Innovate UK

Innovate UK Global Expert Mission Report

Antimicrobial Resistance in India

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PUBLIC

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01. Executive Summary

Antimicrobial Resistance (AMR) has emerged as a key pillar of investment and innovation in India.

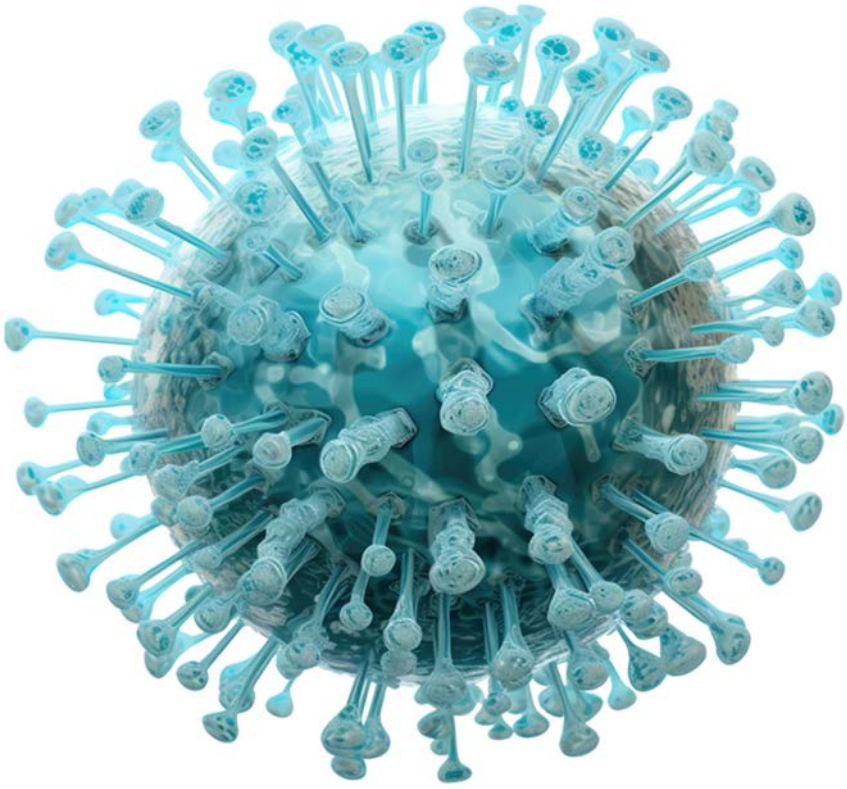
Historically a nascent sector, national and state-level policy has encouraged innovation to flourish with support from internationally renowned research centres. With a vibrant SME ecosystem in the country developing innovative new products and services, there is a real opportunity to strengthen UK-India relationship in the life science sector to combat AMR through bilateral cooperation.

Key Features

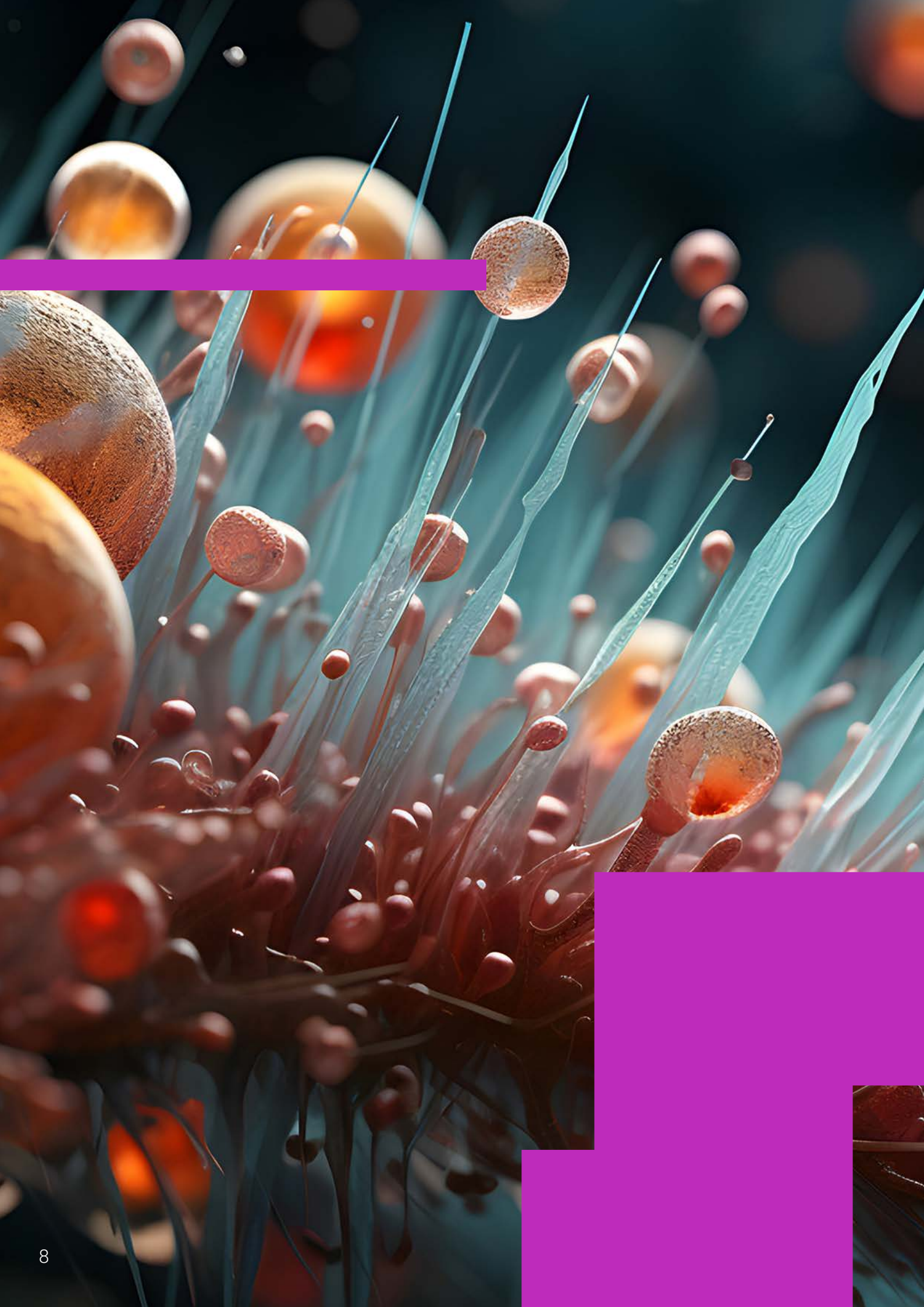
- India's burden of AMR is staggering, in 2019 alone 297,000 deaths were attributed to AMR and a further 1million deaths associated with drug resistant bacteria. By 2050, it is estimated India will account for 20% of all AMR related deaths.
- Antibiotic stewardship in India is poor and while this has improved in recent years it is far below what is required to contain the spread of AMR. There is a significant use of broad-spectrum antibiotics and unapproved formulations which adds to the public health challenge.
- The Government of India is working towards an updated AMR National Action Plan which builds on the current version published in 2017. State-level action plans have also been introduced which is a step in the right direction to address local challenges and work closely with key state-level stakeholders.
- Investment in India continues to rise with AMR given a high priority by the Government of India as demonstrated by the Delhi Declaration at the recent G20 presidency.
- India is a vast country with a complex innovation and regulatory landscape. The Global Expert Mission highlights key government and industry stakeholders driving innovation in AMR.
- There is a clear opportunity and synergies between the UK and India for further bilateral cooperation in diagnostics, vaccines, environment and animal health.
- A number of critical success factors were identified to ensure future programme of activities between the UK and India are successful. These include:
  - Work closely with state-level authorities to understand the challenges at the local level and involve end-users such as farmers and patients in decision making.
  - Clearly communicate the regulatory pathway for phages, microbiome, therapeutics and diagnostics in India and the UK.
  - Strengthen the One Health approach in India by taking the learnings from the UK.
  - Bring together UK and India funding bodies to develop strategic programmes to support innovation.

02. Acronyms

B2B	Business to Business
B2C	Business to Consumer
DBT	Department for Business and Trade
DSIT	Department for Science, Innovation and Technology
FCDO	Foreign, Commonwealth and Development Office
GEM	Global Expert Mission
SIN	Science and Innovation Network
UKRI	UK Research and Innovation



AMR	Antimicrobial Resistance
C-CAMP	Centre for Cellular and Molecular Platforms
BBC	Bangalore Bioinnovation Centre
HAI	Hospital Acquired Infections
NAP	National (AMR) Action Plan
AMSP	Antibiotic Stewardship Programme
ICMR	Indian Council of Medical Research
FDC	Fixed dose combinations
DCGI	Drug Controller General of India
ICAR	Indian Council of Agricultural Research
DIA	Discovery to Innovation Accelerator
CARB-X	Combating Antibiotic-Resistant Bacteria Biopharmaceutical Accelerator
GAN	Global Accelerator Network (of CARB-X)
C-SAP	C-CAMP Startup Advancement Programme
IAIH	India AMR Innovation Hub
MOOC	Massive Open Online Course
NERC	Natural Environment Research Council



03. Introduction

Innovate UKand the Global Expert Missions

Innovate UK supports business-led innovation and is part of UK Research and Innovation (UKRI).[1] UKRI convenes, catalyses and invests in close collaboration with others to build a thriving, inclusive research and innovation system. To this end, Innovate UK helps businesses to identify the commercial potential in new technologies and turn them into new products and services that will generate economic growth and increase productivity. With a strong business focus, Innovate UK drives growth by working with companies to de-risk, enable and support innovation.

As innovation is increasingly a global endeavour and the ambition of UK businesses to become truly international enterprises is at its highest, Innovate UK established its Global Expert Mission (GEM)[2] programme in 2017. Delivered by Innovate UK, in partnership with the FCDO Science and Innovation Network (SIN),[3] GEMs help further Innovate UK's global strategy by providing the evidence base for where it should invest and by providing the opportunities for UK businesses to build partnerships and collaborations with key economies.

1 https://www.ukri.org
2 https://iuk.ktn-uk.org/programme/global-expert-missions/
3 https://www.gov.uk/world/organisations/uk-science-and-innovation-network

Mission Overview and Objectives

This Global Expert Mission brings a team of UK industry experts to assess the AMR R&I ecosystem in India, to identify key areas for collaboration and potential programmes needed to enable UK innovators to partner with Indian institutions.

The objectives of the Mission are to:

- Help determine how Innovate UK can best support UK businesses more effectively and efficiently when considering AMR innovation partnerships with India. Our assessment would include where best to focus efforts on technology and sector areas, locations, and the type of programmes needed to maximise opportunities between India and the UK.
- Develop a deeper understanding of the research and innovation landscape on AMR in India and build relationships with key individuals and organisations.
- Identify synergies between the AMR activities of both countries and relative strengths and weaknesses across the One Health space, including diagnostics, therapeutics, and vaccines.
- To understand the Indian market, key AMR stakeholders and develop long-term engagement strategies to support business collaboration for new products and services.

