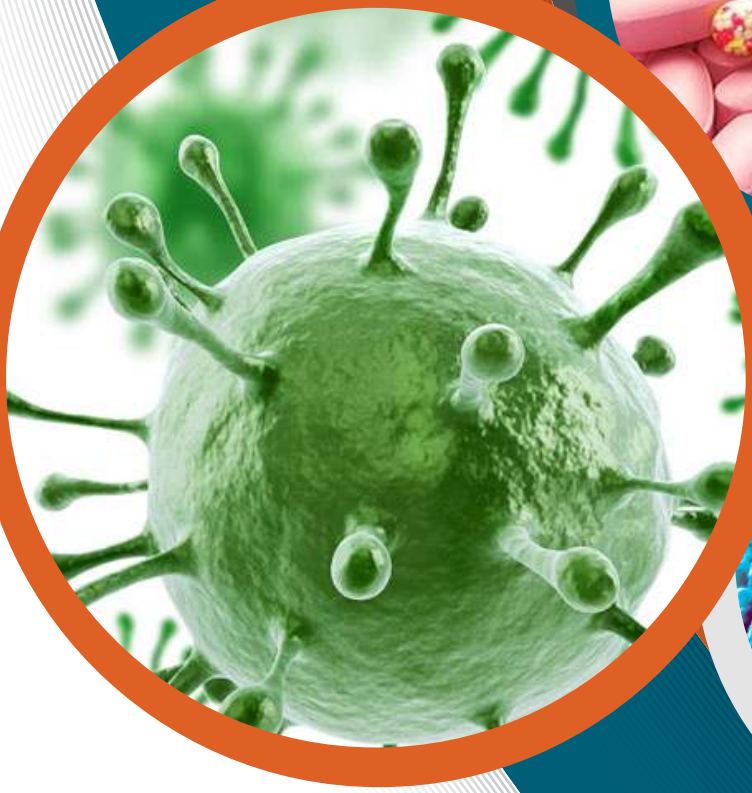
AMR
Tackling Antimicrobial Resistance

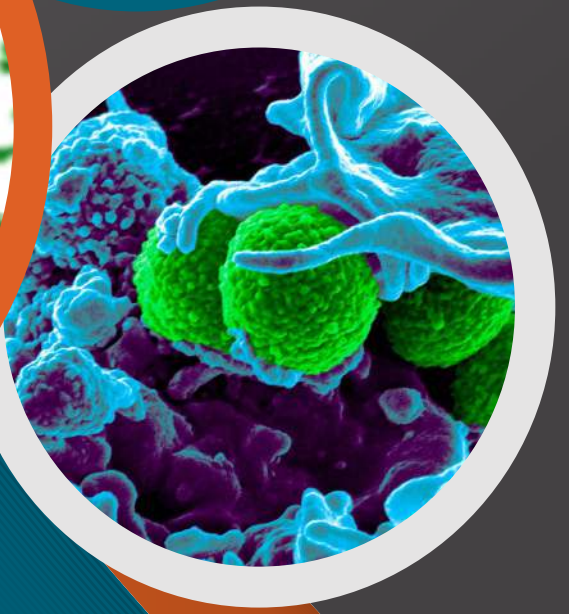
सत्यमेव जयते
DEPARTMENT OF BIOTECHNOLOGY
Ministry of Science and Technology

RESEARCH COUNCILS UK
INDIA

Scoping Report on Antimicrobial Resistance in India

November 2017





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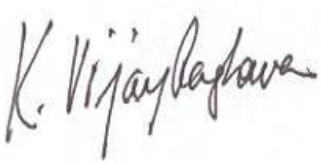
Foreword

Antimicrobial Resistance (AMR) is recognised as a complex problem and addressing it requires countries to make joint efforts across various disciplines. Considering the complex nature of the AMR problem, no individual country has the capacity to address this major public health problem independently. Accordingly, India and the United Kingdom came together to fight against AMR in November 2016 with a new £13 million UK-India research program to conduct collaborative research across multiple disciplines to come up with comprehensive and creative solutions to overcome AMR.

As the first step, the Department for Biotechnology (DBT), Government of India, in partnership with Research Councils United Kingdom (RCUK)- the strategic partnership of the UK's seven Research Councils, commissioned this study to map the AMR research landscape mapping in India. This report summarizes the current AMR situation in India with a focus on antibacterial resistance and identifies the current research gaps to determine future research priorities in India. This report should be a ready reckoner to scientists and policy makers for designing interventions to address AMR problems jointly and unequivocally.

I sincerely hope that this report encourages Indian scientists to fill evidence gaps in addressing the AMR challenge through innovations and new technologies tailored to local needs. Such innovations require effective collaboration among UK and Indian scientists across several disciplines, including medical scientists, natural scientists, sociologists, engineers and economists to name a few.



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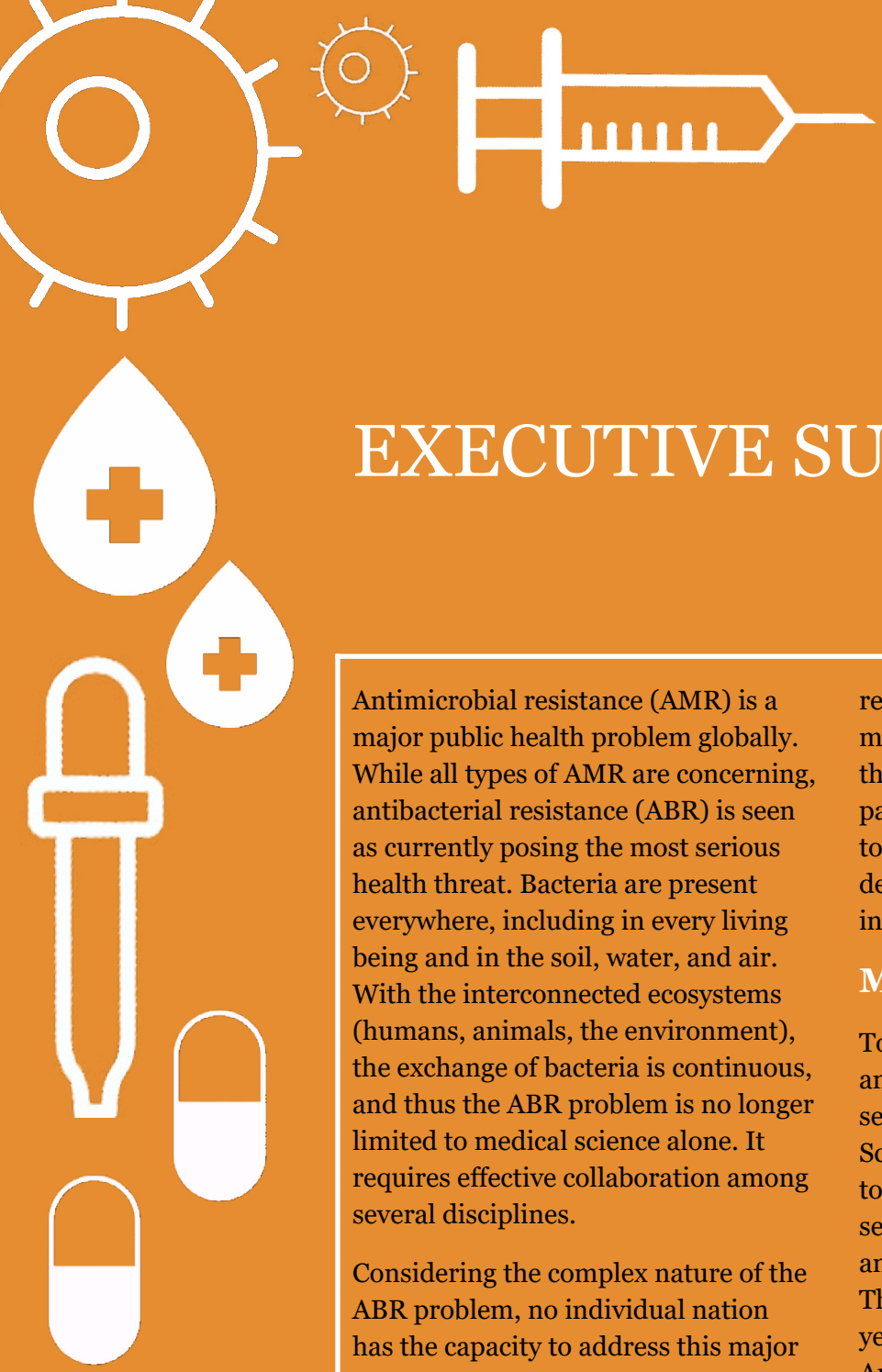
ABBREVIATIONS

ABR	Antibacterial resistance
AMR	Antimicrobial resistance
AMRSN	Antimicrobial Resistance and Surveillance Research Network
ARGs	Antibiotic resistance genes
CIMS	Current Index of Medical Specialties
CPCB	Central Pollution Control Board
DBT	Department of Biotechnology
ESBL	Extended-spectrum beta-lactamase
FDCs	Fixed-dose combinations
FSSAI	Food Safety and Standards Authority of India
GMP	Good manufacturing practices
HAIs	Healthcare-associated infections
ICMR	Indian Council of Medical Research
IPC	Infection prevention and control
MDR	Multidrug resistant
MRL	Maximum residue levels
MRSA	Methicillin-resistant S. aureus
NAP	National Action Plan
NCDC	National Center for Disease Control
NDM	New Delhi metallo-beta-lactamase
NICUs	Neonatal intensive care units
RCUK	Research Councils United Kingdom
STPs	Sewage treatment plants
TB	Tuberculosis
WHO	World Health Organization



EXECUTIVE SUMMARY

Antimicrobial resistance (AMR) is a major public health problem globally. While all types of AMR are concerning, antibacterial resistance (ABR) is seen as currently posing the most serious health threat. Bacteria are present everywhere, including in every living being and in the soil, water, and air. With the interconnected ecosystems (humans, animals, the environment), the exchange of bacteria is continuous, and thus the ABR problem is no longer limited to medical science alone. It requires effective collaboration among several disciplines.

Considering the complex nature of the ABR problem, no individual nation has the capacity to address this major public health problem independently. In response, the United Kingdom and India came together to fight against AMR in November 2016 with a new £13 million UK-India research program. The goal of this initiative was for the UK and India to conduct collaborative research across multiple disciplines to come up with comprehensive and creative solutions to overcome AMR. As the first step, the Department for Biotechnology (DBT), government of India, in partnership with Research Councils United Kingdom (RCUK) decided to undertake mapping of AMR research in India. The aims of the mapping exercise are to understand the current situation of AMR, with particular focus on ABR in India, and to identify the current research gaps to determine the future research priorities in India.

