methods to reduce reliance on antimicrobials. Such research should provide evidence that aids the formulation of strategies in other core pillars of the national plan.

Measures in place

Existing research to understand AMR in the human health sector includes cohort and genomic studies of extensively drug-resistant organisms, and development of new diagnostics, intervention approaches and novel therapeutics. In the non-human sector, research studies have been initiated to understand environmental gene reservoirs of ubiquitous, non-pathogenic microorganisms and their association with phenotypic expression. The mechanisms of AMR in foodborne pathogens are also being investigated.

A review of the AMR research landscape in Singapore from 2009 to 2019 showed an upward trend in the number of research articles published (27); however, the research landscape was observed to be fragmented, largely sector-specific and dominated by the human health sector. AMR research involving more than one sector was comparatively limited (27). Funding for AMR research was largely sector-specific, which limited the number of cross-sector research studies. A pilot programme, the One Health AMR Research Programme (OHARP), was launched in 2021 to fund One Health AMR research and drive cross-sectoral collaborations in three domains: transmission pathways; knowledge, attitudes and practices; and socio-economic impacts.

Areas for further action

These include expanding One Health and sectoral AMR research that supports the national agenda, securing resources for such research, and improving research collaborations across One Health sectors, disciplines, public agencies and academia. Specific research areas are outlined below.

Goals

- **7**. Increase in AMR research relevant to local policy and practices.
- **8.** Research aids the formulation of strategies of national AMR strategies.

Singapore's national research agenda for AMR

Even as AMR research accelerates around the world, domestic research initiatives remain essential to generate local evidence needed to inform local policies and practices. One Health AMR research will provide evidence to support the advancement of the core strategies of the NSAP (14). Distinct from academic research, key features of Singapore's AMR research agenda are:

- **Research for action,** highlighting that research must be relevant to and informs local policy and practices.
- **One Health approach** to foster cross-sector collaborations among researchers studying AMR in humans, animals, food, and the environment.
- **Multi-disciplinary perspectives,** acknowledging that the complexity of AMR requires expertise from diverse disciplines for collective action.

New knowledge and global developments will continue to shape the national agenda. The national AMR research agenda is therefore an evolving one that will be reviewed through consultative approaches as needed to ensure it continues to fulfil the research goals.

Initiatives

One Health

3.1 Expand the One Health AMR research programme to fund research that generates evidence needed to support the actions taken to combat AMR and help prevent cross-sectoral spread of infections. This will be done in consultation with experts across sectors, in academic research and with industry. The programme will be implemented in phases or funding cycles, with each phase building on the previous.

3.2 Increase opportunities for networking and research collaborations across One Health sectors, disciplines, public agencies and academia. This could occur through cross-sectoral seminars, workshops and technical sessions, including ways to improve the communication of such events to ensure their reach. Frameworks to facilitate information sharing and cross-sectoral collaboration in One Health AMR research will also be established.

3.3 Track the uptake and impact of research evidence and recommendations on efforts to control the spread of AMR, so that the long-term effectiveness of policies and

programmes can be assessed. Processes to systematically review evidence and recommendations arising from research will be put in place. Implementation science principles will be applied to promote uptake of actions in areas such as behavioural change. The research evidence needs to be communicated to policy makers, implementers and other relevant stakeholders upstream and downstream using suitable communication language, channels and platforms.

3.4 Areas for further One Health research relevant to the national AMR agenda include**:**

- Social and behavioural science interventions
- Risks of AMR gene transfer between animals, food and humans
- Impact and effectiveness of policies and programmes on AMR
- Social and economic impacts of AMR

Human

3.5 Areas for further research relevant to the national agenda include**:**

- Better understanding of the social, political, cultural, and behavioural aspects influencing AMR to design more effective interventions that cater to the needs of individuals, families, and the community (22).
- Antimicrobial stewardship research priorities, such as the impact of diagnostic stewardship compared to conventional stewardship.
- Assessing stakeholder behaviours, such as behavioural factors driving patients' demand for antibiotics and the impact on doctors' prescribing patterns.
- IPC research and clinical evidence to support good infection prevention and control practices for adoption by hospitals.
- Development of cost-effective point-of-care diagnostic tests relevant to antimicrobial stewardship, particularly for primary care settings.
- New antimicrobials or other strategies (such as phage therapy) to treat multidrug-resistant bacteria.
- Preventive care using non-antimicrobial alternatives e.g. vaccines.

Animal and Food

3.6 Areas for further research relevant to the national agenda include**:**

- Translational research for AMR in the food chain to advance the understanding of AMR transmission and source attribution in the food chain, as well as quantitative and qualitative studies to analyse the socio-economic burden of AMR. This will provide insights into the complex dynamics of AMR transmission.
- Transmission dynamics of ARBs and ARGs within the animal sector, including zoonotic pathways and environmental reservoirs.

- Risk assessment criteria tailored to AMR in the animal sector, focusing on high-risk activities, species and antimicrobial classes.
- Methodologies for AMR testing of animal pathogens where currently unavailable, particularly for pathogens in aquaculture and diseased terrestrial animals.
- Effectiveness of antimicrobial stewardship interventions in reducing AMU and AMR within different animal sectors.
- Behavioural drivers influencing AMU among veterinarians, farmers, and pet owners to design targeted educational and policy interventions.
- Alternative interventions, such as probiotics, vaccines and biosecurity measures on reducing AMR emergence, and their impacts.