Mission Scope

Built around UK business, policy and research representation, the GEM aimed to:

1. **Inform UK Businesses and Government**

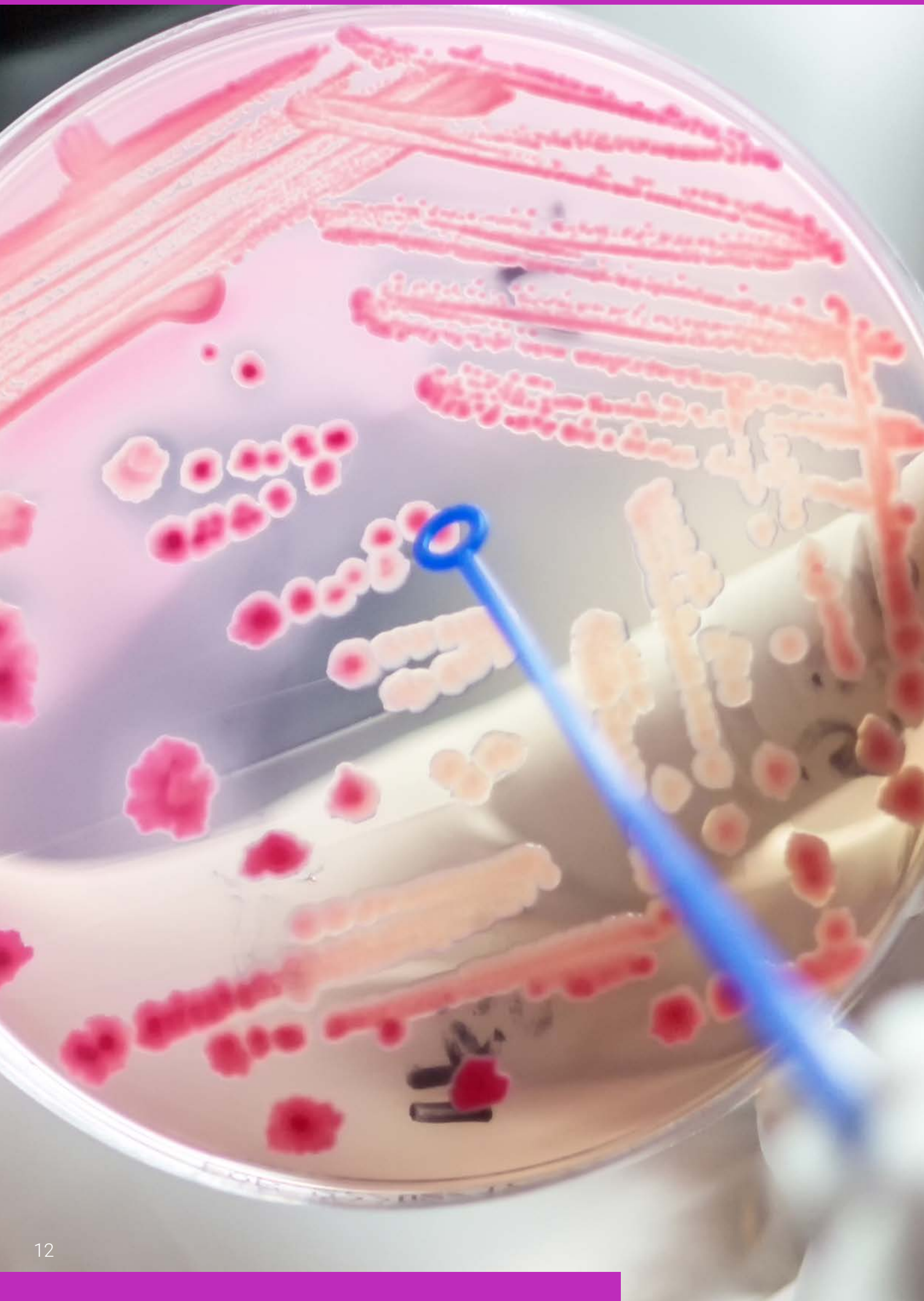
   The findings and opinions of experts on the topic of the GEMs are made available to UK businesses and government departments. These inform UK businesses about potential opportunities for innovation in the country and the UK government on how it can help UK businesses make the most of those opportunities.

2. **Build International Collaborations**

   The expert insights will help inform how Innovate UK can best help UK businesses find and exploit the opportunities for innovation partnerships. The GEM creates connections with key organisations and people that will deepen and widen the collaboration with the partner country to benefit UK business.

3. **Share UK Capabilities**

   During the Mission, the delegation of experts will use the opportunity to promote and share the UK's innovation strengths.

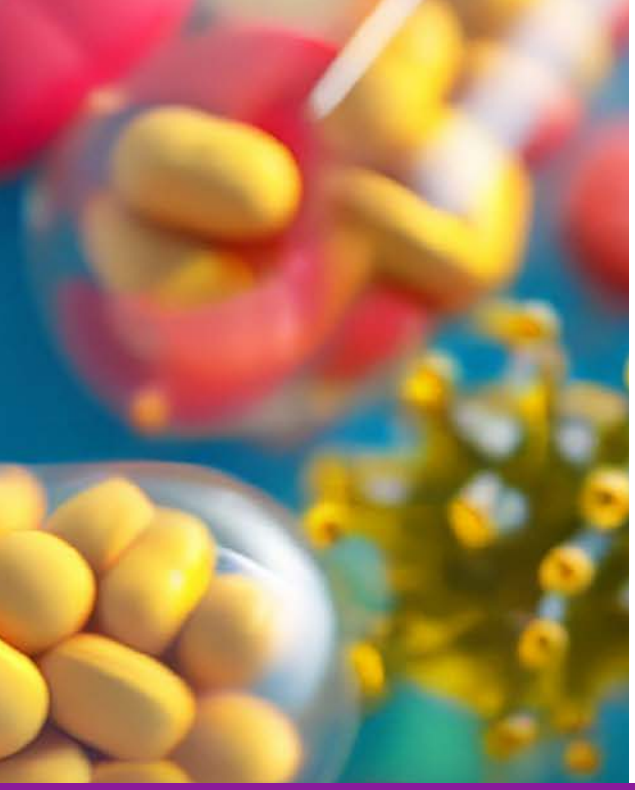


04. Sector Overview

AMR occurs when bacteria, viruses, fungi and parasites build up resistance over time after being exposed to antibiotics, antifungals or antivirals. As a result, medicines that were once effective in treating infections becomes ineffective. Consequently, routine surgical interventions can lead to serious and potentially fatal infections with a recent study showing that between 39% and 51% of bacteria which cause surgical site infection are already resistant to prophylactic antibiotics.[4]

AMR is one of the most severe global threats to health and food safety and is often referred to as the silent pandemic. The global impact of AMR is clear, with economic projections indicating a 3.8% decrease in annual GDP by 2050 and with an annual cost of $1 trillion after 2030.[5,6] According to data estimates, there were 4.95 million deaths related to bacterial AMR in 2019, with 1.27 million deaths attributable to bacterial resistance.[7] The figures clearly point towards AMR as being a multi-faceted problem which requires a multi-pronged approach to combat and reduce its burden in the population. The One Health concept aims to address this by highlighting the inter-relationship between humans, animals and the environment and the need for a joint effort from all three sectors to effectively control, contain and reduce the impact of AMR in the population.

4 Potential burden of antibiotic resistance on surgery and cancer chemotherapy antibiotic prophylaxis
5 Drug-Resistant Infections: A Threat to Our Economic Future
6 Antimicrobial Resistance, World Bank
7 Global burden of bacterial antimicrobial resistance in 2019: a systematic analysis



AMR is a complex, multifaceted societal and economic challenge similar to other global challenges like climate change.

In short, AMR can be described in 10 statements:

1

AMR is a global challenge affecting all countries and potentially impacting everybody; young and old, healthy and diseased. As a result of increased mobility and food transportation, AMR has the potential to spread quickly around the globe

2

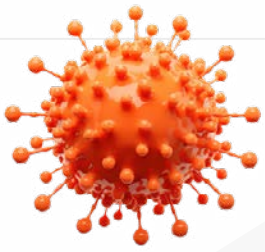
AMR is often referred to as the hidden pandemic and is underestimated as a threat to health security. Currently it is not easy to diagnose and treat even if the causing microorganism has been identified and its antibiotic resistance profile determined. Furthermore, patient data may not always be documented and communicated to the relevant health authorities; there is no standardised system for recording the prevalence of AMR deaths.

3

Reducing antimicrobials for human and veterinary use is urgently needed and adds to the prevention of AMR. However, antimicrobials remain necessary; in countries where antibiotics are difficult to obtain and/or unaffordable, the chances of epidemics substantially increase.[8]

8 Center for Disease Dynamics and Economic Policy: Access barriers to antibiotics

4



AMR prevents the effective treatment of infectious diseases but also complicates medical treatments where antibiotics are used on a routine basis, such as surgery, chemotherapy and stem cell therapy.

5

AMR includes resistant bacteria but also viruses, fungi, yeasts and parasites. Antibiotic resistance in bacteria provides the biggest health and economic problems. Recent outbreaks of resistant fungi (azole-resistant Aspergillus[9] and multidrug-resistant Candida[10]) show that these micro-organisms increasingly threaten public health.

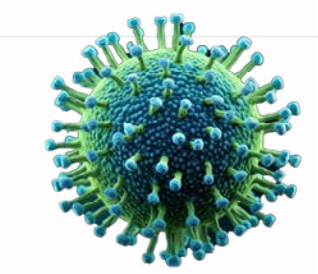
9 Azole Resistance in *Aspergillus fumigatus*: Can We Retain the Clinical Use of Mold-Active Antifungal Azoles?

10 US Center for Disease Control: Candida auris

6

AMR so far has developed against all commercially available antibiotics. Resistant bacteria were found within months or years after the introduction, and sometimes even before commercial introduction, of antibiotics. Second and third-generation antibiotics are at risk of being ineffective in the future.

7



The current pipeline of novel antibiotics is rather empty, despite the constant need for novel antimicrobial products and alternative strategies. Novel antibiotics are the most underserved area within drug discovery and development pipelines. The major reasons for this are the lack of economic incentives for companies to invest in a drug development pipeline for new antibiotics.

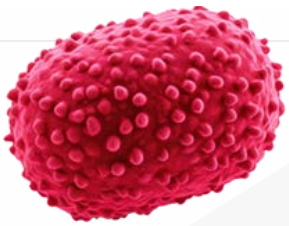
8

AMR at a global scale is escalating whereby low- and middle-income countries (LMICs) bear the harshest burdens in terms of mortality, loss of livestock and economic losses. There are indications that climate change, especially observed in these LMICs, will further spread the impact of AMR.

9

AMR is considered a global One Health challenge involving human health, animal health and the environment. It also brings together related industries such as agriculture, food, water and the tourism sector.
There is no single solution to AMR.

10



The impact of AMR can only be contained by coordinated efforts by international partners.

Global Health Security Index[11]

In the Global Health Security (GHS) index, India scored just above the average at 50.0 in terms of AMR monitoring. While excelling in immunisation due to its role in vaccine production, India's biosafety measures and research practices for responsible science are underdeveloped. Despite excelling in healthcare product manufacturing, particularly evident during the pandemic, India's linkage between human, animal, and environmental health sectors is lacking, impacting disease detection and reporting. The nation's healthcare access and capacity remain constrained, likely due to economic factors and its large population size.

11 India AMR GEM; Innovate UK Business Connect Futures Team; Laura Gataveckaite
2021 GHS Index country profile for India
https://ghsindex.org/country/india/

4.1 AMR in India: Key Insights and Statistics

India's burden of AMR is staggering, in 2019 alone 297,000 deaths were attributed to AMR and a further 1million deaths associated with drug resistant bacteria.[12] With its unique combination of a dense population, diverse healthcare practices and a significant disease burden, it places the country at a critical stage in the global fight against AMR. The implications of this are far-reaching, with India at centre stage playing a vital role in containing and reducing the burden of AMR. It is estimated by 2050 India will account for 20% of the projected 10 million AMR related deaths.[13]

While the One Health concept has significantly changed the way health authorities target AMR, it has, however, introduced additional complexities and the need to coordinate and work collaboratively across sectors. The focus has shifted from human healthcare and stewardship to include animal health, agriculture, manufacturing waste and surveillance. While these challenges are global, particular attention has been placed on India due to their global manufacturing footprint, approaches to antibiotic stewardship, healthcare provision and farming practices.