METHODOLOGY

To understand the AMR situation and research landscape in India, we searched the PubMed and Google Scholar databases for literature relating to AMR in India, using the following search terms: “antimicrobial OR antibiotic AND resistance AND India.” The search was limited to the last five years (July 1, 2012, to June 30, 2017). Articles were screened and selected based on their titles and extracted. Articles relating to tuberculosis, malaria, leprosy, nontuberculous mycobacteria, and HIV were excluded. Recently, another study conducted a tuberculosis research mapping exercise in India (see Maharana et al. 2014). Research publications not associated with Indian-based institutions were also excluded. Each article was assigned to one of the following eight categories:

- Humans: Studies that focused on humans
- Animals: Studies that focused on

animals, including agriculture
- Environment: Studies that focused on the environment
- Novel agents: Studies that focused on natural or synthetic compounds with antimicrobial activity
- Diagnostics: Studies that focused on new diagnostics
- One health: Studies that focused on a combination of these categories: humans, animals, or environment
- Reviews/editorials: Studies that did not include primary research
- Miscellaneous: Studies that did not fit into any of the above categories
- If a study would fit into more than one category, it was assigned to only one main category.

THE ANTIMICROBIAL RESISTANCE SITUATION IN INDIA

Antimicrobial Resistance in Humans

AMR is a global public health threat, but nowhere is it as stark as in India. India has some of the highest antibiotic resistance rates among bacteria that commonly cause infections in the community and healthcare facilities. Resistance to the broad-spectrum antibiotics fluoroquinolones and third-generation cephalosporin was more than 70% in *Acinetobacter baumannii*, *Escherichia coli*, and *Klebsiella pneumoniae*, and more than 50% in *Pseudomonas aeruginosa*.

Carbapenem resistance

The carbapenem class of antibiotics is one of the last-resort antibiotics to treat serious bacterial infections in humans, and resistance to carbapenems among various gram-negative bacteria was extremely high (Gandra et al. 2016; ICMR 2015[1]). The highest carbapenem resistance was observed in *A. baumannii* (67.3%; 70.9%), followed by *K. pneumoniae* (56.6%; 56.6%), *P. aeruginosa* (46.8%; 41.8%) and *E. coli* (11.5%; 16.2%) (Figure ES-1).

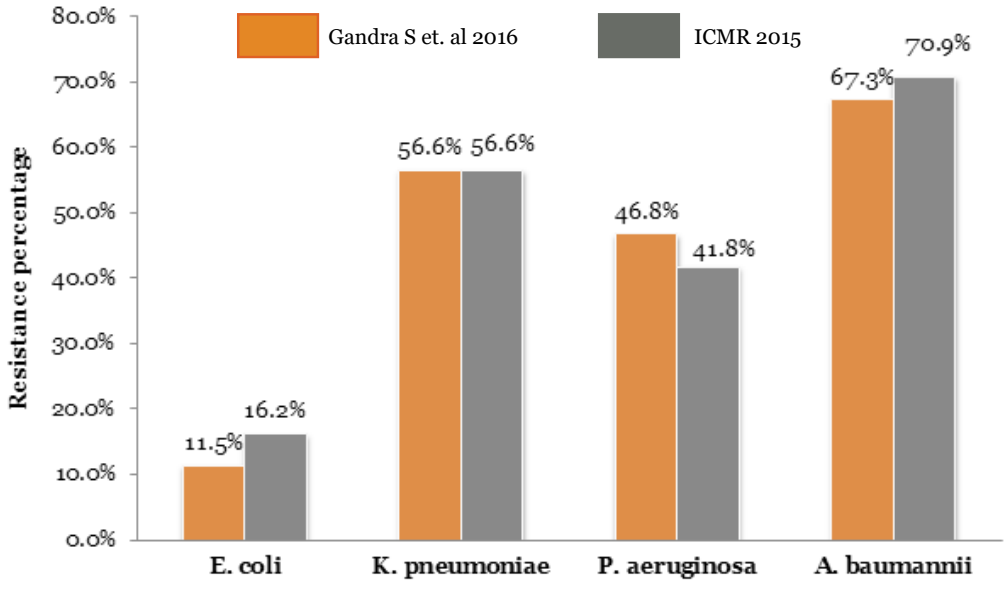


Figure ES-1:

Carbapenem (meropenem/ imipenem) resistance among various bacteria isolated from blood culture

Source: *Gandra et al. (2016); ICMR (2015).*

[1]The ICMR AMR surveillance network includes data from four tertiary care hospitals. This information was obtained from ICMR for the purpose of this report.

Colistin resistance

Colistin is considered to be the last-resort antibiotic in human medicine. With increasing use of colistin for treatment of carbapenem-resistant gram-negative bacterial infections, colistin resistance among gram-negative bacteria has emerged in India (Kaur et al. 2017; Pragasam et al. 2016; Manohar et al. 2017). Bloodstream infections due to dual carbapenem- and colistin-resistant *K. pneumoniae* are associated with 69.3% mortality among Indian patients (Kaur et al. 2017) (Figure ES-2). However, known plasmid-mediated colistin resistance genes *mcr-1* and *mcr-2* were not detected frequently.

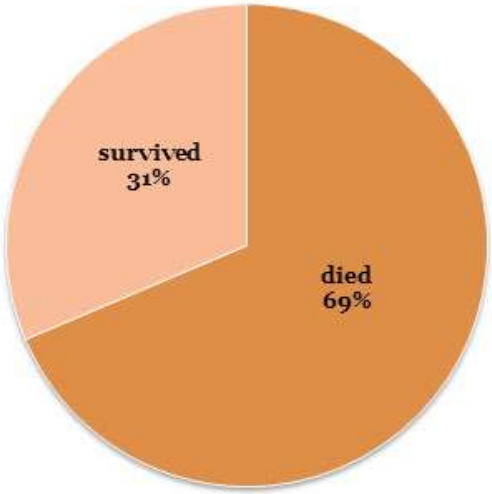


Figure ES-2:

Mortality associated with dual carbapenem- and colistin-resistant *Klebsiella pneumoniae* bloodstream infections

Source: *Kaur et al. (2017).*

Antimicrobial Resistance in Animals

The use of antibiotics in food animals plays a major role in human health, as antibiotic-resistant bacteria can be transmitted between humans and animals through contact, in food products, and from the environment (Landers et al. 2012). Although a limited number of studies were conducted in food animals, high levels of antibiotic-resistant bacteria were identified.

Antibiotic-resistant bacteria in Poultry

Several studies reported isolation of extended-spectrum beta-lactamase (ESBL) producing *E. coli* strains from fecal samples of chickens (Brower et al. 2017; Kar et al. 2015; Shrivastav et al. 2016). Chicken meat samples contaminated with *Salmonella* species resistant to multiple antibiotics have been reported (Kaushik et al. 2014; Naik et al. 2015). New Delhi metallo-beta-lactamase-1 (NDM-1) producing bacteria conferring resistance to carbapenems and *mcr-1/mcr-2* gene producing bacteria conferring resistance to colistin have not been reported in chickens so far.

Antibiotic-resistant bacteria in Livestock

NDM-1 (Ghatak et al. 2013) and ESBL-producing gram-negative bacteria (Das et al. 2017) isolated in milk samples obtained from cattle with mastitis have been reported. In addition, one study reported isolation vancomycin-resistant *Staphylococcus aureus* (VRSA) strains in milk samples obtained from cows with mastitis (Bhattacharyya et al. 2016). Among pigs, a few studies reported detection of ESBL-producing *E. coli* from fecal samples of healthy pigs (Lalzampuia et al. 2013; Samanta et al. 2015). So far, *mcr-1/mcr-2* gene-producing bacteria conferring resistance to colistin have not been reported in livestock.

Antibiotic-resistant bacteria in Aquaculture

In a study involving tilapia fish obtained from urban lakes and rivers, 42% of Enterobacteriaceae isolates obtained from the gut of tilapia fish were ESBL producers (Marathe et al. 2016). In another study, *Vibrio* species associated with food poisoning were identified among shrimp, shellfish, and clams obtained from retail markets in Kerala. These *Vibrio* species were 100% resistant to ampicillin but remained highly sensitive to chloramphenicol (Sudha et al. 2014). NDM-1 and *mcr-1/ mcr-2* gene-producing bacteria have not been reported in fish samples.

Antibiotic Resistance in the Environment

With the interconnectedness of ecosystems, the role of the environment, particularly water, in the spread of antibiotic-resistant bacteria is increasingly gaining attention. A limited number of published studies on the environment indicate high levels of antibiotic-resistant bacteria and antibiotic resistance genes (ARGs) in various water bodies.

Antibiotic-resistant bacteria and genes in Sewage and Hospital wastewater

Hospital wastewater has high levels of antibiotic resistant organisms. A study examining wastewater samples from three different sewage treatment plants (STPs) found that hospital wastewater inflow significantly increased the prevalence of third-generation cephalosporin-resistant *E. coli* (Akiba et al. 2015) (Figure ES-3).