Water and Environment

3.7 **Areas for further research** relevant to the national agenda include**:**

- Impact of anthropogenic activities on AMR levels and profiles in environments with varying degrees of human influence.
- Potential adverse impacts of climate change on AMR. Rising temperature may accelerate bacterial growth and mutation rates, potentially increasing AMR development. Extreme weather such as floods and storms may disperse resistant bacteria and genes across environments. Droughts may concentrate pollutants, potentially intensifying selective pressure for AMR.
- Appropriate detection methods and risk interpretation guidelines. As AMR surveillance in the water and environment sector is relatively nascent and international guidelines on risk assessment have yet to be developed, there is a need to develop locally- or regionally- relevant approaches for risk interpretation. This could be achieved through collaborations with international bodies for risk assessment criteria development.
- Robust risk assessment methodology for AMR in water and environment.

Core Strategy 04.

PREVENTION & CONTROL OF INFECTION

CORE STRATEGY 04. PREVENTION & CONTROL OF INFECTION

Every infection prevented is one opportunity less for antimicrobial use, and for organisms to develop resistance. Singapore's One Health approach to infection prevention and control is aimed at addressing the complex challenges posed by AMR and infectious diseases. Key tools crucial for effective infection prevention need to work synergistically. These include vaccination, healthcare infection prevention and control (IPC), water, sanitation and hygiene (WASH) measures, biosecurity, good animal husbandry and aquaculture practices, animal welfare, laboratory and disease diagnosis capabilities, food safety practices, clean water, waste management measures and personal hygiene. We aim to strengthen infection prevention and biosecurity practices in healthcare, veterinary care, farms and community settings, including increasing uptake of vaccination and suitable alternatives to antimicrobials. We also need to minimise and mitigate contamination of our waters and the environment by drug resistant organisms, antimicrobial resistant genes and antimicrobials.

Measures in place

At the population level, the National Childhood Immunisation Schedule (NCIS)[11] and the National Adult Immunisation Schedule (NAIS)[12] provide recommendations for the mandatory and recommended vaccines throughout an individual's life course. IPC programmes are mandated as part of hospital licensing requirements under the Healthcare Services (Acute Hospital Service) Regulations 2023. Hospitals' IPC programmes implement measures in accordance with national guidelines and directives developed jointly by the MOH and the National Infection and Prevention Control Committee (NIPC).

Food-producing farms in Singapore are licensed by SFA. SFA works with farms to promote and implement biosecurity and good animal husbandry practices to prevent and control disease. The use of vaccines for disease prevention is also encouraged. Vaccination is increasingly being applied in aquaculture, including the use of autogenous vaccines. In 2023, SFA introduced the Aquatic Animal Health Services (AAHS) scheme to provide health services for local farms to consult veterinarians or aquatic animal health professionals on disease management and diagnosis. Dogs and cats imported or bred in

[11] The National Childhood Immunisation Schedule offers vaccination against important childhood infections, including tuberculosis, diphtheria, pertussis, measles and influenza, of which diphtheria and measles immunisations are mandatory under the Infectious Diseases Act 1976.

[12] The National Adult Immunisation Schedule (NAIS) provides a framework for vaccine recommendations in adults, including influenza and pneumococcal vaccinations. Vaccines recommended under the NAIS aim to prevent infections among susceptible individuals and reduce complications, morbidity and mortality.

Singapore for sale in pet shops undergo mandatory vaccination as stipulated by NParks, while routine vaccination is carried out for horses and companion animals.

NEA enforces the Environmental Public Health (EPH) (Registrable Aerosol-generating Systems) Regulations 2021 for cooling towers and other aerosol-generating systems, while recirculating aquatic facilities such as swimming pools, multi-use spa pools and water playgrounds are regulated under the EPH (Licensable Aquatic Facilities) Regulations 2021. To protect water resources, Singapore's sewerage and drainage systems are segregated to prevent cross-contamination between surface water and wastewater. The Deep Tunnel Sewerage System conveys wastewater to centralised water reclamation plants. Treated effluents from these plants are either discharged via long outfalls far out into the sea or channeled for NEWater production. The reverse osmosis and ultra-violet disinfection processes in NEWater treatment effectively remove antibiotics and bacterial pathogens.

Areas for further action

While the rates of some AMR pathogens have declined, rising rates of others such as carbapenemase-producing Enterobacterales (CPE) continue to be a concern. Strengthening and sustaining good infection prevention practices among professionals, industry and the public, as well as improving vaccination uptake, continue to be essential to our strategy.

Goals

- **9.** Strengthened and effective infection prevention and biosecurity practices.
- **10.** Increased uptake of vaccination and alternatives to reduce reliance on antimicrobials.
- **11.** Contamination of waters and the environment by antimicrobials and AMR organisms and genes is minimised and mitigated.

Initiatives

One Health

4.1 Strengthen One Health understanding of infection prevention and controlling AMR spread. By promoting infection prevention and control from the One Health perspective and reinforcing the One Health framework, we can take a comprehensive approach that mitigates risks at the human-animal-environment interface.

4.2. Maintain good personal hygiene and sanitation among the public and in the community as a means of preventing infections and onward transmission of drug-resistant infections. The COVID-19 pandemic has shown that good societal culture and

practices, such as wearing masks when ill or staying home when unwell, can effectively reduce the transmission of pathogens, which consequently reduces the likelihood of unnecessary antibiotic prescriptions. Maintaining environmental hygiene of shared spaces are important preventive measures, as toilets, sinks and hand dryers in communal washrooms have also been shown to be vehicles for drug-resistant infections. Other approaches include instituting infection prevention in workplaces and schools, and regularly communicating food safety practices to consumers.

Human

4.3 Increase the uptake of vaccination among adults to reduce the number and severity of infections, thereby reducing potential need for antimicrobials. Rates of adult vaccinations have increased with the introduction of subsidies but could be further improved. Ways to increase uptake of vaccination among adults will be explored.