12 University of Washington, Institute for Health Metrics and Evaluation

13 The Centre for Disease Dynamics, Economic and Policy, Global Antibiotic Resistance Partnership

India AMR Challenge

India faces a number of challenges related to AMR and while these are global issues many are specific to India.[14]

- **High Rates of AMR:** There is a major issue with India's high rates of AMR. Worldwide, the threat posed by antibiotic-resistant diseases to public health is increasing. Antibiotics may no longer be able to effectively treat common illnesses due to the high prevalence of AMR, which would increase morbidity and mortality.
- **Newborn Mortality Rates:** India has one of the highest rates of AMR worldwide, with over 60,000 neonates succumbing to antibiotic-resistant infections annually.
- **High Burden of Infectious Diseases:** The prevalence of infectious diseases such as pneumonia, typhoid, cholera, malaria, and tuberculosis are particularly high in India. Effective treatment of these diseases has become more challenging with the advent of AMR. The fact that these illnesses are already significant public health issues in the nation makes it particularly worrisome. According to the ICMR, drug-resistant microorganisms have been persistently emerging, making it more difficult to treat some diseases with current medications.
- **Unregulated Antibiotic Market:** One of the main causes of AMR is the development of a sizable, unregulated antibiotic market. Resistance can arise as a result of antibiotic overuse, abuse, and self-prescription. National and state level regulations are required to mitigate the use and distribution of antibiotics.
- **Poor Farming Practices:** The volume of antibiotic used in the agri-and aquaculture industry is unacceptable and requires a national One Health approach to minimise this. The biggest risk is downstream where there is exposure to shellfish, fish, humans, and livestock.

14 Tackling the Threat of Antimicrobial Resistance

High Rates of Antibiotic Use in India[15]

In India, while the per-capita private-sector consumption of antibiotics is comparatively low, there exists a notable volume of broad-spectrum antibiotic consumption, raising concerns about prudent usage. Antibiotic resistance is on the rise in the country due to factors like inappropriate antibiotic utilisation. The complexity of antibiotics availability, sales, and consumption in India is attributed to the manufacture and marketing of fixed-dose combinations, unrestricted over-the-counter antibiotic sales, and emergence of multi-drug resistant bacteria.

In 2019, the average antibiotic consumption was 10.4 defined daily doses per 1,000 persons per day. Notably, there's significant use of broad-spectrum antibiotics and unapproved formulations, adding to the public health challenge.

Private-sector antibiotic use contributes significantly to overall consumption in India. Therefore, addressing these issues necessitates substantial policy and regulatory reforms to monitor and regulate antibiotic sales and use while improving access through the public health system.

Unapproved formulations accounted for 47.1 per cent of the annual defined daily dose consumption. In other words, people in India consumed 2,408 million defined doses of unapproved formulations in 2019. According to the study, Watch antibiotics constituted 72.7 per cent of unapproved products, and combinations discouraged by the WHO constituted 48.7 per cent of fixed-dose combinations.

15 Consumption of systemic antibiotics in India in 2019

India's Healthcare Provision

India's healthcare landscape is diverse and varies across regions. Unlike urban areas with good access to healthcare services, rural areas present a major challenge. Lack of awareness on the use of antibiotics, access to clean sanitary conditions and hospital acquired infections (HAI) are some of the major factors that contribute to the spread of AMR from a primary and secondary care perspective.

In India, antibiotics can often be obtained without a prescription leading to inappropriate use and exacerbating the AMR issue. This is a common practice in the country and one which is widespread in rural areas with limited healthcare access. Importantly, public understanding of AMR remains low in many parts of India with a large population not aware of the ramifications of not completing an antibiotic course. In addition, lack of access to clean sanitary condition and poor infection control significantly increases the spread of resistant bacteria. The national rural health mission mandated by the Ministry of Health and Family Welfare launched the accredited social health activist (ASHA) to work within the rural areas of India and be the interface between community and the public health system.

Role of ASHA Workers

ASHA workers are primarily women selected from their respective villages to be the main point of contact between rural health community and the public health system of India. ASHA workers have the knowledge to provide first contact healthcare and lead local health programme which makes them vital in spreading the awareness of antibiotic use and AMR.

Infection Control in Hospital and Clinical Setting

Poor infection control in hospital and the lack of diagnostics often leads to doctors prescribing broad spectrum antibiotics to patients. Circulation of airborne microbes is a major concern leading to hospital acquired infections (HAI). Biomoneta, an Indian biotechnology company has developed a proprietary technology to capture and neutralise airborne pathogens. The ZeBox technology uses an electric field to filter the air with the microbes attracted to the surfaces causing lysis.

Agriculture, Aquaculture and Animal Husbandry

The aquaculture sector in India has grown significantly in recent years driven in part by dietary habits but also global demand. India represents one of the largest exporters of shrimps with an annual production of 850,000 metric tons in 2022. The south-eastern coastal state of Andhra Pradesh is the largest producer accounting for more than 80% of the countries shrimp export. The significant rise in India's shrimp industry has come with several challenges including the misuse of antibiotics – symptom of current farming practices.

Consumption of poultry, the main source of protein in India is expected to increase by 500% by 2030[16] and is one of the fastest growing livestock sectors in the country. With India currently being the fourth largest producer in poultry, it has brought with it considerable challenge in managing the spread of AMR as intensive integrated and semi-integrated farming practices is widely adopted. The use of antimicrobials in animal feed is a common practice in India which brings with it several issues, primarily the emergence of resistance pathogens due to poor stewardship.

16 Antimicrobial resistance in the environment: The Indian scenario

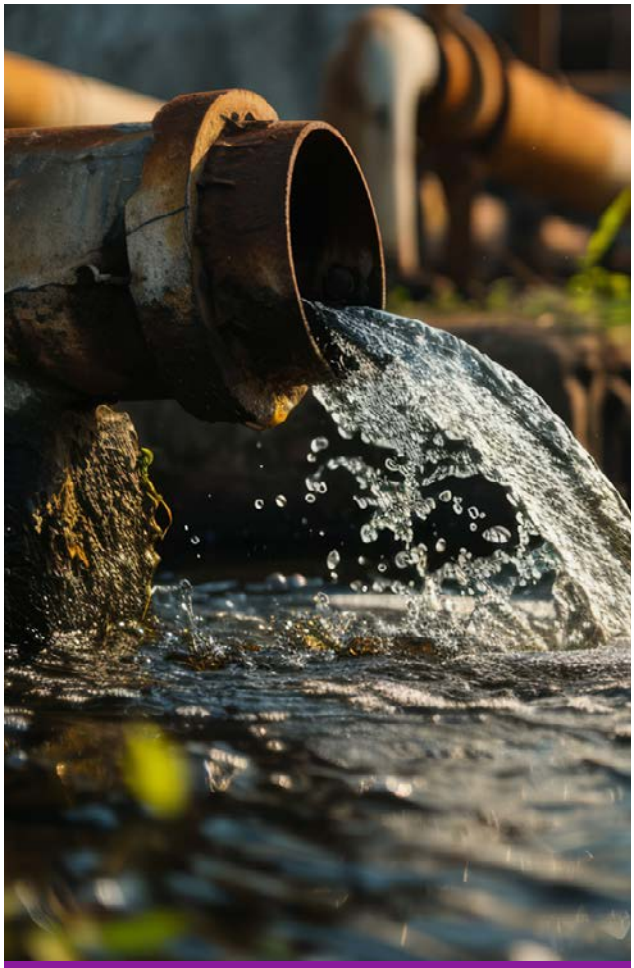
Aquaculture a Hotbed for AMR

While India is one of the largest exporters of shrimp, many of the aquaculture farms belong to small local businesses. Biosecurity measures that are needed to mitigate the spread of AMR can often be costly to install with antibiotics as alternative being much cheaper. There is also a tendency to estimate dosage, leading to accumulation in waterways and contributing the likelihood of resistance developing.

Transition to antibiotic stewardship and responsible use will require a cultural shift. Vaccination or other preventative measures need to be relatively inexpensive to make them the treatment of choice. The cost of not using antibiotics can lead to a 20-30% loss in shrimps costing billions in the aquaculture industry.

Pharmaceutical Manufacturing and the Environment

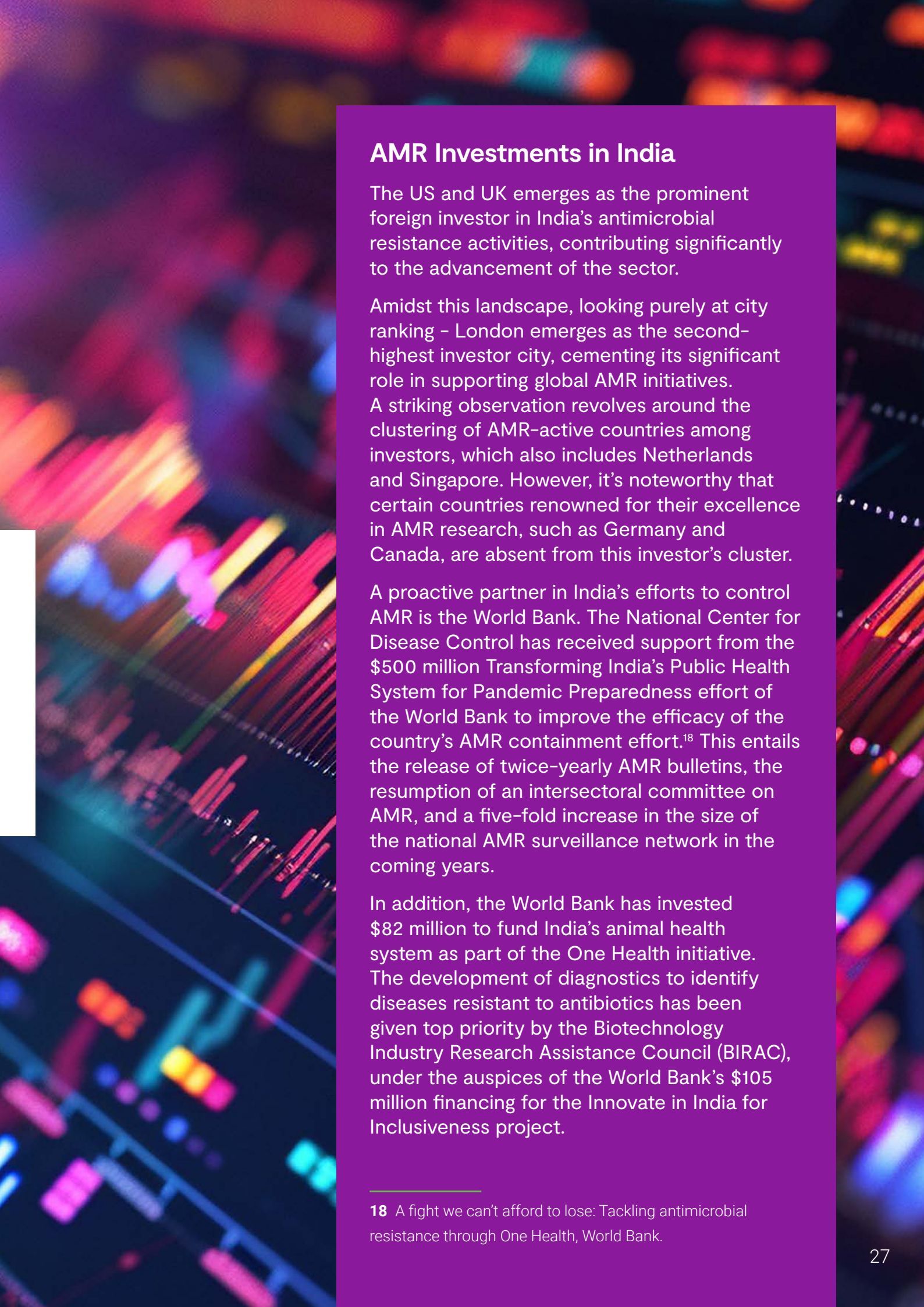
India has become a key player in the global production of pharmaceuticals and is one the largest producers by volume. Many of the generics in the UK are manufactured in India with a number of sites involved in antibacterial production. Responsible manufacturing is vital to mitigate the spread of AMR through wastewater and other discharge. The Zero Liquid Discharge model is increasingly being adopted by companies in India such as Sun Pharma, Viatris and Cipla.[17]



Zero Liquid Discharge Model

Zero liquid discharge (ZLD) is a strategic wastewater management system that ensures that there will be no discharge of industrial wastewater into the environment. It is achieved by treating wastewater through recycling and then recovery and reuse for industrial purpose.