Antibiotic-resistant bacteria and genes in Rivers

Major rivers in India have bacteria with high levels of resistance to broad-spectrum antibiotics such as third-generation cephalosporins. In a study involving River Cauvery in Karnataka, 100% of *E. coli* isolates were found

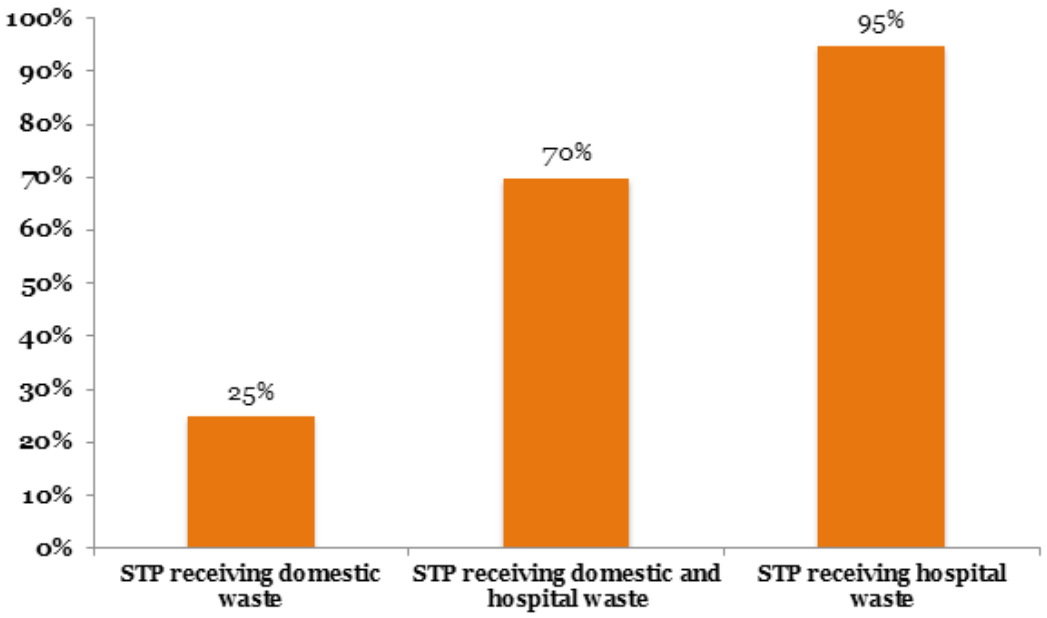


Figure ES-3:

***E. coli* resistance to third-generation cephalosporins among sewage treatment plants (STPs) receiving waste from various sources**

Source: *Akiba et al. (2015).*

to be resistant to third-generation cephalosporins (Skariyachan et al. 2015). In a second study, involving River Yamuna, 17.4% (40) of isolates belonging to different groups of gram-negative bacteria were found to be ESBL producers (Azam et al. 2016). In addition to antibiotic-resistant bacteria, ARGs that confer resistance to broad-spectrum antibiotics, including last-resort agents, were detected in major rivers of India. These include the $bla_{CTX\text{-}M}$ gene (Azam et al. 2016; Akiba et al. 2016; Devarajan et al. 2016), the $bla_{NDM\text{-}1}$ gene (Ahammad et al. 2014; Devarajan et al. 2016; Marathe et al. 2017), and the mcr-1 gene (Marathe et al. 2017).

Antibiotic-resistant bacteria and genes in Surface water and Groundwater

Studies have also shown potable water sources apart from rivers to have bacteria with high levels of resistance to broad-spectrum antibiotics. A study involving water from drinking and recreational sources in the Ayodhya-Faizabad area showed that 17% of *E. coli* and 13% of *Klebsiella* species were resistant to third-generation cephalosporins (Kumar et al. 2013). Another study involving natural sources of water in East Sikkim throughout the year 2011–12 found that 50% of *E. coli* and 72% of *Klebsiella* species were resistant to third-generation cephalosporins (Poonia et al. 2014). And a study involving four tap water samples, one bore-hole water sample, and 23 environmental water samples in the Hyderabad area found that among 23 environmental water samples, 22 had Enterobacteriaceae and other gram-negative bacteria, 100% of them were ESBL producers, and more than 95% were $bla_{OXA\text{-}48}$ producers.

FACTORS DRIVING ANTIBIOTIC RESISTANCE IN INDIA

Antibiotic consumption in Humans

In 2014, India was the highest consumer of antibiotics, followed by China and the United States. However, the per capita consumption of antibiotics in India is much lower than in several other high-income countries (Laxminarayan et al. 2016). Some of the reasons for high resistance rates in India are discussed in this section.

High consumption of broad-spectrum antibiotics

Broad-spectrum antibiotics are those that are effective against a wide range of disease-causing bacteria, in contrast to narrow-spectrum antibiotics, which are effective against specific families of bacteria. From 2000 to 2015, cephalosporin and broad-spectrum penicillin consumption increased rapidly, whereas narrow-spectrum penicillin consumption was low and decreasing (Figure ES-4).

The rapid increase of third-generation cephalosporin consumption could be attributed to multiple factors, such as increasing resistance to fluoroquinolones among bacteria causing enteric fever and bacterial dysentery, making third-generation

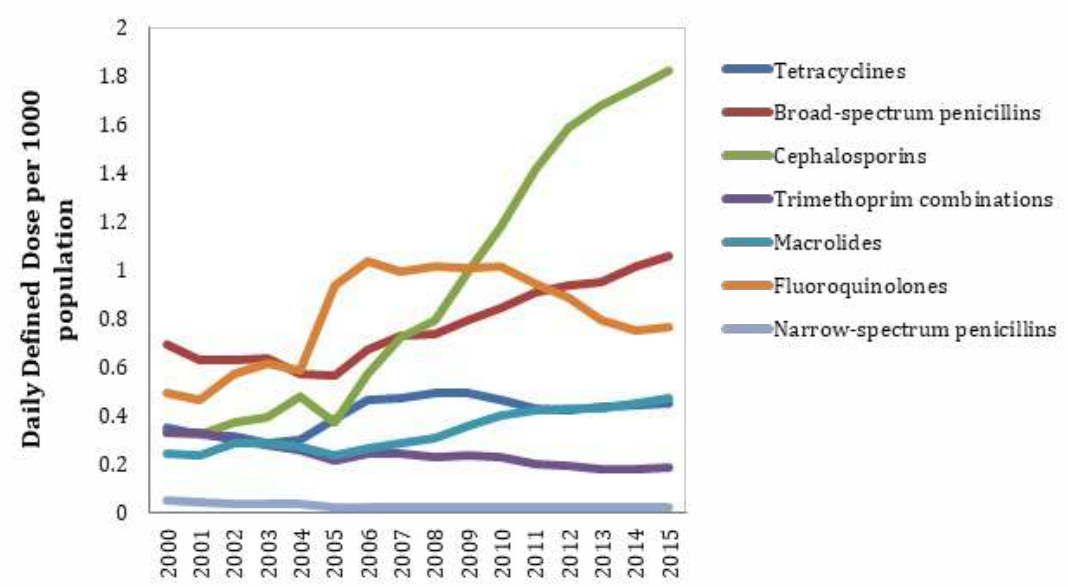


Figure ES-4:

Trends in antibiotic consumption in India, 2000–2015

Source: *QuintilesIMS.*

cephalosporins empiric treatment choices for these two common infections (Taneja 2007; Mukherjee et al. 2013; Gandra et al. 2016). Changing prescribing practices by healthcare providers, with third-generation cephalsoporins being substituted for penicillins in the treatment of upper respiratory tract infections in outpatient settings and lower respiratory tract infections in inpatient settings (Gandra et al. 2017; Kotwani and Holloway 2014; Kotwani et al. 2015). Another factor is a lack of widespread availability of narrow-spectrum agents such as first-generation penicillins (penicillin G, benzathine penicillin) in contrast to third-generation cephalosporins in the pharmacies (Kotwani and Holloway 2013). In India, only one formulation company is making penicillin G or benzathine penicillin, whereas 135 formualtion companies manufacture cefixime, a third-generation cephalosporin (Figure ES-5).

Antibiotic fixed-dose combinations

Antibiotic fixed-dose combinations (FDCs) are combinations of two or more active antibiotics in a single-dosage form. Antibiotic FDCs should be prescribed when the combination has a proven advantage over single compounds administered separately in therapeutic effect, safety, or compliance (Gautam and Saha 2008). However, in India, antibiotic FDCs are heavily prescribed even without the knowledge of a proven advantage over single compounds. Injudicious use of antibiotic FDCs could lead to emergence of bacterial strains resistant to multiple antibiotics. Approximately 118 antibiotic FDCs are available in India (Ahmad et al. 2016; Shankar et al. 2016).

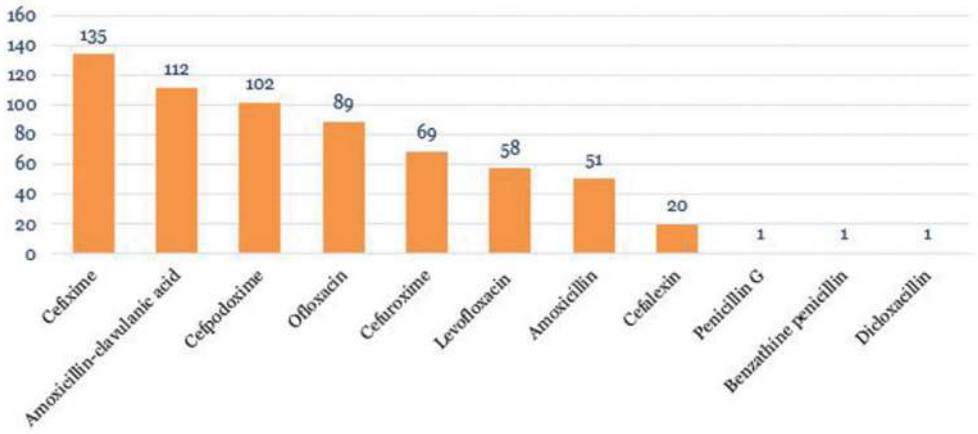


Figure ES-5:

Number of formulation companies manufacturing various antibiotics for human use

Source: *CIMS INDIA, April–July 2017 edition.*

Social Factors

Several social factors drive inappropriate antibiotic use in India. Among the general public, such factors include self-medication, access to antibiotics without prescription, use of pharmacies and informal healthcare providers as sources of healthcare, and lack of knowledge about when to use antibiotics (Barker et al. 2017; Chandy et al. 2013). Among healthcare providers who provide care in the private sector, reasons for inappropriate antibiotic prescribing include perceived patient demand, fear of losing patients if asked for diagnostic investigations, diagnostic uncertainty, economic incentives from pharmaceutical companies, and lack of continuing medical education (Chandy et al. 2013; GARP India 2011; Kotwani and Holloway 2013). Among healthcare providers in the public sector, reasons include a heavy patient load resulting in a lack of time to counsel against antibiotics, pressure to use short-dated medicines including antibiotics, lack of diagnostic facilities, and lack of continuing medical education (Kotwani et al. 2010; Kotwani and Holloway 2013).

Cultural Activities

One of the major cultural activities associated with potential acquisition and spread of antibiotic-resistant bacteria and ARGs is mass bathing in rivers as part of religious mass gathering occasions. In one study (Ahammad et al. 2014), bla_{NDM-1} was found to be over 20 times greater in the Ganges River during pilgrimage season than at other times of year, indicating that pilgrimage areas may act as hot spots for the broader transmission of bla_{NDM-1} and other antibiotic resistance genes.