4.4 Enhance infection prevention and control measures in healthcare settings. A strong infection prevention and control programme is critical for containing multidrug-resistant organisms in the hospital setting to prevent nosocomial acquisition and spread of AMR. Infection prevention and control measures in hospitals are constantly being reviewed and strengthened. This could also involve exploring engineering solutions and improving healthcare infrastructure and reducing overcrowding to support IPC. Behaviour change approaches will be explored to strengthen and sustain staff compliance with IPC practices.

4.5 Devise targeted approaches to reduce the incidence of CPE in healthcare settings. CPE is a growing concern locally and worldwide. A multidisciplinary Technical Advisory Group on CPE, comprising experts in IPC, antimicrobial stewardship and related fields, will be convened to recommend further targeted actions to reduce CPE infections.

Animal and Food

4.6 Promote and facilitate the use of vaccines and alternatives to antimicrobials in livestock (including aquaculture) and pets. It is important to provide access to safe and effective vaccines for disease prevention and to reduce reliance on antimicrobials. Activities will be undertaken to promote the benefits of vaccination to the farming industry, the veterinary sector, and pet owners. The vaccine evaluation processes will also be reviewed to facilitate the import of safe and effective vaccines. Vaccine and feed companies will also be encouraged to develop monitoring and management strategies with farms, to reduce the reliance of antimicrobials. In addition to vaccines, other alternatives to antimicrobials could include alternative feeds and feed additives to promote animal health and enhance disease resistance through improved nutrition.

4.7 Improve animal health management practices in pet breeding establishments. Good animal management practices reduce the occurrence of infectious diseases in animals, leading to a reduced need for veterinary antimicrobials. Reliance on antimicrobials will be reduced through strengthening disease prevention and

control, animal welfare regulations and guidelines, and the promotion of best practice guidelines on good animal husbandry and biosecurity.

4.8 Work with farms to develop comprehensive farm management plans that strengthen biosecurity to prevent the introduction and spread of pathogens. Farms will be required to develop management plans that aim to reduce risks to food safety, reduce the transmission of disease and ensure sustainable production. Sea-based fish farms will also need to state how they will manage water and sediment quality as good water quality is crucial for fish health and reduces their susceptibility to diseases.

Water and Environment

4.9 Regular monitoring for risk assessment and mitigation. Preliminary studies by NEA and PUB show lower levels of antimicrobial resistance bacteria and antimicrobial resistance genes (ARBs and ARGs) in coastal water and reservoir sites compared to waterways (11; 12). Regular monitoring of Singapore's waters and environment plays an important role in identifying possible sources and the risk of contamination by antimicrobials, ARGs and ARBs.

Core Strategy 05.

OPTIMISATION & STEWARDSHIP

CORE STRATEGY 05. OPTIMISATION & STEWARDSHIP

Optimal antimicrobial treatment requires the use of safe, effective antimicrobials in tandem with good antimicrobial stewardship. This will minimise the risk of AMR, protect patient safety and preserve the long-term efficacy of these critical medicines. We therefore need sustained access to essential, safe and effective antimicrobials to treat human and animal infections. Moreover, optimal use is also informed by timely and reliable diagnostic testing. Physicians' medical knowledge and clinical competency, good clinical practice, availability of diagnostic tests, and desire to improve clinical practice are factors significantly associated with low antibiotic prescribing in human health (24). Good stewardship also includes the proper disposal of antimicrobials to prevent environmental contamination which could promote the development of resistance in microorganisms found in the environment. Licensing, regulatory controls and professional oversight are essential to support stewardship measures, improved evidence-based and prudent use of antimicrobials in human health, animal health and food-production.

Measures in place

Therapeutic products, including antimicrobial agents, are regulated under the Health Products Act 2007 and its subsidiary legislation. Antimicrobials are prescription-only medicines and can only be obtained when prescribed by licensed healthcare professionals. Antimicrobial stewardship programmes (ASPs) have been instituted in public acute hospitals since 2011. These are implemented through institutional ASP teams consisting of physicians, pharmacists and executive personnel. Clinical microbiologist support is crucial to effective ASP. ASP in public hospitals is further aided by computerised decision support systems to guide clinicians in making appropriate antimicrobial drug choices. Relevant ASP indicators are collected bi-annually by NARCC for annual reporting to MOH. To aid more appropriate prescribing in primary care, guidelines, such as the ACE Clinical Guidelines (ACGs)[13], have been developed for the treatment of common conditions seen in primary care.

Antimicrobials are not permitted for growth promotion use in Singapore food-producing animal farms and not allowed in animals ready for slaughter. Certain antimicrobials, such as nitrofurans, chloramphenicol and avoparcin, are also prohibited for all uses in feed and food-producing animals. SFA enforces limits on antimicrobial residues in food products; enforcement action is taken when drug residues exceed the maximum residue levels or when prohibited substances are detected in food products. NParks is in the process of strengthening legislation to regulate veterinary use of human therapeutic

[13] ACE: Agency for Care Effectiveness, MOH. ACGs developed include guidelines for Urinary Tract Infections (UTI), 2023; Upper Respiratory Tract Infection (URTI), 2026; Community Acquired Pneumonia (CAP), 2026; Skin and Soft Tissue Infection (SSTI), 2026. For full list of ACGs, refer to https://go.gov.sg/all-acg.

products, to implement a system of veterinary drug registration, and to require prescription for all veterinary antimicrobials, including those used in livestock and aquaculture. To guide appropriate prescribing in the veterinary sector, guidelines[14] for prudent use of antimicrobials in companion animals were also established.

To safeguard the environment, PUB enforces the Sewerage and Drainage Act 1999 and the Sewerage and Drainage (Trade Effluent) Regulations to ensure all trade effluent discharged into the public sewerage system comply within stipulated water quality limits. Stringent regulations are also in place to ensure the proper collection, treatment and disposal of pathogenic waste and pharmaceutical waste (including antibiotics) by toxic industrial waste collectors licensed by NEA. Manufacturing and healthcare facilities typically have licensed waste disposal systems in place.