17 Responsible manufacturing critical to keep AMR in check: Study



AMR Investments in India

The US and UK emerges as the prominent foreign investor in India's antimicrobial resistance activities, contributing significantly to the advancement of the sector.

Amidst this landscape, looking purely at city ranking - London emerges as the second-highest investor city, cementing its significant role in supporting global AMR initiatives. A striking observation revolves around the clustering of AMR-active countries among investors, which also includes Netherlands and Singapore. However, it's noteworthy that certain countries renowned for their excellence in AMR research, such as Germany and Canada, are absent from this investor's cluster.

A proactive partner in India's efforts to control AMR is the World Bank. The National Center for Disease Control has received support from the $500 million Transforming India's Public Health System for Pandemic Preparedness effort of the World Bank to improve the efficacy of the country's AMR containment effort.[18] This entails the release of twice-yearly AMR bulletins, the resumption of an intersectoral committee on AMR, and a five-fold increase in the size of the national AMR surveillance network in the coming years.

In addition, the World Bank has invested $82 million to fund India's animal health system as part of the One Health initiative. The development of diagnostics to identify diseases resistant to antibiotics has been given top priority by the Biotechnology Industry Research Assistance Council (BIRAC), under the auspices of the World Bank's $105 million financing for the Innovate in India for Inclusiveness project.

18 A fight we can't afford to lose: Tackling antimicrobial resistance through One Health, World Bank.

4.2 Actions by the Government of India to Combat AMR

The steep rise in drug-resistant infections and AMR related deaths has prompted the Government of India to launch the AMR National Action Plan.[19] Published by the Union Ministry of Health and Family in April 2017, the document sets out a comprehensive action plan to combat AMR.

Launched on April 19, 2017, the National Action Plan on Antimicrobial Resistance (NAP-AMR) centres on the One Health concept and brings together key stakeholders across government including relevant ministries that have signed the Delhi Declaration on AMR. The NAP aims to increase awareness, bolster surveillance, encourage research, and enhance infection prevention and control in an effort to contain and reduce the incidence of AMR.

- **Attesting to the AMR Declaration of Delhi:**[20] The ministers of the relevant Indian ministries signed the Delhi Declaration on AMR, which is an inter-ministerial consensus. Through the involvement of research institutes, civil society, industry, small and medium-sized businesses, and the promotion of public-private partnerships, the declaration seeks to address AMR through civil, industry and government alliance.
- **Antibiotic Stewardship Programme (AMSP):**[21] In 20 tertiary care hospitals around India, the Indian Council of Medical Research (ICMR) launched the AMSP as a pilot study. The programme's goal is to reduce the overuse and abuse of antibiotics in intensive care units and hospital wards.

19 Measures Taken to Rising Anti-Microbial Resistance in the Country
20 Delhi Declaration on Antimicrobial Resistance
21 Measures taken to address challenges posed by anti-microbial resistance in India

- **Ban on Improper Fixed Dose Combinations (FDCs):** The Drug Controller General of India (DCGI) has prohibited 40 FDCs that were determined to be inappropriate, based on recommendations from the ICMR.
- **Prohibition of Colistin's Use as a Growth Booster in Animal Feed:** The Indian Council of Agricultural Research (ICMR), in association with the Department of Animal Husbandry, Dairy and Fisheries, the Indian Council of Agriculture Research, and the DCGI, has outlawed the use of Colistin as a growth booster in animal feed for poultry.
- **One Health Approach:** To promote interdisciplinary collaboration at the interface of humans, animals, and the environment, the government is working on a One Health approach. Antibiotic resistance, food safety, and zoonotic illnesses are the main priority areas.
- **Integrated One Health Surveillance Network for AMR:** In partnership with the Indian Council of Agricultural Research, the ICMR has launched a project titled "Integrated One Health Surveillance Network for Antimicrobial Resistance" to evaluate how ready Indian veterinary laboratories are to take part in an integrated AMR surveillance network.

4.2.1 The Indian G20 and the Delhi Declaration

In order to implement the One Health approach, improve pandemic preparedness, and fortify current infectious disease surveillance systems, India pledged to strengthen the global health architecture in the Delhi Declaration, which was made during the country's G20 presidency.

This was achieved by creating more resilient, equitable, sustainable, and inclusive health systems. Prioritising the fight against AMR through investment in research and development, infection prevention and control, and antimicrobial stewardship.

State-level Action Plans to Combat AMR

Three states have started their state action plans in accordance with NAP-AMR:

Kerala, KARSAP

Kerala is implementing a State Action Plan on Antimicrobial Resistance (AMR) in line with National and Global Action Plans. The plan emphasises inter-sectoral collaboration and a One Health Approach. Awareness classes are being held at government medical colleges to promote rational antibiotic use and infection control practices. The government has also initiated an AMR surveillance programme in government teaching hospitals and tertiary care private hospitals, focusing on public health infections. In addition, a network of infection surveillance is proposed, with the Department of Microbiology at Government Medical College Thiruvananthapuram (GMCT) operating as the main hub. The state-level action plan aims to address a number of key issues on antibiotic sale, residue control, traceability and to instil evidence-based medicine practices.

Madhya Pradesh, MP-SAPCAR

The Madhya Pradesh government is implementing the Madhya Pradesh State Action Plan for Containment of Antimicrobial Resistance (MP-SAPCAR). The plan aims to improve awareness, strengthen knowledge, reduce infection incidence, optimise antimicrobial use, promote investments for research and innovations, and strengthen India's leadership in the field. The state-level plan includes six strategic priorities and 16 focus areas, including communication, education, surveillance, infection prevention, regulation, access, and financing. It also aims to reduce the spread of AMR and its antimicrobials in various sectors, including healthcare, animal health, and agriculture. The government is also focusing on strengthening India's leadership in international and national collaborations.

Delhi, SAP-CARD

The State Action Plan to Combat Antimicrobial Resistance in Delhi (SAP-CARD) outlines six strategic priorities to address the spread of AMR in Delhi. These priorities include improving awareness and understanding of AMR through effective communication, education, and training. In addition, the plan sets out a roadmap for surveillance, reducing infection incidence through effective infection prevention and control and promoting investments for AMR activities, research, and innovation. It also focuses on establishing inter-departmental collaborations, and establishing partnerships with the private sector, professional associations, and civil society organisations.

05. Innovation Landscape

Major Indian cities like Bengaluru, Mumbai, New Delhi, and Hyderabad are central to the AMR sector. A number of life science start-ups and innovation hubs are located in Bengaluru and Mumbai with an emphasis on diagnostics and therapeutics.

All India Institute of Medical Sciences (AIIMS)[22]

In order to provide as the foundation for fostering excellence in all facets of healthcare, AIIMS was established in 1956. The Institute offers extensive resources for patient treatment, research, and education. AIIMS grants its own degrees and offers undergraduate and graduate teaching programmes in medicine and paramedicine. There are 42 disciplines in which research and teaching are done. The following are some of the goals:

1. To create a model for undergraduate and graduate medical education across all specialisations in order to show medical colleges and other related institutions in India that medical education is of a high calibre.
2. To consolidate world-class educational facilities for staff training in all significant areas of health care into one location.
3. To become self-sufficient in continuing medical study after graduation. In addition to New Delhi, AIIMS has facilities in Bhubaneswar, Jodhpur, Patna, Raipurm Rishikesh, Bhopal and Kalyani.

22 AIIMS New Delhi

Anti-Microbial Resistance Action Centre of Excellence (AM-RACE)

The AM-RACE is an initiative nested at Bangalore Bioinnovation Centre (see below). AM-RACE is an attempt to catalyse the implementation of the antimicrobials prescriptions efforts of the Government through the VaidyaRx - software tool. Pilots with AM-RACE showed strengthened knowledge and improved awareness and understanding of AMR through effective communication, education, and training. A study for validation of VaidyaRx to evaluate variation in approaches is being deployed from Oct 01, 2023. Rotary Club Bangalore has adopted the initiative to ensure that this is sustainable and practically implemented perpetually in sister clubs in Bengaluru, Karnataka, India and beyond.

Bangalore Bioinnovation Centre (BBC)[23]

The BBC is a research and development hotspot that works with academia and biotechs to advance cutting-edge life science innovation from bench to bedside. Situated in the heart of one of the world's most dynamic life science ecosystems, Bangalore Helix Biotechnology Park in Bengaluru, Karnataka, India, the BBC gives innovators access to the knowledge and resources they need to advance their concepts. The BBC focuses on healthcare, food and nutrition, agriculture biotechnology, environmental biotechnology and industrial biotechnology. Since the inception it has supported 170 start-ups including AMR companies Tranalab, Presude Lifesciences, Oxonex Biological, Molecular Solutions and Omix.

23 Bangalore Bioinnovation Centre

Centre for Cellular and Molecular Platforms (C-CAMP)[24]

The C-CAMP in India has been supporting research and innovation in life sciences since 2009. It offers cutting-edge technology platforms for research, development, training, and entrepreneurship. C-CAMP fosters an entrepreneur-friendly culture through Seed Funding Schemes, Entrepreneur Mentorship programmes, and Bio-Incubation facilities. It recognises the importance of AMR and is working to foster R&D efforts in this area. C-CAMP has established several initiatives that could be of relevance for UK-India collaborations in the domain of AMR: Discovery to Innovation Accelerator, India AMR Innovation Hub, C-CAMP Startup Advancement Programme (C-SAP) and BIRAC Regional Entrepreneurship Centre (BREC). The centre has been selected by CARB-X for its prestigious Global Accelerator Network (GAN), a league of 10 world-class organisations to combat AMR and is the Indian partner of the Dutch-Indo WAAH Incubator[25] initiative.

India AMR Innovation Hub (IAIH)[26]

The IIAIH, which was conceptualised and is led by C-CAMP, is a unique think tank on AMR Interventions. It brings together Indian and international stakeholders, including the government, academia, industry, philanthropic, and not-for-profit sectors, to promote consolidation and expedite national efforts against AMR in order to have a larger global health impact. The goal of the IAIH is to bring in all necessary interventions to support the AMR Innovation Ecosystem, such as public health and access policies, capacity building and capability building, AMR stewardship, and public communication.

24 Centre for Cellular and Molecular Platforms
25 A next generation Denmark – Switzerland – Netherlands – India collaboration on One Health
26 India AMR Innovation Hub

Department of Biotechnology (DBT)[27]

In order to fulfil the objectives of the Sustainable Development Goals and National Development Programmes (NDPs), the DBT, Ministry of Science and Technology, is tasked with making India globally competitive in biotechnology research, innovation, translation, entrepreneurship, and industrial growth. In order to address relevant issues with regard to healthcare, clean energy, agriculture, bioresource development and sustainable utilisation, infrastructure, etc., DBT funds extramural research projects in biotech R&D across the nation at various levels, including policy framework, institutional infrastructure creation, industry partnerships, regulatory capacity, talent pool development, leading edge research, supporting important missions, and fostering international collaborations.