Antibiotic consumption in Animals

It is estimated that India was the fifth-largest consumer of antibiotics in food animals (poultry, pigs, and cattle) in 2010, and with rising incomes and changing dietary patterns leading to an increase in the demand for

animal protein, especially for poultry, antibiotic use is projected to grow by 312%, making India the fourth-largest consumer of antibiotics in food animals by 2030 (Van Boeckel et al. 2015). Use of antibiotics as growth promoters in food animals and poultry is a common practice; however, the true extent of this practice is unknown. Antibiotics such as tetracycline, doxycycline, and ciprofloxacin, which are critical to human health, are commonly used for growth promotion in poultry (Brower et al. 2017; CSE 2014). A more concerning issue is the use of colistin for growth promotion, prophylaxis, and therapeutic purposes in poultry (CSE 2014). Studies show the presence of antimicrobial residues in chicken meat and shrimp samples sold for human consumption (Sahu and Saxena 2014; Swapna et al. 2012).

Pharmaceutical industry pollution

The Indian pharmaceutical industry supplies 20% of generic drugs, with an estimated US$15 billion in revenue in 2014 (Nordea Asset Management 2015). With respect to antibiotics, it is estimated that 80% of the antibiotics sold by multinational pharmaceutical companies on the global market are manufactured in India and China (Sum of Us 2015). However, the effluents from the antibiotic manufacturing units contain a substantial amount of antibiotics, leading to contamination of rivers and lakes in India (Larsson et al. 2007; Lübbert et al. 2017; Gothwal and Shashidhar 2017).

Pharmaceutical companies can be broadly classified as active pharmaceutical ingredient (API) manufacturers and formulation companies. API manufacturers produce antibiotics in bulk that are then sold to formulation companies to produce finished products like tablets, syrups and vials. Effluents coming from both types of manufacturing units contain antibiotic residues but significantly higher amount of residues are expected in the effluents of API manufacturing units. The existing good manufacturing practices (GMP) framework is restricted to drug safety and does not include environmental safeguards. Regulation of environmental discharges from the manufacturing units is left to the local governments. In India, the Central Pollution Control Board (CPCB) established effluent standards for pharmaceutical industry waste, and all state pollution control boards follow the same standards. Unfortunately, the current standards do not include antibiotic residues, and thus they are not monitored in the pharmaceutical industry effluents (CPCB Effluent Standards 2013).

In India, there are at least 40 antibiotic API manufacturers and at least 250 antibiotic formulation companies manufacturing at least one antibiotic for human use. The leading manufacturers of antibiotics for human use in India are displayed in Figure ES-6.

Although published studies on antibiotic pollution have been restricted to the Hyderabad area in the state of Telangana, the number of

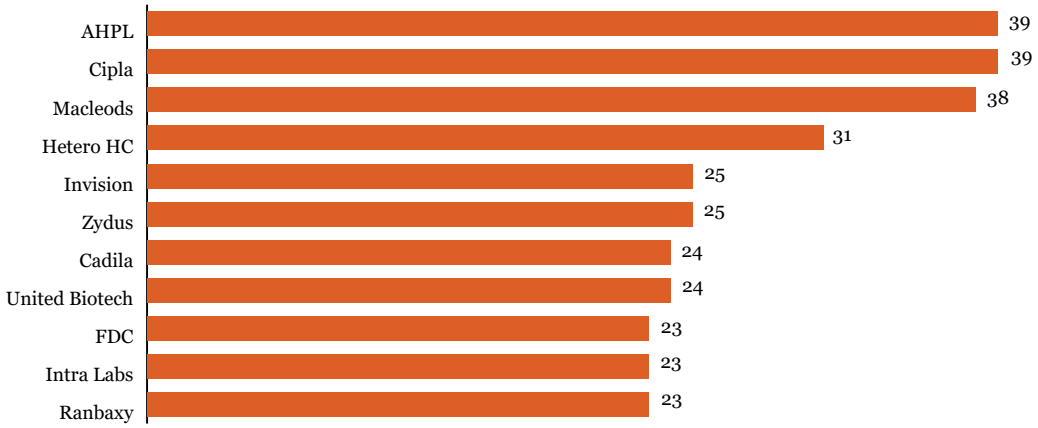


Figure ES-6:

Leading antibiotic formulation companies and the number of antibiotics they manufacture for human use in India

Source: *CIMS INDIA, April–July 2017 edition.*

pharmaceutical companies involved in manufacturing antibiotics suggests the potential possibility of environmental antibiotic pollution in several other locations in India as well (Figure ES-7). Some of the antibiotic API manufacturer hot spots include, Ankleshwar and Karkhadi in state of Gujarat, Aurangabad, Mumbai area, and Tarapur in the state of Maharashtra, Baddi and Paonta Sahib in the state of Himachal Pradesh, Derabassi in the state of Punjab and Hyderabad area in the state of Telangana.

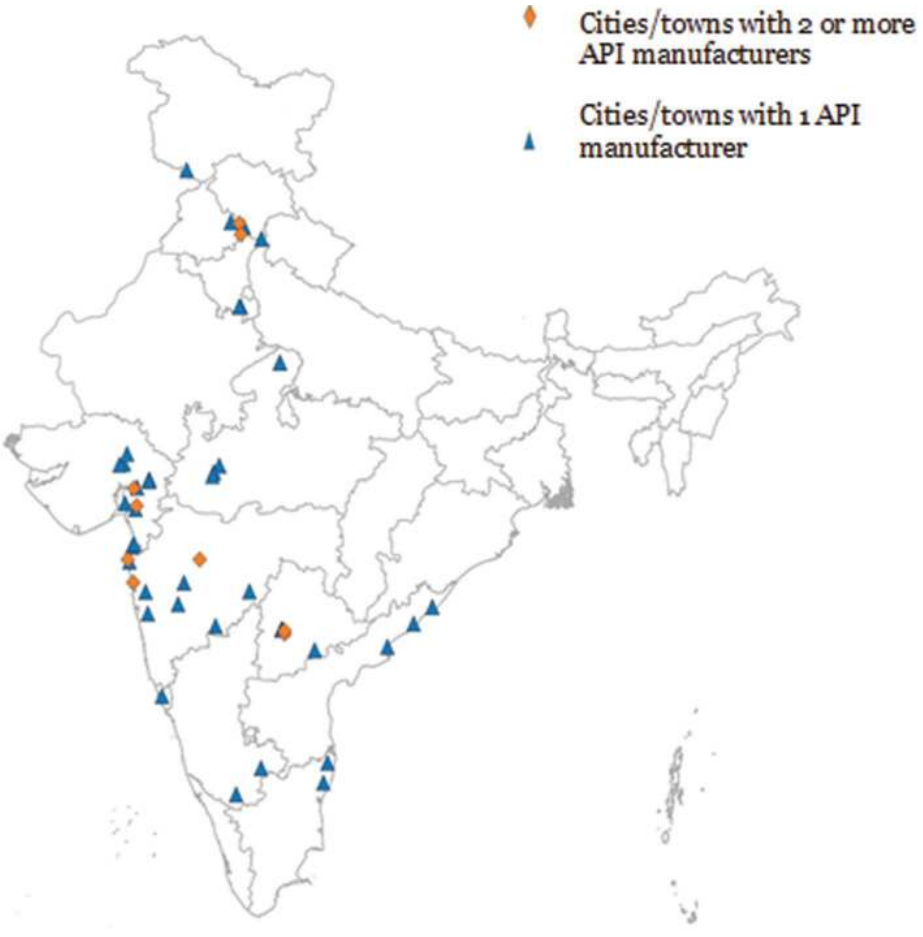


Figure ES-7:

Sites of human antibiotic active pharmaceutical ingredient (API) manufacturing companies in India

Note: *Manufacturing unit locations were identified by reviewing websites of individual companies*

Environmental Sanitation

Antibiotic selection pressure is a prerequisite for the emergence of resistance; however, poor sanitation plays a major role in the spread of antibiotic-resistant bacteria and ARGs. More than 50% of the Indian population does not have access to sanitation facilities for safe disposal of human waste (World Bank 2017). In addition, a large proportion of sewage is disposed untreated into receiving water bodies, leading to gross contamination of rivers with antibiotic residues, antibiotic-resistant organisms, and ARGs (Marathe et al. 2017).

Infection Control practices in Healthcare settings

The prevalence of various healthcare-associated infections (HAIs) among Indian hospitals ranges from 11% to 83%, in contrast to the World Health Organization (WHO) estimate of about 7% to 12% of the HAI burden among hospitalized patients globally (Ramasubramanian et al. 2014). Only a few multicenter studies have been conducted assessing infection control practices in India. One study in the state of Gujarat that assessed infection control practices in 20 delivery care units showed that surgical gloves were reused in over 70% of facilities, only 15% of the facilities reported wiping of surfaces immediately after delivery in labor rooms, and one-third of facilities did not have wash basins with hands-free taps (Mehta et al. 2011). These poor infection prevention practices in delivery care units reflect the types of organisms seen in early onset neonatal sepsis cases. In a recent large prospective study involving three NICUs, *Acinetobacter* species (a common healthcare-acquired pathogen) was the most common organism causing early onset neonatal sepsis (occurring within 72 hours of birth) (Figure ES-8).

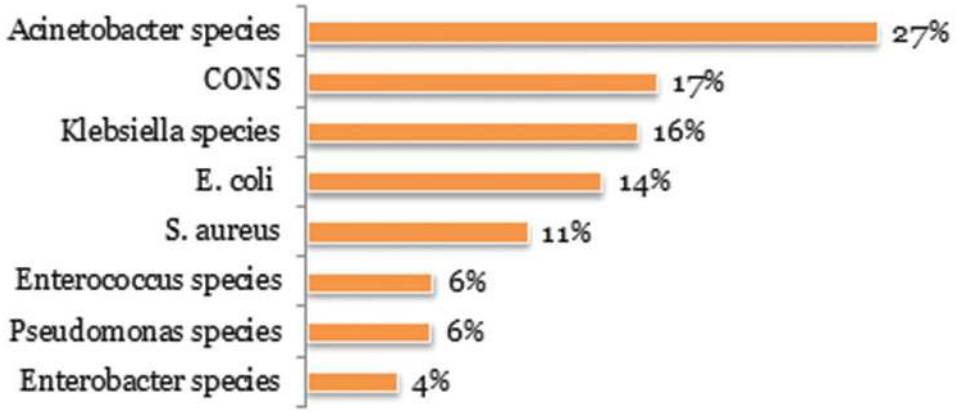


Figure ES-8:

Causes of early onset neonatal sepsis in three NICUs in Delhi

Source: *Chaurasia et al. (2016)*

Note: *CONS = coagulase-negative Staphylococci*

AMR Policy situation in India

In India, the issue of AMR came to the attention of policymakers with the 2010 discovery of NDM-1 and the controversy[2] over its name. Subsequently, AMR-related policies were initiated in 2011 by publishing the National Policy on Containment of AMR. In addition, other nongovernmental initiatives such as the Chennai Declaration were published to create a roadmap to tackle the AMR problem. Over the last seven years, several policies were enacted, and in April 2017, a comprehensive National Action Plan for Containment of AMR was launched. The timeline of AMR policy–related activities appears in Table ES-1.