Areas for further action

The main gaps to address lie in the wider implementation of antimicrobial stewardship and regulatory controls for veterinary drugs, to ensure more appropriate and judicious use of antimicrobials in human and animal health. Up-to-date national antibiotic use guidelines are also needed in the primary care setting (24; 28).

Goals

- **12**. Sustained access to essential, safe and effective antimicrobials to treat infections.
- **13**. Evidence-based and prudent use of antimicrobials, supported by regulatory controls and professional oversight.

Initiatives

One Health

5.1 Foster interdisciplinary collaboration between animal and human health professionals on antimicrobial stewardship. This contributes towards the common goal of appropriate antimicrobial use across sectors. Sharing and adoption of evidence-based practices based on sector-specific requirements could be drawn from parallels in antimicrobial stewardship practices in healthcare settings and monitoring of antimicrobial use.

5.2. Map the disposal of antimicrobials along the entire supply chain, from manufacturing, suppliers, prescribers, laboratories, animal facilities and other users. Understanding disposal by all other users along the supply chain will allow a more

[14] Guidelines for the Prudent Use of Antimicrobials in Companion Animals, 2021 (36)

comprehensive understanding of how antimicrobials are handled and disposed, and the development of appropriate education initiatives as needed.

Human

5.3 Strengthen antimicrobial stewardship in hospitals. Collaborative work will be coordinated among public and private hospitals on improving antimicrobial stewardship. Antimicrobial stewardship in other healthcare facilities such as the community hospitals and subacute care facilities will also be explored. This will also involve strengthening local expertise through training and improving the recognition of ASP. In addition, innovative strategies and tools will be explored to optimise antimicrobial use, including the use of artificial intelligence to guide appropriate prescribing (29).

5.4 Facilitate appropriate antimicrobial use in the community. Primary care accounts for most of antibiotic use in Singapore. To improve appropriate use, we will need insights into community antimicrobial prescribing patterns in primary care, potentially via point prevalence surveys or research studies. A study found that most general practitioners, or GPs, (82.7% of 427 respondents) felt that antibiotics were overprescribed in primary care. Low antibiotic prescribing was associated with good medical knowledge and clinical competency, good clinical practice, availability of diagnostic tests and desire to improve clinical practice. The practice of giving antibiotics 'to be on the safe side' was significantly less likely to be associated with low antibiotic prescribing (24). Interventions to reduce inappropriate antibiotic prescribing will take into consideration these findings. Suitable models of ASP will also be explored in consultation with primary care physicians.

5.5 Equip healthcare professionals with up-to-date, evidence-based guidelines to guide prescribing and reduce over-reliance on broad-spectrum antibiotics. Antibiotic prescribing guidelines for primary care will be developed to cover common conditions treated in primary care, taking the local antibiogram into consideration. Guidelines need to be evidence-based, kept up-to-date and could include areas such as new antimicrobials, paediatric dosing and allergy de-labelling. Ways to incentivise uptake and compliance will also be explored. Information on community drug resistance profiles will also be shared to inform better prescribing.

5.6 Improve shared decision-making (SDM) to enhance antimicrobial stewardship. Shared decision-making is a collaborative process where patients and clinicians make a treatment decision together through proactive exploration of patients' needs and concerns. Empowering patients through their involvement in the decision-making process (15), interactions with healthcare professionals, and control of their hospital care can increase their participation in SDM on antibiotic therapy in hospitals (30). Education tools and decision aids will be developed to equip patients with the right information to make informed choices and support SDM.

5.7 Promote diagnostic stewardship to guide antimicrobial use. Increased use of diagnostic testing to avoid unnecessary antibiotic use will be encouraged from a value-driven care perspective. Access to affordable point-of-care or rapid diagnostic tests to

help doctors determine if an infection could be caused by a virus can help to reduce unnecessary prescribing of antibiotics. This would be supported by the relevant research to develop cost-effective and rapid point-of-care tests.

Animal and Food

5.8 Establish a robust regulatory framework for supply chain control of all veterinary health products including antimicrobials. A sound regulatory framework will ensure responsible supply and use of safe and effective antimicrobials along the entire supply chain. This will be achieved by veterinary drug registration and supply chain control covering import, manufacture, distribution and sale. Veterinary drug registration will encompass minimal labelling standards (e.g. active ingredient(s), concentration, recommended dosage and directions) to ensure that they are used appropriately. These regulatory levers will ensure that veterinary health products sold in Singapore are safe, effective and supplied only through prescription.

5.9 Develop national guidelines for antimicrobial use for the different animal sectors with input from industry, and ensure updates take into account current scientific evidence. Drug resistance profiles of animal pathogens in the community will be collated and communicated to guide prescribing and used to complement national treatment guidelines.

5.10 Develop tools to support effective communication by veterinarians to mitigate pet owners' expectations to address inappropriate antibiotic prescribing (31). This includes fostering SDM between pet owners and veterinarians (31). Similar to SDM in human health, SDM between pet owners and veterinarians on treatment decisions can lead to more appropriate antimicrobial treatments. Education tools and decision aids will be developed to support SDM in veterinary care.

Water and Environment

5.11 Explore wastewater surveillance to understand population-level antimicrobial consumption patterns and inform stewardship strategies. This could be achieved through detecting and quantifying antimicrobial residues and resistant organisms in wastewater.

5.12. Monitor effluent discharges from water reclamation plants to the sea. We aim to build up monitoring data for treated effluent to understand the load of antimicrobial residues, antimicrobial resistant bacteria and antimicrobial resistant genes to the marine environment.