The Regional Centre for Biotechnology (RCB), the International Centre for Genetic Engineering and Biotechnology (ICGEB), three Public Sector Undertakings (BIRAC), Bharat Immunologicals and Biologicals Corporation Limited (BIBCOL), and Indian Vaccine Corporation Ltd (IVCOL) are the other statutory organisations that DBT uses to carry out its operations. Additionally, DBT operates through fourteen autonomous institutions.

Earlier in 2023,[28] India became a member of the Global AMR Research and Development (R&D) Hub, through the Department of Biotechnology, Ministry of Science and Technology. This brings 16 nations, the European Commission, two charitable foundations, and four international organisations (as observers) into the global partnership aimed at addressing issues and enhancing coordination and collaboration in global AMR R&D.

27 Department for Biotechnology, Ministry of Science and Technology
28 Press release for India Global AMR R&D Hub Partnership

Indian Council of Medical Research (ICMR)[29]

One of the oldest medical research organisations in the world is the ICMR, New Delhi, which serves as the supreme authority in India for the planning, directing, and advancement of biomedical research.

The ICMR has always made an effort to respond to the nation's health issues by both seeking to discover workable solutions and meeting the increasing needs of scientific advancements in biomedical research. ICMR is involved in many AMR-related initiatives, including:

- Expanding antimicrobial resistance research and surveillance activities in the secondary level hospitals.
- Establishing ICMRs Genomic Surveillance for Antimicrobial Resistance.
- Implementing partner in India to activate and facilitate learning for MOOC in collaboration with the London School of Hygiene and Tropical Medicine on Diagnostics and AMR.
- Call for proposals on diagnostics for AMR especially for primary and acute care settings.
- Annual Report Antimicrobial Resistance Research and Surveillance Network.

Antimicrobial Resistance Surveillance and Research Network (AMRSN)

The Indian Council of Medical Research, in 2013, initiated the AMRSN to enable compilation of data on six pathogenic groups on antimicrobial resistance from the country. The overarching aim of this network was to understand the extent and pattern of antimicrobial resistance (AMR) and use this evidence to guide strategies to control the spread of AMR.

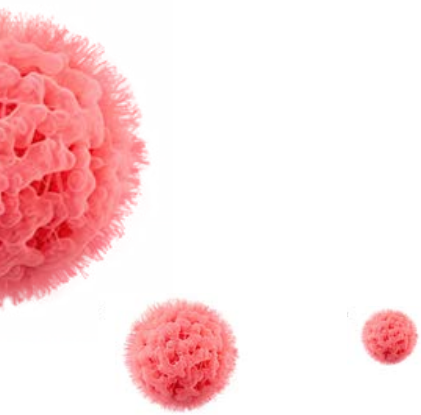
29 Indian Council for Medical Research

Indian Veterinary Research Institute (IVRI)[30]

The IVRI was one of the first research institutes in the area to focus on livestock development and research, having been founded in 1889. The institute's primary mandate encompasses research, teaching, consulting, and technology transfer activities, with over 200 faculty members. The institute offers top-notch undergraduate and graduate veterinary science education in addition to conducting research in animal and veterinary science. Thrust areas include Animal Health and Welfare (including vaccines and diagnostics, host-pathogen interactions, monitoring and surveillance of animal diseases, antimicrobial resistance and alternate antimicrobials), Animal Genetic Resources, Animal Nutrition, Animal Physiology and Reproduction, Livestock Management and Improvement, Post-harvest Management and Value addition.

Foundation for Neglected Disease Research (FNDR)[31]

A non-profit biotech research and development group the FNDR is devoted to finding and creating innovative treatments, tools, and diagnostics for illnesses that have a significant socioeconomic impact. Since its founding in 2014, FNDR has produced a portfolio of pharmaceuticals ranging from early-stage discovery to late-stage clinical trials for the treatment of tuberculosis, nontuberculous mycobacteria, malaria, dengue, leishmania, serious bacterial infections, fungal infections, COVID-19, and RSV. Bengaluru, India is home to FNDR's R&D Centre, which has cutting-edge BSL2 and BSL3 laboratories for both in vitro and in vivo research. Preclinical infectious disease research is another service that FNDR offers on a fee-for-service basis. FNDR is addressing pandemic preparedness, antibiotic resistance, and other public health issues under the One Health paradigm.



30 Indian Veterinary Research Institute
31 Foundation for Neglected Disease Research

Infection Control Academy of India (IFCAI)[32]

The top non-profit in India promoting infection prevention and control is the IFCAI, which was founded in 2016. The vision of IFCAI is to train 1,000,000 healthcare professionals on infection prevention and control (IPC) by 2025 in India and low-resource settings. Starting from the WHO IPC core components, the objectives of IFCAI include:

- To promote and ensure capacity building in infection control training and research.
- To award recognition in Infection control programmes.
- To undertake all activities aimed at creating awareness to address the increasing health challenges faced by India.
- To focus on creating higher standards of Hygiene and Infection Control, driving public health-oriented research and consultancy initiatives for shaping Hygiene and Infection Control policies.
- To offer customised programmes to address India's Hygiene and Infection Control needs.
- To create meaningful career prospects and opportunities for Hygiene and Infection Control professionals.
- To establish standards in Hygiene and Infection Control education by enabling the formation of an independent accreditation system.
- To create a network of world-class institutes and faculty for training and producing high-quality Hygiene and Infection Control professionals.

32 Infection Control Academy of India

Institute of Public Health (IPH)[33]

The non-profit IPH, Bengaluru was founded with the goal of establishing a just and empowered society via the development of an equitable, integrated, decentralised, and participatory health system. The Department of Scientific and Industrial Research (DSIR), a division of the Ministry of Science and Technology, has designated the Institute of Public Health as a Scientific and Research Organisation (SIRO). The mission of IPH is to strengthen health systems to ensure healthy communities through a team of committed and value-based professionals. AMR is one of the domains.

33 Institute of Public Health

National Centre for Disease Control (NCDC)[34]

The Institute's mission is primarily focused on three areas: research, creation of skilled health labour, and services.

Services

The Institute uses epidemiological and diagnostic technologies to investigate illness outbreaks across the nation, assuming the lead in these efforts. Additionally, it offers diagnostic service referrals to state health directorates, medical universities, research facilities, and private citizens. The Institute's service offerings also include the provision of educational resources, vaccine storage and distribution, biological quality control, and scientific research materials. Two for this report relevant services offered are listed below:

A. Investigations into outbreaks

The institute looks into and suggests preventative methods for the spread of several infectious illnesses throughout the United States and its territories, as well as to some of its neighbours in the South East Asian region. By gathering data from the states and districts, the institute also monitors outbreaks across the nation, particularly in the early stages of their rise. In addition to training state authorities in emergency readiness, the centre looks into rumours of diseases that are thought to be extinct, such as smallpox cases.

B. Services for Referrals

Referral Diagnostic Services: The institute offers diagnostic services for a variety of infectious disorders with a microbiological origin, with a focus on those for which hospitals and medical colleges typically do not have diagnostic resources. Among them are:

- Viral illnesses include AIDS, Rabies, Coxsackie virus, AIDS, poliomyelitis, measles, rubella, cytomegalovirus, and other Enteroviruses.
- Bacterial diseases include plague, anthrax, ricketsioses, meningitis, diphtheria, acute respiratory infections, cholera, and more recent enteropathogens.
- Mycotic illnesses are common fungal infections that can be both superficial and deep.
- Parasitic illnesses: hydatidosis, leptospirosis, malaria, and kala-azar.

34 National Centre for Disease Control

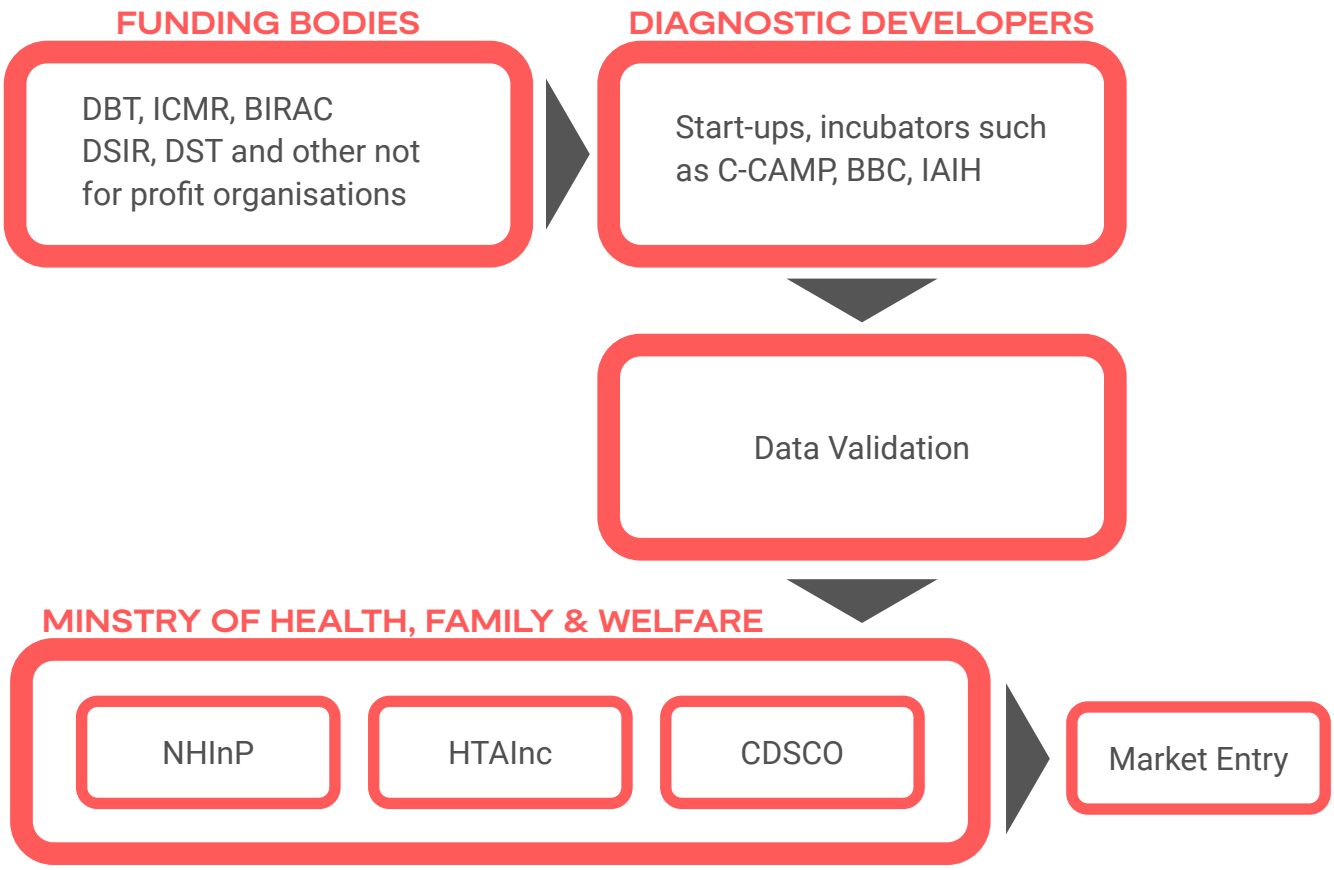


Figure 1. *Approval process for diagnostic devices in India. NHInP: National Healthcare Innovation Portal, HTAIn: Health Technology Assessment India, CDSCO: Central Drugs Standard Control Organisation. An AMR point-of-care diagnostic test can reduce antibiotic use by enabling early detection and rapid testing of antimicrobial susceptibility. India has taken initiatives to develop diagnostics, including the National Essential Diagnostics List and the Free Diagnostics Service Initiative.*

Figure adapted from Sharma M, Gangakhedkar RR, Bhattacharya S, Walia K. Understanding complexities in the uptake of indigenously developed rapid point-of-care diagnostics for containment of antimicrobial resistance in India. BMJ Glob Health. 2021

National AMR Surveillance Network (NARS-Net)

National Reference Laboratories (NRLs): The programme has established two NRLs. The Center for Bacterial Diseases and Drug Resistance, which performs EQAS for programme sites, focusing on bacterial pathogens. Additionally, this lab verifies the AMR alerts that the programme site submits. The second NRL under this initiative is for fungal pathogens and was set up at the Vallabhbhai Patel Chest Institute's fungal laboratory in Delhi.