Table ES-1:

Timeline of AMR Policy–Related Activities in India

Year	Activity
2010	Establishment of the National Task Force on AMR Containment
2011	Publication of the Situation Analysis on AMR
2011	Publication of National Policy on AMR Containment
2011	Jaipur Declaration on AMR Containmentontainment
2011	The Food Safety and Standards (Contaminants, Toxins and Residues) Regulations in seafood
2011	Establishment of the National Programme on AMR Containment under the Twelfth Five Year Plan (2012–2017)
2012	National Program on Antimicrobial Stewardship, Prevention of Infection and Control by ICMR
2013	Establishment of a National AMR Surveillance Network by NCDC and ICMR
2014	Inclusion of antibiotics in Schedule H1 category to avoid nonprescription sales of antibiotics
2016	Launch of the Red Line Campaign on Antibiotics to create awareness on rational use of antibiotics
2016	Publication of National Treatment Guidelines for Antimicrobial Use in Infectious Diseases by NCDC
2016	National address by prime minister on the issue of antibiotic resistance in his *Man Ki Baat* (a radio program hosted by the honorable prime minister of India) in August
2017	Publication of the National Action Plan for Containment of AMR and Delhi Declaration
2017	The Food Safety and Standards (Contaminants, Toxins and Residues) Regulations in food animals

[2]https://timesofindia.indiatimes.com/india/Lancet-says-sorry-for-Delhi-bug-/articleshow/7261135.cms?referral=PM

THE ANTIMICROBIAL RESISTANCE RESEARCH LANDSCAPE IN INDIA

Overall summary of studies

A total of 2,152 studies published by researchers based in Indian institutions were identified. The breakdown of these publications into major categories is shown in Figure ES-9.

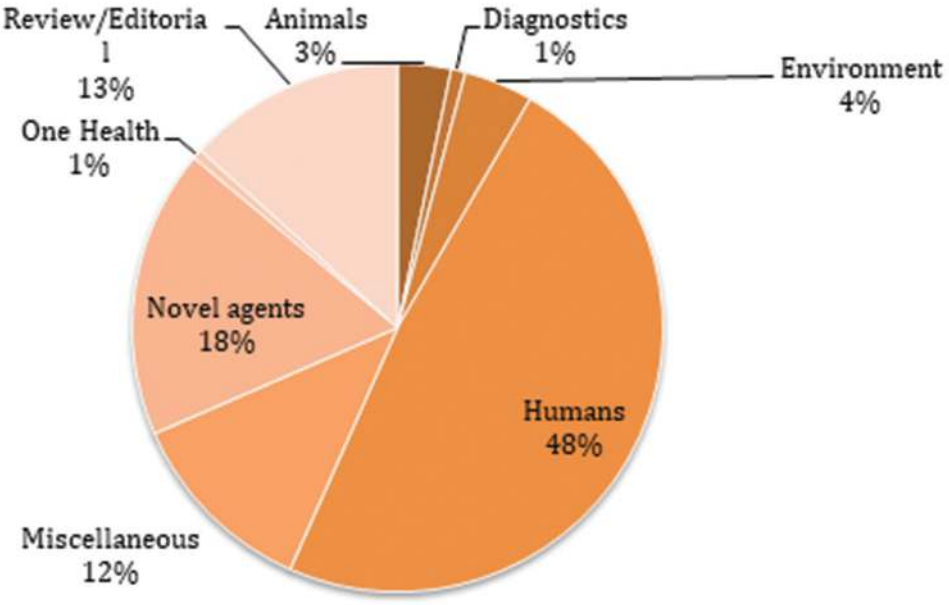


Figure ES-9:

Number of publications in each of the seven categories of AMR research (N=2,152)

There were approximately 630 institutions with at least one publication on AMR. Christian Medical College, Vellore, accounted for 3.1% of the total publications (excluding review studies), followed by All India Institute of Medical Sciences, New Delhi, with 2.5% of the total publications. The top 10 institutions that published AMR-related research studies are shown in Figure ES-10.

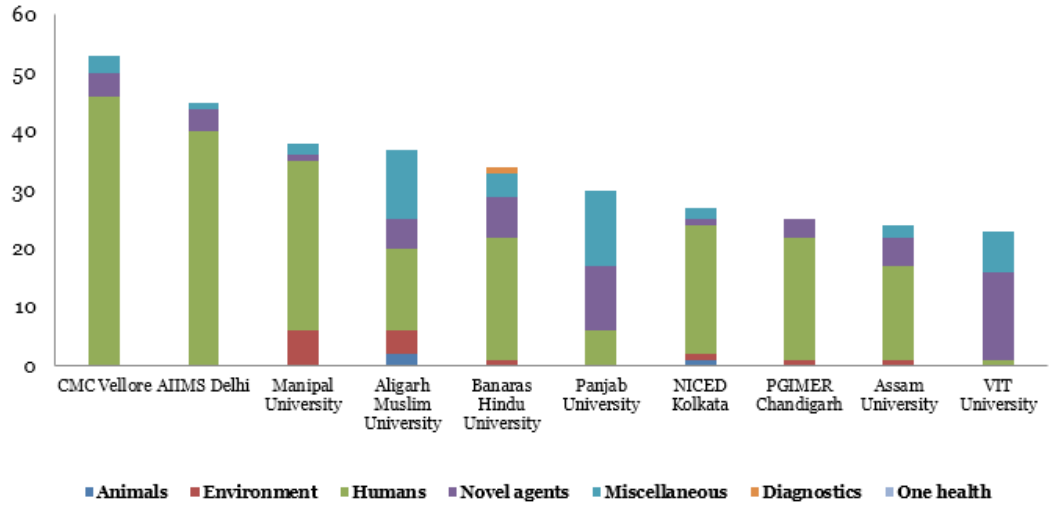


Figure ES-10:

Top 10 institutions with AMR publications by category (excluding review publications)

RECOMMENDATIONS FOR FUTURE STUDIES

This mapping exercise indicates that AMR research studies in India were of limited scope in all areas, including humans, animals, environment, and others. In humans, the majority were retrospective single-center surveillance-based studies examining the prevalence of phenotypic resistance and molecular characterization of resistance for various pathogens. Animal studies were confined to examining resistance profiles of bacteria isolated from food animals; studies examining the frequency of antibiotic use and reasons for use during animal rearing were absent. Similarly, environmental studies were confined to examining resistance profiles of bacteria or antibiotic resistance genes isolated from various water bodies. Novel agent studies were limited to in vitro experiments, and none of them progressed to clinical evaluation. Studies concentrating on comprehensive understanding of molecular mechanisms of emerging resistance among various pathogens were lacking. A limited number of studies focused on new diagnostics and interdisciplinary studies. Studies categorized as "one health" were merely surveillance studies looking at the resistance proportion in various bacteria isolated from humans, animals, and the environment. Studies examining the impact of various policies were also lacking. The following research in various categories is urgently needed in India:

Humans

- Understanding transmission mechanisms by which antibiotic resistance spreads in hospitals and in the community
- Developing and studying the impact of various antimicrobial stewardship activities and infection control measures in healthcare facilities with varying resources and in the community
- Examining the impact of behavioral interventions on antibiotic use in healthcare settings and in the community
- Developing methods for communicating the issue of antibiotic resistance to the general public and healthcare workers and studying their impact on antibiotic use
- Focusing on the burden of antibiotic resistance in various groups (neonates, children, young adults, the elderly) in the community and in various levels of healthcare settings
- Studying supply systems and market dynamics of antibiotic production to understand the lack of availability of narrow-spectrum antibiotics or old antibiotics such as penicillin

Animals

- Conducting large-scale studies on surveillance of antibiotic resistance in food animals
- Conducting large-scale studies on antibiotic use for various purposes (growth promotion, prophylaxis,

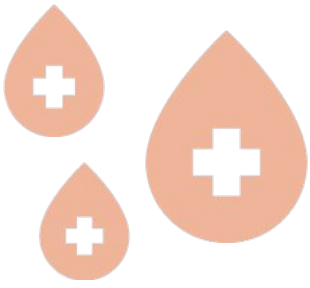
treatment) among food animals, especially in poultry
- Understanding the social aspects of antibiotic use in food animals and subsequent behavioral interventions
- Studying variations in antibiotic use in different farming practices, such as industrial and backyard farming
- Examining alternative practices of food animal rearing and their economic impacts
- Focusing on supply systems and market dynamics of antibiotic production for animal use
- Understanding transmission mechanisms by which antibiotic resistance spreads from food animals to humans

Environment

- Studying the extent of environmental antibiotic pollution through pharmaceutical industrial waste (wastewater, solid waste and air) in various parts of India
- Developing standards and detection tools for antibiotic residues in pharmaceutical industrial effluents
- Examining acquisition of antibiotic-resistant bacteria during religious mass gatherings in rivers
- Focusing on waste management to reduce the contamination of rivers during religious mass gatherings
- Developing novel technologies to remove antibiotic-resistant bacteria and ARGs from STPs and hospital wastewater
- Examining behavioral aspects of human waste disposal and its contribution to the problem of antibiotic resistance

Others (novel agents, diagnostics, one health, miscellaneous):

- Studying novel diagnostics and their impact on antibiotic use and clinical outcomes in humans
- Understanding molecular mechanisms of bacterial resistance
- Focusing on the one health approach to understand the transmission mechanisms by which antibiotic resistance can spread between different (animal, human, environmental) reservoirs
- Studying the relative contribution of different reservoirs to the burden of antibiotic resistance.