LOCAL PARTNERSHIPS & INTERNATIONAL COLLABORATION

LOCAL PARTNERSHIPS

Partnerships help strengthen our efforts across all core strategies. In addition to close collaboration among public sector agencies, public-private partnerships help us leverage the private sector's expertise, innovation capabilities and reach to address the complex challenge of AMR. Since 2021, private sector healthcare professionals have been represented on national AMR committees in the human health sector, such as on NARCC. In the agriculture sector, SFA rolled out the Aquatic Animal Health Services (AAHS) schemes engaging private sector veterinarians to provide professional consultation and disease management services to local fish farms.

In this context, the private sector includes (but not limited to) human healthcare and veterinary health professionals, research institutes, Institutes of Higher Learning (IHLs), and the industry (such as pharmaceutical, food production, trade, pet and ornamental fish).

Strengthen multisectoral collaboration

P1. Further strengthen One Health collaboration and coordination among implementing agencies. To the extent appropriate, multisectoral coordination mechanisms and structures will be further formalised, documented, reviewed, evaluated and updated on a regular basis.

Education and Outreach

P2. Partner private sector professionals in public and professional education. Primary care doctors were identified as highly valued educators for infection prevention, antibiotic use and AMR, and seen as trusted sources of information by members of the community (15; 18). Private sector health and veterinary professionals are therefore important partners in the education of the public and pet owners, while IHLs, such as local universities and polytechnics, are valuable resources of technical expertise. Up-to-date knowledge to support professional education, guidelines for use in primary and veterinary care will be developed together with private sector professionals. Combining the trusted role of a doctor/veterinarian with the dissemination of scientific evidence will be important in our outreach strategy (15). We aim to increase the involvement of private sector professionals in continuing professional education events, and partner private sector and industry professionals to improve the knowledge of farmers on AMR, good biosecurity measures and disease control. Opportunities for the sharing of best practices among respective industries, both local and international, will be created.

P3. Support doctor-patient/client communication by equipping primary care and veterinary professionals with up-to-date patient/client education materials. Informative materials, such as take-home or digital education materials for patients, parents and pet owners will be developed in partnership to aid engagement.

Innovative Solutions

P4. Foster partnerships with industry and facilitate their research and development efforts. The investment in new medicines, vaccines, diagnostic tools and other products to counter AMR is a long-term one, and partnerships with industry will be vital to ensuring sustainability. Support is needed on two levels: to promote prudent use of antimicrobials to prolong their effectiveness; and to develop new medicines and technologies to overcome AMR.

P5. Develop joint solutions with industry to reduce reliance on antimicrobials, leveraging what each sector values most. Several feed producers, vaccine developers and academic institutions based in Singapore conduct research to develop viable alternatives for the farming industry, such as vaccines, pre- and probiotics, compounds to improve gut health and food absorption, and technologies for pathogen control to reduce reliance on antimicrobials. Under collaborative environments, new and viable solutions that align AMR-reducing practices with profitability could be developed, such as better packaging, clearer labelling on treatment products for farm use or promoting food from animals raised according to prudent use principles.

INTERNATIONAL COLLABORATION

International collaboration is crucial as AMR is a global health threat that transcends borders. The spread of drug-resistant organisms is facilitated by the international movement of people, animals, food and other products. As an international trade and travel hub, Singapore is susceptible to the risk of imported AMR. Therefore, only by extending our efforts beyond local borders can AMR be truly tackled. International collaboration is crucial to combat antibiotic misuse in food production and enhance food safety.

Alongside our international partners, Singapore has been actively participating in guideline development and capacity building. Moving ahead, our international and regional engagements aim to achieve the goals of the Global Action Plan on AMR and the ASEAN Strategic Framework to Combat AMR through a One Health Approach, with focus on the following: (i) Pursuing alignment; (ii) Strengthening partnerships; (iii) Supporting surveillance; (iv) Collaborating in innovation and research; and (v) Benchmarking for our continuous improvement.

Pursue international and regional alignment.

IC1. Align with the directions of the Quadripartite (FAO, WHO, WOAH and UNEP) as relevant to national interests. Singapore's NSAP is aligned with the Global Action Plan on AMR, and we are committed to global cooperation to achieve the goals of the 2024 UNGA Political Declaration on AMR.

IC2. Adopt international standards and best practices to enable harmonisation of methods, comparability of data and implementation of best practices, adapted to the national context. International standards, such as the Clinical and Laboratory Standards Institute (CLSI) and European Committee on Antimicrobial Susceptibility Testing (EUCAST), are adopted for antimicrobial susceptibility testing across One Health sectors. National practices on infection prevention and control (IPC), biosecurity, surveillance and risk assessment take guidance from WHO, WOAH, FAO guidelines and standards.

Strengthen international and regional partnerships.

IC3. Support the work of the Quadripartite organisations. Singapore is a member of FAO, WHO, WOAH and UNEP. We will continue to collaborate through our technical experts and collaborating centres, and take active participation in international standard setting and guideline development. Specific to the region[15], Singapore has ongoing close collaborations with the FAO's Regional Asia Pacific (RAP) office to tackle AMR in the food and agriculture sector. Through various AMR regional projects such as the development of guidelines and improving capacities of AMR surveillance in laboratories and countries

[15] Depending on the project, 'regional' could refer to Asia, Asia-Pacific, the UN Western Pacific Region (WPR) and Southeast Asia (SEA) regions, or the WOAH Asia and the Pacific region.

in the region, Singapore aims to positively impact the reduction of AMR spread in the food and agriculture sector in the region.

IC4. Collaborate with countries to pursue areas of common interests in advancing capacities for addressing AMR, such as through bilateral or multi-lateral technical cooperation, and sharing best practices in governance and implementation.