Sentinel AMR Surveillance Sites: To improve AMR identification and control, the programme is assisting state medical colleges. The programme has opened surveillance sites across India in a phased manner which currently comprises of 40 labs across 31 states and territories:

01 Phase 1 Sites

1 BJMC Ahmedabad
2 BJMC Pune
3 GMC Chandigarh
4 GSVM Kanpur
5 LHMC Delhi
6 MMC & RI Mysore
7 SMS Jaipur
8 Safdarjung Delhi

02 Phase 2 Sites

9 GMC Trivandrum
10 KAPV Govt. MCH Tiruchirappalli
11 GMC Guwahati
12 NEIGRIHMS Shillong
13 MGM MC Indore
14 IGMC Shimla

03 Phase 3 Sites

15 GMC Aurangabad
16 OMC Osmania
17 GMC Guntur
18 AGMC Agartaia
19 SCB MC & H Cuttack
20 GMCH Jammu

04 Phase 4 Sites

21 BDS PGIMS Rohtak
22 RIMS Ranchi
23 IGIMS Patna
24 GMC Haldwani
25 JLNMC Raipur

05 Phase 5 Sites

26 GMC Bhopal
27 STM Kolkata
28 GMERS Valsad
29 LLRM Merrut

06 Phase 6 Sites

30 CMCH Coimbatore
31 MAMC Delhi
32 SPMC Bikaner
33 KIMS Hubli
34 IGMC & RI Puducherry
35 NAMO MERI Silvassa

Location of National AMR Surveillance Network Sites

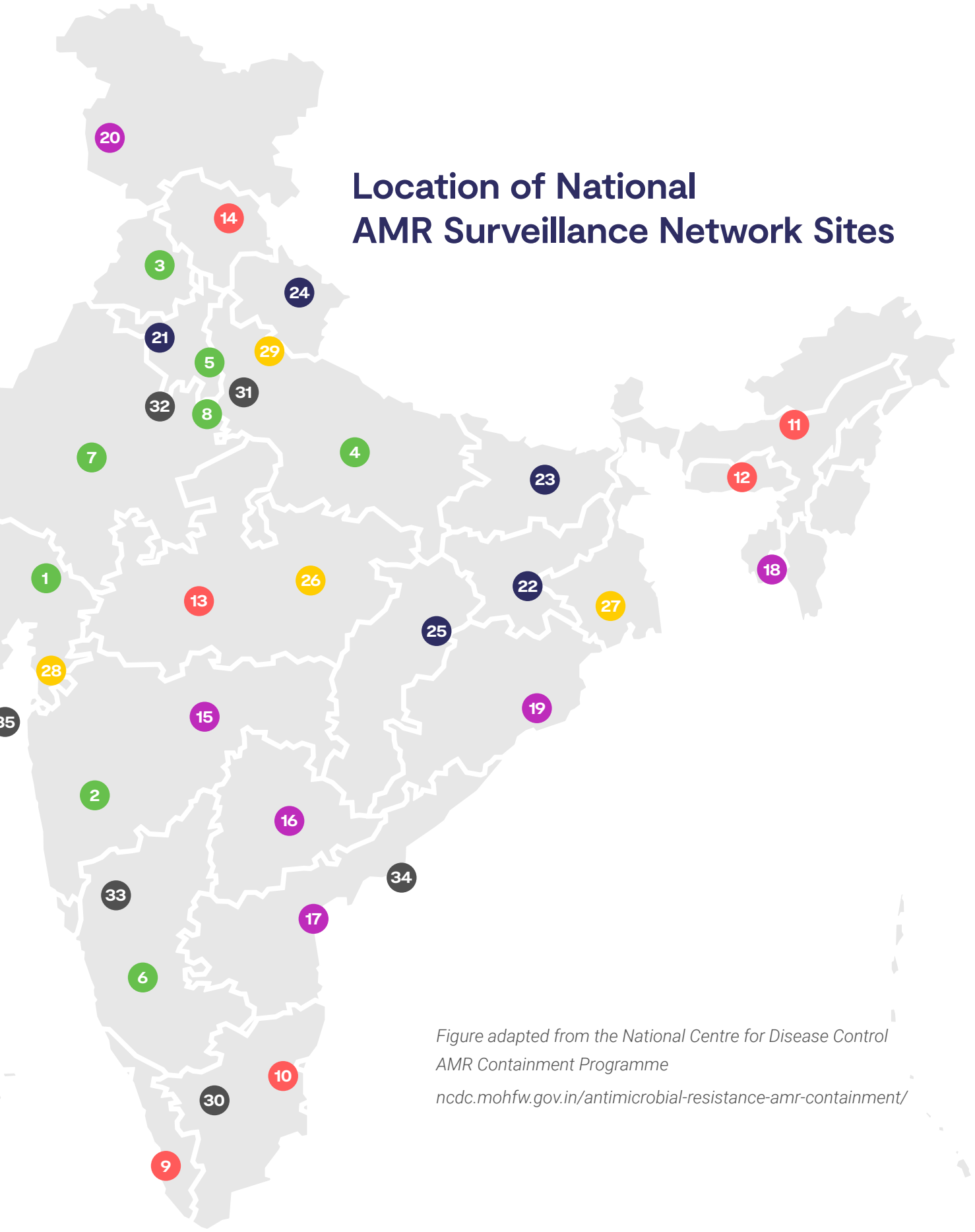


Figure adapted from the National Centre for Disease Control AMR Containment Programme

ncdc.mohfw.gov.in/antimicrobial-resistance-amr-containment/

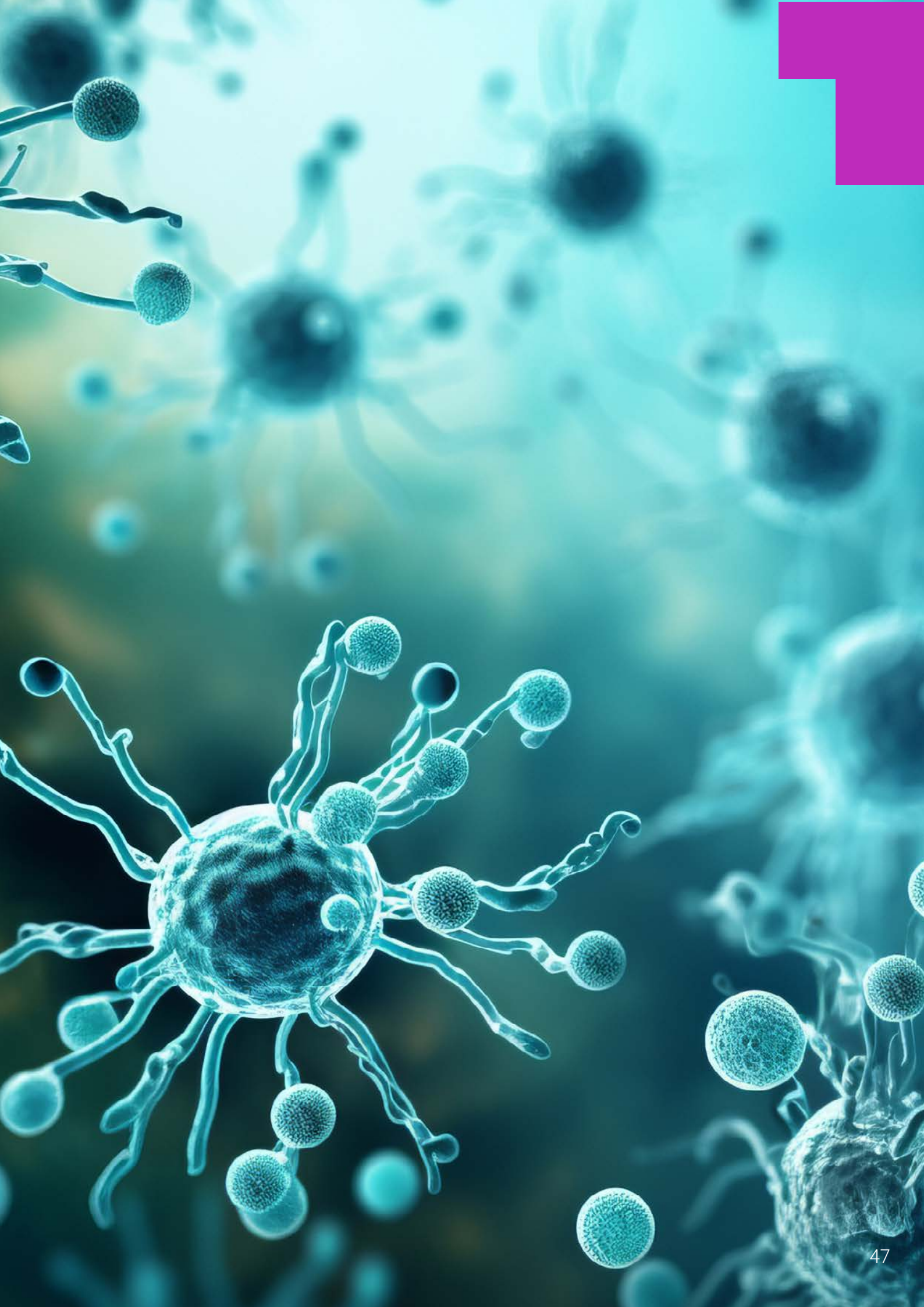
One Health Trust (OHT)[35]

Researchers from the OHT work on several projects across Asia to address antibiotic resistance, zoonotic and vector-borne illnesses. In order to assist policymakers in making decisions on illness prevention, detection, and treatment, the OHT India office in Bangalore is proposing a ground-breaking One Health surveillance system.

The OHT, formerly known as the Center for Disease Dynamics, Economics and Policy (CDDEP), was established in 2010 with the goal of enhancing the health and welfare via research and stakeholder involvement. OHT researchers have been conducting critically important research on major global health issues including antimicrobial resistance, Covid-19, vaccines, medical oxygen shortages, hospital infections, malaria, TB, and pandemic preparedness and response. Concerns like biodiversity preservation, climate change, and the impact of dietary changes on the environment are all included in OHT's mandate.

To address the AMR challenge, OHT is working to close the knowledge gap, promoting vaccination and infection prevention control and support the responsible use of antibiotics through stewardship and evidence-based treatment guidelines.

35 One Health Trust



UK's Investment in AMR and Global Collaboration

The UK is at the forefront of AMR innovation and stewardship and has worked diligently with international partners on research and innovation. The Global AMR Innovation Fund (GAMRIF) supports early-stage innovation projects in areas typically underfunded in AMR research. The UK has expanded efforts to address the global AMR crisis through several initiatives, including:

- UK Government developed its AMR strategy, revised in 2019, with a rolling 5-year action plan with Innovate UK as a key delivery partner. The resultant National Action Plan emphasises the funding for research and innovation, including public-private partnerships to promote the development of new priority vaccines, therapeutics and diagnostics spanning human and animal health.
- The UK is leading the way in implementing a subscription-based model to circumvent low antibiotic sales and usage. With a fragmented market, the new business model will pay a fixed fee to access the antibiotics regardless of how much is being used to treat patients. The purpose of the new model is to encourage companies to invest in antimicrobial research.
- The UK Department of Health and Social Care have invested £50 million in its Global AMR Innovation Fund to address the problems of AMR in Low- and Middle-Income Countries (LMICs).
- The UK is committed to developing new vaccines to combat AMR and infectious diseases through the Global Health Security team. Funding of £477 million was allocated to establish projects in and for LMICs and it included a £110 million UK Vaccine Network Programme to develop new vaccines and technologies to tackle diseases with epidemic potential (a high priority for Official Development Assistance programme; ODA), £70 million of which is being delivered by Innovate UK.
- The UK has invested £210 million to partner with countries across Asia and Africa to tackle AMR. The investment will support the second phase of the UK-India Fleming Fund, with £3 million allocated to facilitate collaboration on AMR surveillance.