SECTION 1

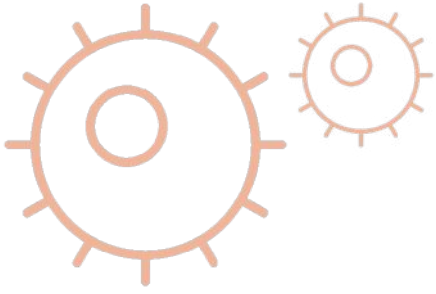
BACKGROUND AND PURPOSE

Antimicrobial resistance (AMR) is a major public health problem globally. AMR is the ability of microorganisms (bacteria, virus, fungi, parasites) to overcome the effect of antimicrobials (antibiotics, antivirals, antifungal, antiparasitic agents) and continue to proliferate, whereas antibacterial resistance (ABR) refers to the ability of bacteria to overcome the effect of antibiotics and continue to multiply. While all types of AMR are concerning, ABR is seen as currently posing the most serious health threat. This is because routine bacterial infections are much more common, making antibiotic consumption significantly greater than consumption of other antimicrobial agents, and infections with resistant bacteria are associated with adverse health outcomes.

The discovery of antibiotics in the 1940s revolutionized medical care and had an enormous impact on human and animal health. The role of antibiotics expanded from treating serious infections to preventing infections in surgical patients, protecting cancer patients and promoting growth and preventing disease in livestock and other food animals. However, several bacterial organisms have become resistant to more than one antibiotic, and resistance to last-resort antibiotics is increasing. Declining antibiotic effectiveness has risen from being a minor problem to a major societal threat, regardless of a country's income or the sophistication of its healthcare system.

Bacteria are present everywhere, including in every living being and in the soil, water, and air. With the interconnected ecosystems, the exchange of bacteria is continuous, and thus the ABR problem is no longer limited to medical science. It requires effective collaboration among several disciplines, such as microbiology, evolutionary biology, epidemiology, ecology, sociology, and engineering. Accordingly, a multidisciplinary approach involving medical scientists, natural scientists, sociologists, engineers, economists, and communication specialists is needed to overcome ABR.

India is among the countries with the highest bacterial disease burden in the world, and thus the consequences of ABR could be devastating. Considering the complex nature of the ABR problem, no individual nation has the capacity to address this major public health problem independently. In response, the United Kingdom and India came together to fight against AMR, in November 2016, with a new £13million UK-India research program. The goal of this initiative was for the UK and India to conduct collaborative research across multiple disciplines to come up with comprehensive and creative solutions to overcome AMR. As the first step, the Department for Biotechnology (DBT), government of India, in partnership with Research Councils UK (RCUK) decided to undertake mapping of AMR research in India. The aims of the mapping exercise are to understand the current situation of AMR, with particular focus on ABR in India, and to identify the current research gaps to determine the future research priorities in India.



SECTION 2

METHODOLOGY

Considering the complex nature of AMR, the United Kingdom and India bilateral collaborative initiative is a welcoming move and exemplifies the appropriate strategy to overcome the threat of AMR. This research mapping exercise is confined to ABR and does not include mapping of research for tuberculosis and other non-bacterial infections like malaria and HIV. Other studies (e.g., Maharana and Maharana et al. 2014) have recently conducted research mapping exercises on tuberculosis and malaria in India.

To understand the AMR situation and research landscape in India, we searched the PubMed and Google Scholar databases for literature relating to AMR in India, using the following search terms: "antimicrobial OR antibiotic AND resistance AND India." The search was limited to the last five years (July 1, 2012, to June 30, 2017). Articles were screened and selected based on their titles and extracted. If articles could not be selected by title name, abstracts were read, and if necessary, full articles were obtained and read to determine whether they should be included. Articles relating to tuberculosis, malaria, leprosy, nontuberculous mycobacteria, and HIV were excluded. Research publications not associated with Indian-based institutions were also excluded. Duplicate articles from both databases were identified and removed.

The following information was extracted from articles:

- Title
- Year of publication
- Authors' names
- First or corresponding author and his or her institution
- State where the institution was located

If the first author and corresponding author were affiliated with different institution, we considered the corresponding author's institution only. In addition, each article was assigned to one of the following eight categories:

- **Humans:** Studies that focused on humans
- **Animals:** Studies that focused on

animals, including agriculture
- **Environment:** Studies that focused on the environment
- **Novel agents:** Studies that focused on natural or synthetic compounds with antimicrobial activity
- **Diagnostics:** Studies that focused on new diagnostics
- **One health:** Studies that focused on a combination of these categories: humans, animals, or the environment
- **Reviews/editorials:** Studies that did not include primary research
- **Miscellaneous:** Studies that did not fit into any of the above categories

If a study would fit into more than one category, it was assigned to only one main category. Human studies were subcategorized as follows:

- **Surveillance:** Studies that reported prevalence of antibiotic resistance (phenotypic and molecular) or antimicrobial use in various settings, including hospitals and the community
- **Clinical:** Studies that assessed clinical outcomes of infections, risk factors, or effects of new interventions (such as treatments, stewardship, infection control), or case reports related to antibiotic resistance
- **Social:** Studies that involved knowledge, attitude, behavior, practices, ethical issues, economic aspects, policy, or regulatory aspects related to antibiotic use and resistance
- **Transmission:** Studies that focused on understanding transmission of resistant bacteria in humans

As the above methodology does not capture the current ongoing research activities, we sent a questionnaire to lead researchers in the field of AMR identified in through this mapping exercise, asking about their current ongoing research activities. All the information was entered into Microsoft-Excel (2013) and subsequently imported into STATA v15.0 (StataCorp, College Station, Texas, USA), and descriptive analysis was conducted.

Although the majority of studies included in the section on the AMR situation in India (section 3) were from the five-year study period, we included some important studies that are related to AMR but were not part of the study period and were not conducted in India. For example, we included some new studies that were published before July 1, 2012, or after June 30, 2017, and government reports that are not identified in the literature search. The AMR research landscape section (section 4) and the discussion and recommendations section (section 5) were entirely based on published studies during the five-year study period.

SECTION 3

THE ANTIMICROBIAL RESISTANCE SITUATION IN INDIA

3.1. Antimicrobial Resistance in Humans

3.1.1. Healthcare delivery in India

Healthcare services in India are delivered by both public and private sector (Gupta and Bhatia 2017; Patel et al. 2015). The public healthcare system is a three-tier structure, divided into primary, secondary, and tertiary care services. All services at public facilities, including preventive care, diagnostic services, and outpatient and inpatient hospital care, are delivered free of charge (Gupta and Bhatia 2017). Medications that are part of the essential drug list, including antimicrobials, are free, while other prescription drugs are purchased from private pharmacies (Patel et al. 2015). Although public healthcare services are available to all citizens, poor quality of services and severe shortages of staff and supplies force individuals to seek private care (Rao et al. 2011; Patel et al. 2015). There was a steady decrease in the use of public hospitalization services between 1995 and 2014 in both urban and rural areas (Patel et al. 2015). In India, the total number of doctors, nurses, and midwives is 11.9 per 10,000 population, which is half the World Health Organization (WHO) benchmark of 25.4 workers per 10 000 population (Rao et al. 2011). The private health sector ranges from individual private clinics to large tertiary care hospitals. The majority of individuals providing private primary care services, particularly in rural areas, have no formal training (Rao et al. 2011; Das J et al. 2015). The private hospital sector has expanded rapidly in the last two decades due to India's economic liberalization, growing middle class, and rise in medical tourism (Gupta and Bhatia 2017). In 2014, the private sector accounted for 70% of outpatient care and 60% of inpatient care (Patel et al. 2015). Out-of-pocket payments made at the point of service account for 70%

of healthcare expenditures (Patel et al. 2015; Das J et al. 2015). There is limited uptake of voluntary private insurance in spite of tax exemptions for insurance premiums (Gupta and Bhatia 2017). However, private insurance covers only hospitalizations and not outpatient services.

3.1.2. Resistance rates in humans by bacteruim

India has some of the highest antibiotic resistance rates among bacteria that commonly cause infections in the community and healthcare facilities. A recent national-scale laboratory-based study (Gandra et al. 2016) and data from the newly established Indian Council of Medical Research (ICMR) AMR surveillance network[1] showed high levels of resistance to first-line and broad-spectrum antibiotics among various bacteria isolated from bloodstream infections (Table 3.1). Resistance to the broad-spectrum antibiotics fluoroquinolones and third-generation cephalosporin was more than 70% in *Acinetobacter baumannii*, *Escherichia coli*, and *Klebsiella pneumoniae*, and more than 50% in *Pseudomonas aeruginosa*. The proportion of resistance to the carbapenem class of antibiotics, considered to be one of the last-resort agents, was very high among these four gram-negative bacteria. Approximately 70% of *A. baumannii*, 57% of *K. pneumoniae*, more than 40% of *P. aeruginosa*, and more than 10% of *E. coli* were carbapenem resistant (Figure 3.1). Unfortunately, resistance to colistin, which is the last-resort antibiotic in human medicine, also emerged in these four organisms (Table 3.1).

Table 3.1:

Percentage of resistance to various antibiotics among four gram-negative bacteria isolated from blood cultures

Gram-negative bacteria	Study	Year of data collection	Ciprofloxacin	Ceftriaxone/ ceftazidime	Meropenem/ imipenem	Piperacillin-tazobactam	Colistin
Acinetobacter baumannii	Gandra et al. 2016	2014	84%	93%	67.3%	—	4.1%
	ICMR 2015	2015	—	83.1%	70.9%	—	—
Escherichia coli	Gandra et al. 2016	2014	85.1%	83.3%	11.5%	37.3%	3.1%
	ICMR 2015	2015	76.4%	79%	16.2%	34%	0.2%
Klebsiella pneumoniae	Gandra et al. 2016	2014	72.9%	79.9%	56.6%	62.7%	3.2%
	ICMR 2015	2015	—	86.9%	56.6%	64.6%	0.5%
Pseudomonas aeruginosa	Gandra et al. 2016	2014	55%	67.9%	46.8%	61.8%	0%
	ICMR 2015	2015	54.5%	44.9%	41.8%	26.9%	0.6%

[1]The ICMR AMR surveillance network includes 2015 data from four tertiary care hospitals. This information was obtained from ICMR for the purpose of this report.