Support global and regional surveillance.

IC5. Contribute to global data sharing platforms. Robust global surveillance contributes to a better understanding of the AMR situation around the world, enabling more coordinated response strategies. Singapore will continue to participate in global AMU and AMR data sharing initiatives such as WHO's Global Antimicrobial Resistance and Use Surveillance System (GLASS)[16], the WOAH's ANImal antiMicrobial USE Global Database (ANIMUSE)[17]and International FAO Antimicrobial Resistance Monitoring (InFARM)[18] . Gonococcal resistance is reported to both WHO Gonococcal Antimicrobial Surveillance Programme (GASP) and GLASS, while multidrug-resistant TB rates are reported to WHO's Global Project on Anti-Tuberculosis Drug Resistance Surveillance.

IC6. Sustain regional AMR surveillance capabilities in the food and agriculture sector. A key tool is the FAO Assessment Tool for Laboratories and AMR Surveillance Systems (ATLASS). ATLASS provides a comprehensive framework for evaluating and improving national AMR surveillance systems and laboratory capacities in the food and agriculture sector. Singapore has been working closely with FAO to support regional capability building in the use of the FAO-ATLASS tool in the food and agriculture sector as well as participating in ATLASS missions to build surveillance capacity in the region.

Collaborate on innovation and research.

IC7. Forge international research collaborations on AMR. Tapping on partnerships with international health research funding agencies will enable more efficient use of research funding and resources. Singapore researchers are partners in multiple international initiatives, including global point prevalence surveys on human antimicrobial use and resistance. We will continue to collaborate with the regional and global scientific community to improve understanding of drug-resistant infections.

Benchmark for continuous improvement.

IC8. International benchmarking. Participating in global surveillance and harmonising surveillance methodologies enable us to benchmark Singapore's efforts in controlling AMR and may highlight areas for improvement. We aim to draw lessons from best practices of countries that have been successful in combating AMR in their specific

[16] Global Antimicrobial Resistance and Use Surveillance System (GLASS) (who.int)
[17] ANIMUSE (woah.org)
[18] InFARM System | Antimicrobial Resistance | Food and Agriculture Organization of the United Nations (fao.org)

areas. We will continue to participate in international assessments and evaluations, such as FAO ATLASS and WHO's International Health Regulations Joint External Evaluation (IHR JEE), and incorporate results from these into our monitoring and evaluation to identify areas for improvement.

IC9. Monitoring global AMR indicators. We will continue to participate in the Tracking AMR Country Self-assessment Survey (TrACSS) and improve the collection of global indicators, such as the Sustainable Development Goals (SDG) AMR indicators[19] . These indicators will also be monitored at the national level for benchmarking and continuous improvement.

Serve as a regional hub

IC10. Establish a regional collaborating centre. To strengthen regional capacity and coordination, Singapore will continue to advance solutions on the reduction of AMR regionally. This may be achieved through the establishment of regional collaborating centre(s) for advocacy, capacity building, training and/or research in AMR, in partnership with national and international organisations in both public and private sectors.

ASEAN Cooperation on AMR

The Southeast Asia region has been described as a high-risk region for AMR (32). Recognising the need for concerted action in the region, member states of the Association of Southeast Asian Nations (ASEAN) made key commitments to combat AMR through the 2017 ASEAN Leaders' Declaration (ALD) on AMR. To operationalise the ALD, the ASEAN Strategic Framework to Combat AMR through One Health Approach (ASF-AMR) (33) was developed under the leadership of the Philippines. Subsequently, Thailand and Singapore led the development of a Monitoring and Evaluation (M&E) framework in 2024 to track progress of the ASF-AMR.

Aligned with these developments, Singapore's efforts in ASEAN will focus on the following areas:

IC11. Support the implementation of the ASF-AMR. Singapore will continue to work with ASEAN Member States, the ASEAN Secretariat and other relevant ASEAN bodies to implement, monitor and evaluate the ASF-AMR. The ASF-AMR will be implemented through the ASF-AMR Implementation Plan led by the ASEAN Health Division (AHC2), as well as the action plans of the ASEAN Sectoral Working Group for Livestock (ASWGL), the ASEAN Sectoral Working Group for Fisheries (ASWGFi) and other relevant sectoral groups. Progress of the ASF-AMR will be monitored via regular regional reporting.

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[19] Proportion of bloodstream infection due to methicillin-resistant *Staphylococcus aureus* (MRSA) (%) (who.int) and proportion of bloodstream infection due to *Escherichia coli* resistant to third-generation cephalosporins (%) (www.who.int).

IC12. Strengthen and harmonise regional capacity and capability. Singapore plays an active role as the lead country for coordinating AMR activities in the ASEAN Livestock and Fisheries sectors. This includes leading the joint development of regional guidelines; harmonisation of veterinary drug requirements; strengthening of regional laboratory capacity through training; and collaboration with international agencies such as FAO and WOAH. We will continue to partner ASEAN Member States and international organisations to build up regional capacity and capability for AMR testing and control, as relevant to the needs of the region. In the area of antimicrobial stewardship, the annual Singapore Antimicrobial Stewardship Training Course (SASTC) introduces local and regional participants to the knowledge, skills and best practices that are needed to implement ASPs in their institutions. We will continue to work with partners and countries to strengthen ASP in the region.

CONCLUSION

Recognising that long-term and sustained efforts are required to contain and control AMR, the second NSAP builds on the achievements of the first, with greater emphasis on measuring effectiveness and impact.

Moving ahead, we aim to adopt a more proactive approach to policy formulation, prioritising sustainability through the identification of outcomes, key monitoring indicators and associated actions. NSAPv2 takes a long-term view and is designed to be adaptable and iterative, taking into account the local context and integrating new evidence through feedback loops.