India's Vibrant SME Ecosystem

The delegation visited C-CAMP, Bangalore Bioinnovation Centre and the Rotary Club in Bangalore to engage with emerging and established biotech start-ups working at the forefront of AMR research. Meeting with stakeholders identified the innovation opportunity, challenges and the support mechanism to help start-ups thrive in a highly competitive field. In Vijayawada the team visited SRM University AP and held a number of roundtables with Indian AMR experts as part of the International Conclave on AMR and Future Antibiotics (ICAFA) 2023.

Bugworks

Bugworks is a USA-based company (Saratoga, CA) with subsidiaries located in Australia (Adelaide) and India (Bangalore). Novel dual target acting microorganisms have been found and are currently undergoing clinical testing. Bugworks is creating a new family of immunotherapies and broad-spectrum antibacterial drugs to treat cancer and infection patients that require critical care. Bugworks is generally considered as the flagship antimicrobials company in India.

FaunaTech

FaunaTech provides an innovative handheld diagnostics platform powered by smartphones that can be used to screen milk quality and monitor cattle health at the farm level, as well as to detect key infections early and minimise the use of antibiotics. At FaunaTech, the goal is to use cutting-edge diagnostic technology to safeguard farm animals and increase dairy farmers' productivity throughout the world.

Biomoneta

A healthcare startup driven by innovation, Biomoneta® develops products for air free of germs. Their products prevent the spread of illnesses and product contamination by destroying germs in cleanroom environments, hospitals, clinics, ambulances, labs, and other settings. Leading Japanese and Indian healthcare investors, as well as the governments of India and Karnataka, have backed Biomoneta, a firm in the C-CAMP portfolio.

Rapiddx

To shorten the time between sample collection and susceptibility detection, Rapiddx is creating a quick antimicrobial susceptibility test (AST) platform. Their goal is to fight AMR by offering high-quality, reasonably priced healthcare solutions. Utilising data analytics, microfluidics, and mechanics, Rapiddx offers state-of-the-art answers to AMR's problems.

MyLabs Discovery Solutions

A range of diagnostic kits for pathogen identification and viral load tracking are offered by Mylabs. Standardised and dependable solutions for routine testing are offered by fully verified and FDA certified processes. Detection and automated sample preparation and assay setup are integrated with automation with the Compact x to maximise productivity and streamline workflows from sample to result

Module Innovations

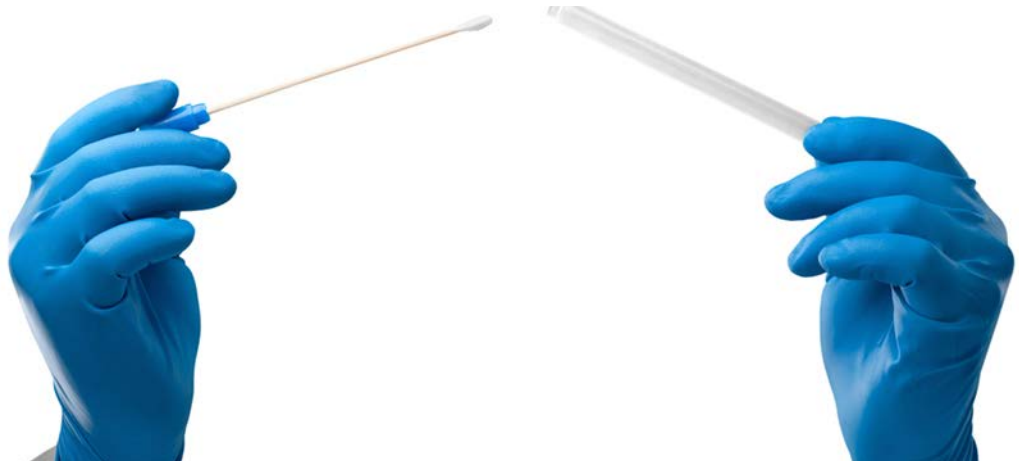
Utilising the strengths of biotechnology and nanotechnology, Module is developing potent solutions for the ultrafast diagnosis of urinary tract infections (UTIs) and the uropathogen's susceptibility to microbes. They can provide UTI positive/negative results using USENSe in as little as 15 minutes, and the AST profile with ASTSENSe in as little as 2 hours, patented SDSAN technology.

Trivitron

Trivitron began in 1997 as a medical technology firm offering cost-effective healthcare solutions. Hospitals, private healthcare practitioners, independent clinics and labs, extended care facilities and renal care centres are the target markets for Trivitron's products. Being a leader in the industry, Trivitron is seeking new ways to combine technology with clinical efficacy to provide better value for money.

CrisprBits

One of the first Indian businesses, CrisprBits, is utilising the revolutionary gene-editing technique CRISPR to create affordable, high-quality biological science solutions. CRISPR is currently being used by CrisprBits to create ubiquitous surveillance and diagnostics. They are making it possible to use CRISPR editing in fields that are addressing urgent healthcare needs, such as creating disease tissue models from edited induced pluripotent stem cells (iPSCs) and developing the next generation of CAR-T cells.



Decode Age

Decode Age has led the way in longevity research in India. Their aim is to provide everyone with access to the most recent scientific developments in this subject. They prioritise producing high-quality, scientifically supported goods that improve people's lives and health. Research on the gut microbiome is one area where Decode Age really shines. They are home to a cutting-edge Next-Generation Sequencing (NGS) Lab devoted to in-depth research in this field. Their team's expertise in microbiome research and bioinformatics has provided them a major competitive advantage. In India, Decode Age is the pioneer firm providing the sophisticated Shotgun Gut Microbiome test.

Microvioma

Microvioma offers innovative solutions in Microbiology for One Health, catering to individuals striving for One Health objectives including Environment, Foods (Agriculture), Human Life, and Animal Life. The organisation is also engaged in the creation of new products that target the microbiome to improve quality of life in all aspects of one health and in drug discovery related to that goal.

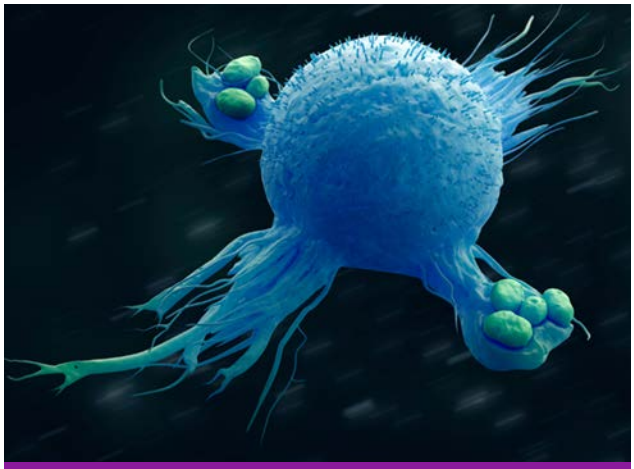
Surveillance and Stewardship

Microvioma is involved in diverse AMR activities including surveillance, antimicrobial susceptibility mapping, policy formulation, research and innovation, collaboration at international, national, and sub-national levels, and stewardship to improve awareness and understanding of AMR.

AMRACE, led by Microvioma and Bangalore Bioinnovation Center, is a collaborative initiative focusing on addressing antimicrobial resistance through stewardship, diagnostics, and interventions, empowering Indian scientists and policymakers.

Tranalab

Tranalab Private Limited is presently engaged in the investigation and creation of novel techniques for the manufacturing of biosimilars. They are focusing on intellectual property prospects and investigating systems with wide platform potential. Their current concentration is on producing “High Value - Low Volume” proteins, but as technology advances, they hope to branch out into bulk volume proteins as well.



Alternative Therapeutics

Tranalab is developing drug-peptide conjugates with potential against multidrug resistant tuberculosis, based on its platform technology for macrophage targeting. The company is also exploring concepts for creating platforms against ESKAPE microorganisms. Tranalab was one of the winners of CCAMP AMR Quest 2023.

Presude Lifesciences

Presude Lifesciences is a comprehensive provider of drug discovery and development services, run by internationally experienced biopharma experts. Presude is a research-focused business that specialises in medicinal chemistry, tailored synthesis, and biological profiling of potential drugs for a variety of therapeutic indications, such as immuno-oncology, inflammation, autoimmunity, and anti-infectives. They cover a wide range of customer needs along the drug discovery and development value chain.

Oxonex biologicals

The goal of OxonEx is to safely bring the best of nature to you. They are positioned to lead a revolution in the biotech sector by bringing it closer to the rejuvenating powers of nature with their innovative nature-based technologies.

Xome Life Sciences

Xome Life Sciences Pvt. Ltd., a biotechnology business situated in Bangalore, was founded in 2020. Their mission is to revolutionise drug development and clinical trials by means of their groundbreaking genomes research. Their goal is to create an AI-powered Virtual Human Platform by utilising the potential of genomics, metabolomics, and microbiome research. The goal of this platform is to increase knowledge of the interactions occurring at the multi-omics level in the human body. The Department of Science and Technology (DST), Startup India, Bangalore Bioinnovation Centre (BBC), BIRAC, and Startup India all sponsor Xome.

Molecular Solutions

Molecular Solutions focuses on

1. Diagnostic testing for the detection of bacteria and viruses as well as testing for antibiotic sensitivity. Using cutting edge technology, they offer fast, dependable, high-quality molecular and microbiological tests.
2. Data-Driven Policy and Prescription Antibiotic Decision-Making. Their ID consultants collaborate with clients to discuss which antibiotics to use or stop using, plan for escalation and de-escalation, direct antimicrobial stewardship efforts, develop predictive antibiograms using patient data and provide infection prevention and epidemiology in hospitals.

01 C-CAMP

Faunatech
Biomoneta
Bugworks
Rapiddx
MyLabs Discovery Solutions
Module Innovation
Trivitron
CrisprBits
Decode Age

02 BBC

Microvioma
Tranalab
Presude Lifesciences
Oxonex Biologicals
Xome Life Sciences
Molecular Solutions
AM-RACE

Stakeholder Engagement in Vijayawa

A series of round table discussions were held with AMR experts to discuss in detail India's approach to the One Health concept including the role of diagnostics, surveillance and therapeutics including vaccines.