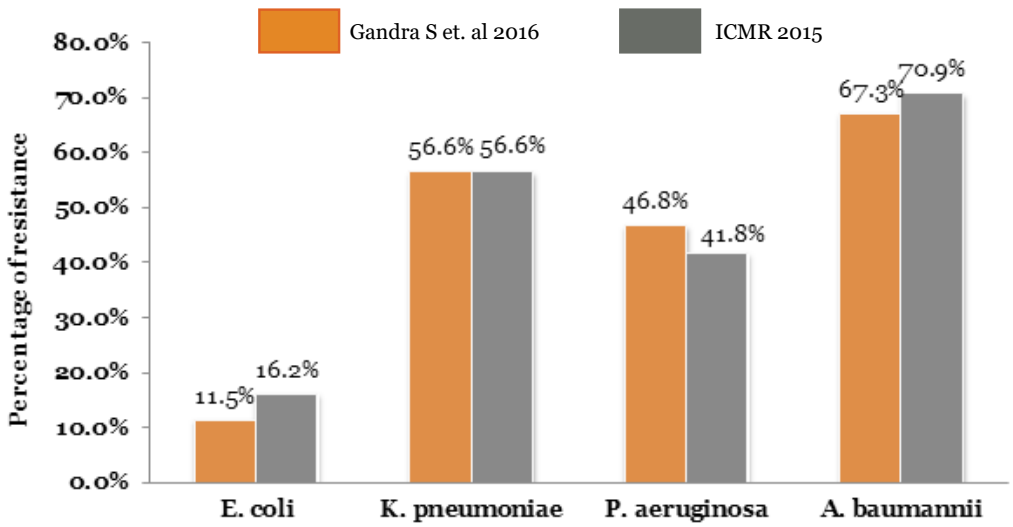


Figure 3.1:

Carbapenem (meropenem/imipenem) resistance among four gram-negative bacteria isolated from blood cultures

Source: *Gandra et al. (2016); ICMR (2015).*

Among gram-positive bacteria, the proportion of methicillin-resistant *Staphylococcus aureus* (MRSA) was 46.5% in the study by Gandra et al. (2016) and 42.6% in the ICMR AMR surveillance network. Vancomycin-resistant and linezolid-resistant *S. aureus* were also reported (Table 3.2). For *Enterococcus faecium*, Gandra et al. (2016) found that ampicillin resistance was 97.1% and vancomycin resistance was 10.5% (Table 3.2).

Streptococcus pneumoniae, which is a major cause of pneumonia in children in India, shows a high level of resistance to first-line antibiotics. A prospective multihospital-based study in 11 states examining resistance in *S. pneumoniae* between 2011 and 2015 among children younger than five years of age showed 66% resistance to trimethoprim-sulfamethoxazole (TMP-SMX), 37% to erythromycin, and 8% to penicillin (Manoharan et al. 2017).

Table 3.2:

Percentage of resistance to various antibiotics among *Staphylococcus aureus* and *Enterococcus faecium* isolated from blood cultures

Gram-negative bacteria	Study	Year of data collection	Ampicillin	Cefoxitin/ oxacillin	Linezolid	Vancomycin
Staphylococcus aureus	Gandra et al. 2016	2014	—	46.5%	0.6%	1.7%
	ICMR 2015	2015	—	42.6%	0%	0.2%
Enterococcus faecium	Gandra et al. 2016	2014	97.1%	—	1.7%	10.5%

The percentage of resistance to broad-spectrum antibiotics among bacteria causing enteric fever and gastrointestinal infections was also high (Table 3.3). In *Salmonella* Typhi, ciprofloxacin resistance was approximately 30% in the study by Gandra et al. (2016) and the ICMR surveillance network. Ceftriaxone-resistant *S.* Typhi strains were also reported (Table 3.3). Interestingly, Gandra et al. (2016) found that for *S.* Typhi, resistance to the older antibiotics ampicillin and TMP-SMX decreased over the seven-year period. Ampicillin resistance decreased from 13.1% in 2008 to 5.3% in 2014, and TMP-SMX resistance decreased from 17.1% in 2008 to 4.2% in 2014. Among *Shigella* species, resistance to ciprofloxacin and TMP-SMX was 80% and resistance to ampicillin was 100% in one study (Bhattacharya et al. 2012) (Table 3.3). Among *Vibrio cholerae*, ampicillin resistance ranged from 64% to 100%, furazolidone resistance was more than 75%, and tetracycline resistance ranged from 17% to 75% in two studies (Mandal et al. 2012; Raytekar et al. 2014) (Table 3.3).

Table 3.3:

Percentage of resistance to various antibiotics among *Salmonella* Typhi, *Shigella* species, and *Vibrio cholerae*

Bacteria	Study	Year of data collection	Ampicillin	Ceftriaxone	Ciprofloxacin	Tetracycline	TMP/SMX
Salmonella Typhi	Gandra et al. 2016	2014	5.3%	1.7%	29%	—	4.2%
	ICMR	2015	6.3%	0.6%	27.9%	—	2.3%
Shigella species	Bhattacharya et al. 2012	2000–2002	72.7%	0%	0%	—	57.6%
	Bhattacharya et al. 2012	2006–2009	100%	12%	82%	—	80%
Vibrio cholerae	Mandal et al. 2012	2008–20010	64.3%	2%	3.2%	16.9%	—
	Raytekar et al. 2014	2009–20012	100%	—	79%	75%	100%

Similarly, a high proportion of antibiotic resistance was also observed in *Neisseria gonorrhoeae*, which is a major cause of sexually transmitted infection (Table 3.4). One study in the regional reference laboratory comparing the antibiotic resistance of *N. gonorrhoeae* between 2002–2006 and 2007–2012 showed that ciprofloxacin resistance increased from 78% to 89.7% and azithromycin resistance increased from 0.8% to 1.5% (Bala et al. 2015) (Table 3.4).

Although resistance to ceftriaxone was not detected, decreased susceptibility to ceftriaxone was observed, and this percentage increased from 0.8% in 2002–2006 to 1.5% in 2007–2012.

Table 3.4:

Percentage of resistance to various antibiotics among *Neisseria gonorrhoeae*

Study	Years of data collection	Ciprofloxacin	Azithromycin	Ceftriaxone	Tetracycline	Tetracycline
Bala et al. 2015	2002–2006	78%	0.8%	0	13.6%	—
Bala et al. 2015	2002–2006	78%	0.8%	0	13.6%	—

Finally, multidrug-resistant (MDR) and extensively drug-resistant (XDR) *Mycobacterium tuberculosis* cases are increasingly reported in India. India has the highest burden of tuberculosis (TB), with an estimated incidence of 2.8 million cases in 2015, accounting for 27% of global TB cases (TB India 2017). The incidence of MDR-TB was 4.6%, accounting for 27% of global MDR-TB cases. In a recent review, XDR-TB cases varied from 0.3% to 60% of MDR-TB cases in India (Prasad et al. 2017).

3.1.3. Carbapenemases

The carbapenem class of antibiotics is one of the last-resort antibiotics to treat serious gram-negative infections in humans. Carbapenemases are beta-lactamase enzymes produced by bacteria and are capable of neutralizing various classes of antibiotics, including penicillins, cephalosporins, monobactams, and carbapenems, making them ineffective when administered (Falagas et al. 2013). Infections arising from carbapenemase-producing bacteria are difficult to treat, as there are limited therapeutic options, and treatment options vary by individual carbapenemases (Falagas et al. 2013). In India, New Delhi metallo-beta-lactamase-1 (NDM-1), or bla_{NDM-1}, has been the predominant gene encoding for carabpenem resistance in Enterobacteriaceae, and bla_{KPC} is not frequently detected (Logan and Weinstein 2017). However, recent studies indicate increasing occurrence of bla_{OXA-48} (Table 3.5). In a single center study, which examined 115 isolates of carbapenem-resistant *K. pneumoniae* collected between 2015 and 2016 from bloodstream infections, 19% of them had bla_{NDM}, 13% had bla_{OXA-48}, and 28% had both bla_{NDM} and bla_{OXA-48} (Veeraraghavan et al. 2017). Another study that examined 45 carbapenem-resistant *E. coli* isolates obtained from urinary tract infections showed the presence of bla_{NDM} in all isolates, but 55% of them also had the bla_{OXA-48} gene (Khajuria et al. 2014). This coexpression of two carbapenemases (bla_{OXA-48} & bla_{NDM}) is alarming, as it poses additional challenges to treating infections caused by these bacteria.

Table 3.5:

Different types of carbapenemases in Enterobacteriaceae detected in India

Study	Organism	Specimen	% bla_{NDM}	% bla_{OXA-48}	% bla_{OXA-48} & bla_{NDM}
Veeraraghavan et al, 2017	*K. pneumoniae*	Blood	19%	13%	28%
Khajuria et al. 2014	*E. coli*	Urine	45%	0	55%

3.1.4. Colistin resistance

Colistin is considered to be the last-resort antibiotic in human medicine. With increasing use of colistin for treatment of carbapenem-resistant gram-negative bacterial infections, colistin resistance has emerged in India (Kaur et al. 2017; Pragasam et al. 2016; Manohar et al. 2017). In a single center study, bloodstream infections due to dual carbapenem- and colistin-resistant *K. pneumoniae* were associated with 69.3% mortality among Indian patients (Kaur et al. 2017) (Figure 3.2). However, the presence of plasmid mediated colistin resistance genes *mcr-1* and *mcr-2* was not detected frequently (Pragasam et al. 2016; Manohar et al. 2017). So far, only one study has reported the presence of the *mcr-1* gene in *E. coli* isolated from the urine sample of a hospitalized patient (Kumar et al. 2016).

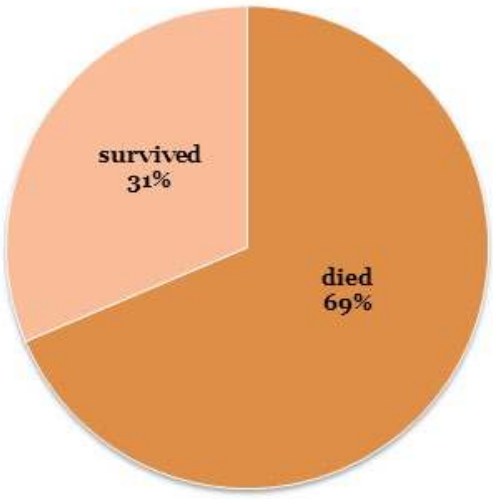


Figure 3.2:

Mortality associated with dual carbapenem- and colistin-resistant *Klebsiella pneumoniae* bloodstream infections

Source: *Kaur et al. (2017).*

3.1.5. Neonatal infections due to antibiotic-resistant bacteria

Antibiotic-resistant bacterial infections are increasingly reported among neonates. A review of bloodstream infections among neonates and children between 2000 and 2015 in India showed that the most common pathogens isolated were *S. aureus* and *Klebsiella* species (Dharmapalan et al. 2017). Among the *S. aureus* isolates, 50% were methicillin-resistant *S. aureus* (MRSA), and 63% of *Klebsiella* species were third-generation cephalosporin resistant. In a recent prospective cohort study conducted between 2011 and 2014 in three neonatal intensive care units (NICUs) in New Delhi, *Acinetobacter* species and *Klebsiella* species were found to be the two most frequent organisms isolated in neonatal sepsis cases (Chaurasia et al. 2016). In this study, 82% of the *Acinetobacter* species and 54% of the *Klebsiella* species were MDR, defined as resistant to three or more antibiotic classes. However, the most concerning issue is that 78% of *Acinetobacter* species and 35% of the *Klebsiella* species were carbapenem resistant.