REFERENCES & GLOSSARY

REFERENCES

1. *Antimicrobial resistance: Tackling a crisis for the health and wealth of nations.* **Review on AMR, led by O'Neill, J.** 2014.

2. *Global burden of bacterial antimicrobial resistance 1990–2021: a systematic analysis with forecasts to 2050.* **GBD 2021 Antimicrobial Resistance Collaborators.** 2024, Lancet , Vol. 404, pp. 1199–226.

3. **One Health AMR Workgroup.** *Singapore's National Strategic Action Plan on AMR.* 2017.

4. *Estimating the excess bed days and economic burden of health-care associated infections in Singapore public acute-care hospitals.* **Cai Y, Venkatachalam I, Kwa A, Tambyah P, Hsu LY, Marimuthu K and Graves N.** 9, s.l. : Infection Control & Hospital Epidemiology, 2021, Vol. 43.

5. *Estimating the economic cost of carbapenem resistant Enterobacterales healthcare associated infections in Singapore acute-care hospitals.* **Cai Y, Hoo GSR, Lee W, Tan BH, Yoong J, Teo Y-Y, et al.** 12: e0001311, s.l. : PLOS Global Public Health, 2022, Vol. 2.

6. *The attributable mortality, length of stay and healthcare costs of methicillin-resistant Staphylococcus aureus infections in Singapore.* **Cai Y, Philip EC, Arora S, Sim J XY, Chow W, Nazeha N et al.** 100427, s.l. : IJID Regions, 2024, Vol. 12.

7. **Institute of Health Metrics Evaluation.** *The burden of antimicrobial resistance (AMR) in Singapore.*

8. *One Health Report on Antimicrobial Utilisation and Resistance 2021, Singapore.* **One Health Antimicrobial Resistance Workgroup.** Published in 2024.

9. *Relating knowledge, attitude and practice of antibiotic use to extended-spectrum beta-lactamase-producing Enterobacteriaceae carriage: results of a cross-sectional community survey. BMJ Open2019;9:e023859. doi:10.1136/bmjopen.* **Mo Y, Seah I, Lye PSP, et al.** 2019, BMJ Open, Vol. 9, p. e023859.

10. *Prevalence and genomic analysis of ESBL-producing Escherichia coli in retail raw meats in Singapore.* **Guo S, Aung KT, Leekitcharoenphon P, Tay MYF, Seow KLG, Zhing Y, Ng LC, Aerestrup FM, Schlundt J.** 2021, J Antimicrob Chemother, Vol. 76, pp. 601-605.

11. *One Health Report on Antimicrobial Utilisation and Resistance, Singapore, 2019.* **One Health Antimicrobial Resistance Workgroup.** Published in 2021.

12. ***NEA, manuscript in preparation.***

13. ***Disease Policy and Strategy Division, and Health Analytics Division, Ministry of Health and Health Promotion Board, Singapore.*** *National Population Health Survey.*

Singapore : Disease Policy and Strategy Division, and Health Analytics Division, Ministry of Health, Republic of Singapore, 2023. ISBN 978-981-18-7201-3.

14. ***Health Intervention and Policy Evaluation Research (HIPER).*** *Evaluation of the National Strategic Action Plan on AMR in Singapore (2017-2023) (unpublished). Saw Swee Hock School of Public Health, NUS. Singapore : s.n., 2024.*

15. "Antibiotics are for everyone, our past and our future generations, right? If antibiotics are dead, we will be in big trouble": Building on community values for public engagement on appropriate use of antibiotics in Singapore. ***Guo H, Hildon ZJ-L and Chow A.*** *2022, Front. Public Health, Vol. 10:1001282.*

16. Health Information Orientation Profiles and Their Association with Knowledge of Antibiotic Use in a Population with Good Internet Access: A Cross-Sectional Study. ***Guo, H., Lim, H.Y. and Chow, A.*** *2022, Antibiotics, Vol. 11:769.*

17. The Associations between Poor Antibiotic and Antimicrobial Resistance Knowledge and Inappropriate Antibiotic Use in the General Population Are Modified by Age. ***Guo, H., et al.*** *2022, Antibiotics, Vol. 11:47.*

18. Relating knowledge, attitude and practice of antibiotic use to extended-spectrum beta-lactamase-producing Enterobacteriaceae carriage: results of a cross-sectional community survey. ***Mo Y, Seah I, Lye PSP, et al.*** *2019, BMJ Open 2019, p. 9:e023859.*

19. Public knowledge, attitudes and practices related ti antibiotic use and resistance in Singapore: a cross-sectional population survey. ***Lim JM, Duaong MC, Cook AR et al.*** *2021, BMJ Open, Vol. 11, p. e048157.*

20. Pet owners' knowledge of antibiotic use and antimicrobial resistance and their antibiotic practices: Comparison between contexts of self and pet. . ***Aithal S, Guo H, Teo BH, et al.*** *2, 2025, Antibiotics, Vol. 14, p. 158.*

21. A Qualitative Study on the Implementation of the National Action Plan on Antimicrobial Resistance in Singapore. ***Chua AQ, Verma M, Villannueva SVA, Roxas E, Hsu LY, Legido-Quigley H. A.*** *12 (8), 2023, Antibiotics (Basel), Vol. 31, p. 1258.*

22. Combating Antimicrobial Resistance in Singapore: A Qualitative Study Exploring the Policy Context, Challenges, Facilitators and Proposed Strategies. ***Singh SR, Chua AQ, Tan TS, Tam C, Hsu LY and Legido-Quigley.*** *4, 2019, Antibiotics, Vol. 8.*

23. ***One Health Antimicrobial Resistance Workgroup.*** *National Strategic Action Plan on AMR Progress Report 2018 - 2020. Singapore : s.n., 2021.*