Public panel discussion on **AMR**, including representatives of:

- SRM University
- Infection Control Academy of India
- AMRITA[36]
- AIIMS

Round table **One Health**, including representatives of:

- Federation of Asian Biotech Associations (FABA)
- National Institute of Animal Biotechnology (NIAB)
- Central Institute of Fisheries Technology (CIFT)

Round table on **Therapeutics and Vaccines**, including representatives of:

- Infection Control Academy of India (IFCAI)
- Nitte University Centre for Science Education and Research
- Central Institute of Fisheries Technology

Round table on **Diagnostics and Therapeutics**, including representatives of:

- Nitte University
- NTR College of Veterinary Science, Sri Venkateswara Veterinary Institute
- Blueflower Children's Hospital and Diagnostics

36 Amrita Vishwa Vidyapeetham University

06. Opportunities for Future Collaboration

The team engaged with key stakeholders from industry, government and academia to explore and understand the India AMR innovation landscape and identify opportunities for bilateral engagement. Focussing on the thematic areas, a series of round tables were held with senior officials and C-level executives covering:

i. **The role of diagnostics and therapeutics innovation in human and animal health.**

ii. **The purpose of environmental surveillance and monitoring.**

iii. **Synergies between the UK and India on research and innovation.**

AMR in the Environment

Environmental spread of resistant genes results from the discharge of antibiotics (and other antimicrobials) by pharmaceutical manufacturers and hospitals, for example, into wastewater. These antibiotics can lead to the emergence of resistant microorganisms, both of which spread further through sewage and surface water. With India being one of the largest manufacturers of pharmaceuticals and producers of food animals including seafood in the world, it is pertinent to explore opportunities to mitigate discharge into wastewater. The challenge, however, is capturing antibiotics at the point of discharge either at wastewater treatment plants or manufacturing sites.

There is a need to work closely with relevant authorities and both state and national level regulators to build capacity for environmental testing. The surveillance of sewage and sharing of environmental AMR data is crucial to India's effort to mitigate environmental spread of AMR.

Key innovation areas include:

- India to implement environmental monitoring of AMR in national and state action plans in collaboration with the UK through joint workshops.
- Implement IoT and real time monitoring of wastewater and sewage samples.
- Develop and scale water cleaning technologies.
- Joint UK – India database for AMR environmental data.

Animal Health

A major driver of AMR in the animal sector is the excessive and uncontrolled use of antibiotics in the intensive farming of chickens, cows and other domestic animals. Around 70% of the country's population are engaged in agriculture and livestock[37] with one of the highest numbers of dairy animals in the world - 61 million dairy producing bovines.[38] Antimicrobials are commonly added in sub-therapeutic dose in animal feed to promote growth and while the use of growth promoters has been banned in other parts of the world it is still common in India. The relaxed regulatory enforcement and lack of field veterinarians has enabled indiscriminate use of antimicrobials in livestock farming.

Engagement with key stakeholders has revealed a number of opportunities for cooperation between India and the UK including developing guidelines for animal use, co-develop strategies to minimise antimicrobial usage and monitoring, implement learnings from the UK RUMA stewardship programme in India and facilitate cooperation between the British and Indian Veterinary Association.

Key Innovation Areas Include:

- Rapid, point of care (PoC) diagnostics for animal use.
- Development of alternatives to antibiotics - explore phage technology to combat AMR.
- Develop an innovation pipeline for animal health vaccines.
- Develop a national One-Health AMR dashboard.

37 Godara P, Sharma N, Rajput D. Adoption of dairy management practices among the livestock owners of Bikaner district of Rajasthan. *J Entomol Zool Stud.,* 2018.

38 Number of milk cows worldwide in 2023, by country

Responsible Use of Medicines in Agriculture Alliance (RUMA)

This is a non-profit cross sector alliance of 26 organisations representing the UK supply chain from farm to fork. Using evidence-based data, the group provides leadership across the UK livestock industry to encourage and improve responsible use of veterinary medicines. RUMA focuses on AMR and is committed to supporting the One Health initiative with a tagline of **use as little as possible, as much as necessary**. For example, RUMA has partnered with the British Poultry Council (BPC) to highlight the sectors success in antibiotic stewardship. In the last decade there has been more than 70% reduction in total antibiotic use and up to 95.5% reduction in clinically important antibiotics.[39]

39 Sector in focus campaign – poultry meat: ten years of antibiotic stewardship


BAYER

Vaccines for AMR

The rapid rise in resistance bacteria to new antimicrobials makes it challenging to produce new and effective drugs. Vaccines have played a critical role in human health and is an effective approach to mitigating AMR. Human and veterinary vaccines can drastically reduce bacterial infection, reducing antibiotic use and incidence of AMR. Vaccines play a pivotal role in India where secondary infection and symptoms from existing diseases drive antibiotic use. Engagement with clinicians and government stakeholders identified opportunities for further exploratory work in pathogen surveillance, improving uptake of vaccines for existing diseases and joint UK-India partnership to select target pathogens and designing effective vaccines.

Key Innovation Areas Include:

- Development India-strain vaccines for human and animal health.
- Development auto-genous vaccines for aquaculture.
- Development of immunomodulators for aquaculture.
- Development of multi-valent vaccines.
- Thermostabilising and improving immunogenicity of existing vaccines.
- Access to Indian AMR pathogens and bio samples to drive innovation and development of new vaccines.

Diagnostics

PoC diagnostic is critical for the timely identification of bacterial or viral infection which can mitigate inappropriate use of antibiotics. The use of rapid PoC has enormous potential in India to identify resistant bacteria and if required to prescribe the appropriate antibiotic. Conventional diagnosis is time-consuming leading to long turnaround times and therefore innovation in new diagnostic tests is urgently required. PoC diagnostic should be specific, reliable, fast, relatively inexpensive and operate inside and outside of the laboratory. A number of areas were highlighted for future bilateral cooperation such as access to AMR clinical samples, working with clinical trial networks for drug resistant infections, UK – India exchange of clinical and microbiome samples and working closely with innovation hubs such as C-CAMP to co-develop diagnostic tools for AMR.

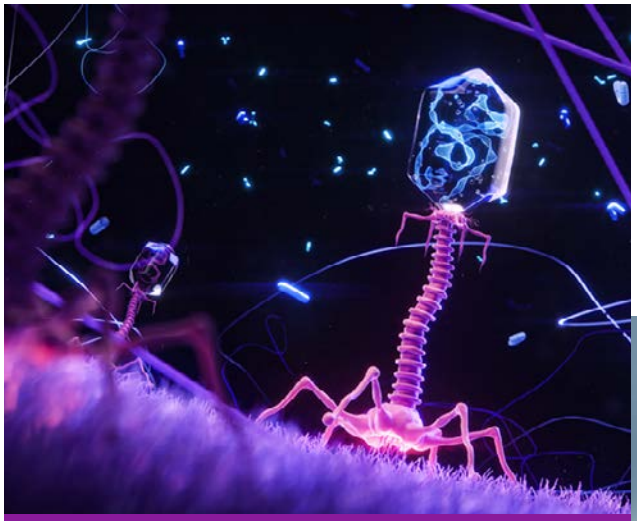
Key Innovation Areas Include:

- Fast, accurate (sensitive, specific) and affordable diagnostics.
- Testing and monitoring technologies at state and national level.
- Development of new biomarkers and diagnostics.
- Predictive AI models to identify early disease onset and new treatments.
- AI and host derived diagnostics.

AMR Diagnostic to Play a Key Role in Advancing UK – India Partnership

There is a clear opportunity for the UK and India to establish a closer working relationship in diagnostic development. The second funding call by PACE[40] between April and September 2024 will be looking at developing novel diagnostics and will be open to Indian organisations. This will open up greater collaboration between the two countries, establish an innovation pipeline and facilitate knowledge exchange.

40 https://paceamr.org.uk/



Joint UK-India Investment in Phage Technology

Conversations with senior stakeholders from industry and academia indicate an opportunity to utilise phage technology to create novel and innovative therapeutics to address AMR. Phage is increasingly being explored in India as credible alternatives to traditional antibiotics and with similar interests in the UK it presents an opportunity for joint UK-India collaboration. The challenge, however, is the scepticism in large scale manufacturing of bacteriophages around quality and cost and the requirement to meet GMP standards. Potential bilateral CR&D programmes would need to focus on these challenges before using phage's as prescribed medicine.

“It was a privilege to meet so many innovators in the AMR space. India is rapidly becoming a global powerhouse of medtech innovation with enormous potential for UK companies to build commercial and research partnerships. The university and incubator support for innovative companies was highly impressive and the large number of start-up companies developing products that have the potential to positively impact healthcare demonstrates India’s commitment in this space.”

Chief Business Officer, aVaxiPen Limited

07. Critical Success Factors

1. Access to Indian AMR surveillance data is limited with a lack of data sharing between private and public institutions.
2. Limited access to isolates in Indian clinical trials as well as difficulties with patient recruitment making clinical trials in India time consuming.
3. Lack of regulatory synergy between the UK and India with respect to AI based diagnostics as well as the lack of guidance in India needed to effectively implement emerging AI technologies. While the landscape is improving there is uncertainty around regulations and guidance on wider emerging AMR technologies.
4. Fragmentation in the Indian innovation and research landscape as well as in Indian markets. The complex innovation and funding landscape makes it difficult to identify key stakeholders and the journey from laboratory to patient.
5. India has invested substantially to support innovation and create a vibrant SME ecosystem. While there is an excellent support system for start-ups there is little incentive for businesses to scale and launch products/services to the market.
6. Insufficient communication and collaboration between key AMR stakeholders across the One Health space. This is largely driven by the large number of Indian AMR stakeholders working in silo and therefore minimal exchange of information and know-how between the One Health sectors.
7. Lack of education in India of the AMR threat. A number of initiatives exist to educate and promote antibiotic stewardship but there is still insufficient investment with no clear communication in many states in India. The launch of state-level AMR actions plan will help with this.

Critical Success Factors for Successful Programmes with India

India, with its complex innovation landscape with national and state-level AMR challenges presents an enormous opportunity for UK organisations. Successful engagement with key AMR stakeholders requires navigating and understanding the cultural differences, state-level priorities, start-up ecosystem and the regulatory and innovation landscape. Several factors were identified that would support future engagement with India in diagnostics, therapeutics and vaccines, animal health and the environment.

Diagnostics

- Recruiting the right patients (ones showing resistance) for effective diagnostic development and the sharing and access of data to measure resistance pattern and antibiotic use.
- Investment in diagnostic R&D. There is a need for improved clinical and reimbursement model to drive diagnostic innovation in India.
- Better education of the public and health professionals on the importance of diagnostic.

Therapeutics and Vaccines

- Work closely with local authorities to educate and improve vaccine uptake in the population including children.
- Engage with Indian vaccine manufacturers and develop early commercial agreements to ensure India has access to UK technology.

Animal Health

- There is a need for consistent data collection across India with better exchange of information with the UK.
- Involve farmers (agri- and aquaculture) when implementing state and national level AMR action plans.
- Establish closer relationship with UK institutions (industry and academia) to share learnings and policy in animal health.

Environment

- Closer engagement with national regulatory authorities and local stakeholders to build relationship and future collaboration.
- Build deep industry connection to promote environmental monitoring of AMR.

08. Conclusions

AMR will have its biggest impact in Low- and Middle-Income Countries (LMIC) with evidence already showing that India is at a key inflection point in the fight against AMR. By 2050, it is estimated that India will account for 20% of all AMR related deaths. The issue of AMR is not confined to India but is a global challenge, one which will spread across borders and impact everyone. India, with its vast and complex healthcare landscape, innovation ecosystem and poor antibiotic stewardship presents a unique challenge and an opportunity for bilateral cooperation.

There is a clear intent by the Government of India to educate, invest and drive innovation to combat AMR. A vibrant SME ecosystem exists in the state of Karnataka supported by DBT at the state-level with excellent funding infrastructure to promote commercialisation of early-stage research. There are clear synergies between India and the UK in its policy, desire and approaches to address AMR. While the focus has been on human health, India is starting to implement the One Health concept by breaking down silos and working closely with different government agencies. Common challenges still exist that are associated with SMEs and industry-academia partnership such as IP and the translation of laboratory/clinical research to viable products.

With the rapid rise of AMR in India and globally, new antimicrobials, alternative therapeutics and faster and accurate diagnostic is urgently needed. The UK with its excellent infrastructure, stewardship and its approach to One Health presents an opportunity to share learnings and facilitate B2B and G2G engagement to strengthen UK-India relationship.

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