24. Medical and psychosocial factors associated with antibiotic prescribing in primary care: survey questionnaire and factor analysis. ***Lee TH, Wong JGX, Lye DCB, Chen MIC, Loh VWK, Leo YS, Lee LK, Chow ALP.*** *2017, Br J Gen Pract, p. e168.*

25. Prevalence of health literacy and its correlates from a national survey of older adults. ***Suppiah SDi, Malhotra R, Tan YW, Jessup RL, Chew LST, Tang W, Beauchamp A.*** *6, 2023, Research in Social and Administrative Pharmacy, Vol. 19, pp. 906-912.*

26. ***WHO.*** *Global research agenda for antimicrobial resistance in human health. s.l. : Geneva: World Health Organization; 2024. Licence: CC BY-NC-SA 3.0 IGO., 2024.*

27. ***Poon S, Goh DM, Khoo A, Lin YN, Leo YS, Lee TH.*** *Antimicrobial resistance research in Singapore - mapping current trends and future perspectives. medRxiv. [Online] 2023. https://doi.org/10.1101/2023.11.28.232991.*

28. Exploring antibiotic prescribing in public and private primary care settings in Singapore: a qualitative analysis informing theory and evidence-based planning for value-driven intervention design. ***GuoHL, Hildon ZL, Loh VWK,Sundram M, Muhamad Alif Bin Ibrahim, Tang WE, and Chow A.*** *2021, BMC Fam Pract, Vol. 22, p. 205.*

29. Ten-year narrative review on antimicrobial resistance in Singapore . ***Chua AQ, Kwa ALH, Tan TY, Legido-Quigley H, Hsu LY.*** *8, 2019, Singapore Med J , Vol. 60, pp. 387-396.*

30. Empowered hospitalized patients are involved in shared decision making on antibiotic therapy: a quantitative analysis . ***Chow A, Guo H, Hoa A, Ng TM, Lye DCB.*** *2024, J Hospital Infection , Vol. 151, pp. 109-115.*

31. Expectation of antibiotics amongst owners of dogs and/or cats during non-routine visits to veterinary clinics in Singapore: a cross-sectional study. ***Aithal S, Guo H, Teo BH, Chua T, Hildon ZJ-L and Chow A.*** *Front. Vet. Sci., Vol. 11.*

32. Risk Assessment for antibiotic resistance in South East Asia. ***Chereau F, Opatowski L, Tourdjman M, Vong S.*** *2017, BMJ, Vol. 358, p. j3393.*

33. ***ASEAN.*** *ASEAN Strategic Framework to Combat Antimicrobial Resistance through One Health Approach. 2020.*

34. One Health: A new definition for a sustainable and healthy future. ***One Health High-Level Expert Panel, Adisasmito WB, Almuhari S, Behravesh CB, Bilivogui P, Bukachi SA et al.*** *6:e1010537, 2022, PLoS Pathogens, Vol. 18.*

35. The impact of multidrug resistance in healthcare-associated and nosocomial Gram-negative bacteraemia on mortality and length of stay: cohort study. . ***Lye DC, Earnest A, Ling ML, Lee TE, Yong HC, Fisher DA, Krishnan P, Hsu LY.*** *5, 2012, Clinical Microbiology and Infection, Vol. 18, pp. 502-508.*

36. ***National Parks Board, Animal and Veterinary Services, and Singapore Veterinary Association.*** *Guidelines for the Prudent Use of Antimicrobials in Companion Animals. Singapore : s.n., 2021.*

GLOSSARY

Antimicrobials	Antimicrobials are agents that act against microbes, and include antibiotics, antivirals, antifungals and antiparasitics. An antimicrobial either kills the specific microorganism it targets, or stops the microorganism from multiplying, helping the body's immune system to fight the infection caused by the microorganisms.
Antibiotics	Antibiotics are a type of antimicrobial agent produced by a living organism, typically a microorganism, that are active against bacteria. Antibiotics are the most important type of antibacterial agent for fighting bacterial infections.
Antibiotic Resistance	The ability of a bacterium to grow or survive in the presence of an antibiotic at a concentration that is usually sufficient to inhibit or kill bacteria of the same species and that exceeds concentrations achievable in the human / animal. It is a subset of antimicrobial resistance.
Antimicrobial Resistance	The ability of a microorganism to grow or survive in the presence of an antimicrobial at a concentration that is usually sufficient to inhibit or kill microorganisms of the same species and that exceeds concentrations achievable in the human / animal. Includes resistance to antibiotics, antivirals, antifungals etc.
Antimicrobial Stewardship	The use of coordinated interventions to improve and measure the use of antimicrobials by promoting optimal drug regimen, dose, duration and route. The aim is for optimal clinical outcomes and to limit selection of resistant strains. This is a key component of a multi-faceted approach to preventing antimicrobial resistance.
Goals	The NSAPv2 Goals are the long-term objectives and the desired outcomes or results of each Core Strategy.
Healthcare-associated Acquired Infections	Infections acquired as a result of medical intervention e.g. in hospitals or in other clinical settings
Indicators	Indicators, or M&E indicators, are the quantifiable metrics used to track the progress of the NSAPv2 and assess its effectiveness. They include a combination of impact, output, outcome and process indicators to measure performance.
Multidrug resistance	Resistance to three or more classes of antimicrobials.

One Health	One Health is an integrated, unifying approach that aims to sustainably balance and optimise the health of people, animals and ecosystems. It recognises that the health of humans, domestic and wild animals, plants, and the wider environment (including ecosystems) are closely linked and interdependent (34).
Targets	Targets are specific, concrete and measurable benchmarks or outcomes that are to be achieved by a stated date or timeframe.