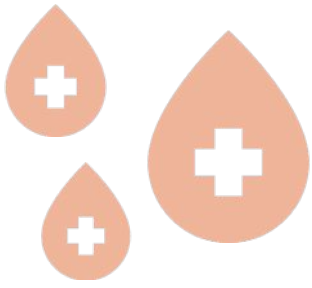
3.2. Antibiotic Resistance in Food Animals

The use of antibiotics in food animals plays a major role in human health, as antibiotic-resistant bacteria can be transmitted between humans and animals through contact, in food products, and from the environment (Landers et al. 2012). The same antibiotics used to treat human infections are commonly used in animals, raising the concern about diminishing the effectiveness of these agents at the expense of human health. With a rise in incomes, there has been an increase in the demand for animal-derived protein in India. From 2000

to 2030, it is expected that poultry consumption will increase by 577% in India (Van Boeckel et al. 2015). Similarly, India is the largest producer of milk and second-largest producer of fish, and this production continues to increase (State of Indian Agriculture 2015–16). This is leading to intensive farming with increasing reliance on antibiotics in place of improving hygiene and sanitation. Although a limited number of studies were conducted in food animals, high levels of antibiotic-resistant bacteria were identified.

3.2.1. Antibiotic-resistant bacteria in poultry

In a recent study involving 18 poultry farms, 1,556 isolates of *E. coli* obtained from cloacal samples of 530 birds were tested for susceptibility to 11 antibiotics (Brower et al. 2017). Resistance profiles were significantly different between broiler and layer farms. Broiler farms were 2.2 times more likely to harbor resistant *E. coli* strains than layer farms. Increased prevalence of ESBL-producing strains was observed in broiler farms (87% compared with 42% in layers) (Table 3.6). Broiler chickens are bred for meat; they grow rapidly and live for less than eight weeks before they are slaughtered (Sahu and Saxena 2014). The high resistance in broiler chickens indicates increased use of antibiotics either for growth promotion or for prophylaxis to prevent infection during their short lifespan (Sahu and Saxena 2014). Two other studies (Shrivastav et al. 2016; Kar et al. 2015) showed that the proportion of ESBL-producing *E. coli* in poultry was 33.5% and 9.4%, respectively. Few studies examined for the presence and antibiotic susceptibility of *Salmonella* species in chicken meat samples and in samples from healthy chickens and their environment. In one study, the prevalence of *Salmonella* species in chicken meat samples was 7%, and they were 100% resistant to erythromycin but 100% sensitive to ciprofloxacin (Naik et al. 2015). In a second study, the prevalence of *Salmonella* species in chicken meat samples was 23.7%, and they were 100% resistant to ampicillin, moderately sensitive to ciprofloxacin, and highly sensitive to ceftriaxone (Kaushik et al. 2014). A study by Samanta et al. (2014) found that the prevalence of *Salmonella* species in healthy chickens and their environment was 6.1%, and they were 100% resistant to ciprofloxacin, gentamicin, and tetracycline. In another study, the prevalence of *Salmonella* species was 3.1%, and they were moderately resistant to various antibiotics (Singh et al. 2013) (Table 3.6).



Study	Year(s) of data collection and state	Specimen	Organism	Findings
Brower et al. 2017	2014 Punjab	Cloacal swab samples Broilers (n=270) Layers (n=260)	Not applicable	ESBL producing strains (%) Broilers: 87% of cloacal swabs Layers: 42% of cloacal swabs
Shrivastav et al. 2016	2015 Madhya Pradesh	Cecal swabs	*E. coli* (n=400)	ESBL producers (%) Broilers: 33.5%
Kar et al. 2015	2013–2014 Odisha	Fecal sample	*E. coli* (n=170)	ESBL producers (%) Poultry: 9.4%
Naik et al. 2015	2013–2014 Chattisgarh	Chicken meat samples (n=200)	*Salmonella* species (n=14)	Prevalence of *Salmonella*: 7% Resistance % Ciprofloxacin:0% Erythromycin:100% Oxytetracycline: 42.8%
Kaushik et al. 2014	2010–2013 Bihar	Chicken meat samples (n=228)	*Salmonella* species (n=54)	Prevalence of *Salmonella*: 23.7% 100% resistance AmpicillinGentamicin Highly sensitive Ceftriaxone Azithromycin Moderately sensitive Ciprofloxacin Tetracycline
Samanta et al. 2014	Year not mentioned West Bengal	Cloacal samples, eggs and environment samples of backyard poultry flocks (n=360)	*Salmonella* species (n=22)	Prevalence of *Salmonella*: 6.1% Resistance % Ciprofloxacin: 100% Gentamicin: 100% Tetracycline:100% Ceftriaxone: 0
Singh et al. 2013	Year not mentioned Uttar Pradesh	Cloacal samples, eggs and environment samples (n=720)	*Salmonella* species (n=26)	Prevalence of *Salmonella*- 3.3% Resistance% Ampicillin: 0% Ciprofloxacin: 11.5% Gentamicin: 7.7% Tetracycline:23.1%

Table 3.6:

Antibiotic resistance in poultry in various studies in India

3.2.2. Antibiotic-resistant bacteria in livestock

Among livestock, several studies focused on the resistance profile of bacterial pathogens isolated from milk obtained from animals with clinical or subclinical mastitis. Vancomycin-resistant *S. aureus* was isolated from milk samples in one study (Bhattacharyya et al. 2016) (Table 3.7). In this study, 3.2% of *S. aureus* isolates obtained from cow milk and 2.4% of *S. aureus* isolates obtained from goat milk were found to be vancomycin resistant. A Southern Indian study (Preethirani et al. 2015) that examined milk obtained from buffaloes with mastitis isolated coagulase negative staphylococci (CONS) (n=125), streptococci (n=35), *S. aureus* (14), and *E. coli* (n=21). Oxacillin resistance among CONS, streptococci, and *S. aureus* was 5.6%, 28.6%, and 21.4%, respectively. With *E. coli*, all isolates were resistant to ampicillin, whereas resistance to ceftriaxone and enrofloxacin was 42.1% and 47.4%, respectively. One study reported isolation of *Streptococcus agalactiae* from milk samples of cows suffering from mastitis and found that 11.1% of *S. agalactiae* isolates were resistant to ampicillin (Jain et al. 2012). In another study, various gram-

negative organisms were isolated from milk samples among cattle suffering from mastitis, of which 48% were ESBL producers (Das et al. 2017). One study reported detection of the bla_{NDM-1} gene in *E. coli* isolated from milk samples of cows suffering from mastitis (Ghatak et al. 2013) (Table 3.7).

A study examined the presence of bacteria among raw milk samples obtained from various sources such as household milk, milk from cattle farms, and milk vendors (Thaker et al. 2012). In this study, *E. coli* isolates were found in 38 of the 100 raw milk samples. The study reported high resistance to ampicillin (100%) and moderate resistance to streptomycin (57.89%) and oxytetracycline (47.37%). A lower percentage of resistance was observed for TMP-SMX (13.16%) and chloramphenicol (5.26%). Among pigs, two studies reported detection of ESBL-producing *E. coli* from fecal samples of health pigs (Lalzampuia et al. 2013; Samanta et al. 2015). Interestingly, the prevalence of ESBL-positive *E. coli* was higher from backyard pig farms (28%) than from organized farms (8%) (Samanta et al. 2015) (Table 3.7)

Table 3.7:

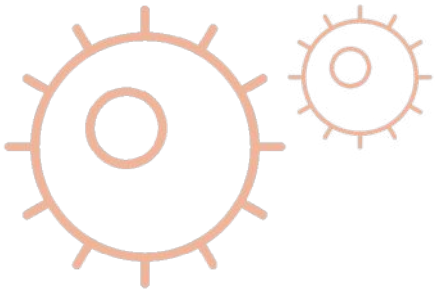
Antibiotic resistance in livestock in various studies in India

Study	Livestock	Year(s) of data collection and state	Specimen source	Organism	Findings
Bhatta-charyya et al. 2016	Cows Goats	2012–2015, West Bengal	Milk samples (subclinical and clinical mastitis) (354 samples)	*S. aureus* (n=274) Cow (n=211) Goat (n=63)	Vancomycin resistant *S.aureus* Cows: 2.4%, Goats: 3.2%
Mubarack et al. 2012	Cows	2009–2010, Tamil Nadu	Raw milk (clinical/ subclinical bovine mastitis) (250 samples)	*S. aureus* (n=152)	Antibiotic resistance Ampicillin: 3.9% Erythromycin:13.8% Gentamicin: 0% Penicillin: 41.4% Streptomycin: 25.7% Tetracycline:11.8%
Preethirani et al. 2013	Buffaloes	Year not mentioned, Karnataka	Milk samples (subclinical and clinical mastitis) (190 samples)	Coagulase negative Staphylococci (CONS) (n=125) *S. aureus* (n=14) Streptococcus s pecies (n=35) *E. coli* (n=19)	Oxacillin resistance % CONS: 5.6% *S. aureus*: 21.4% *Streptococcus* species: 28.6% *E. coli* resistance % Ampicillin:100% Enrofloxacin: 47.4% Ceftriaxone: 42.1%
Jain et al. 2012	Cows (89 cows)	Not mentioned	Milk samples (subclinical mastitis)	*Streptococcus agalactiae* (n=27)	Resistance % Ampicillin: 11.1% TMP-SMX: 11.1% Enrofloxacin: 7.4% Erythromycin: 33.3% Gentamicin: 3.7% Streptomycin: 85.1% Tetracycline: 55.5%
Das et al. 2017	Cattle	Year not mentioned, West Bengal	Milk samples (subclinical mastitis)	Gram-negative organisms (n=50) (*Escherichia coli, Proteus, Pseudomonas, Klebsiella, and Enterobacter*)	ESBL producers: 48%

Ghatak et al. 2013	**Cattle**	**2012, West Bengal**	**Milk samples (subclinical and clinical mastitis)**	***E. coli* (n=8)**	**One isolate harbored *bla*$_{NDM-1}$**
Thaker et al. 2012	**Cattle**	**2011, Gujarat**	**Raw milk (100 samples) individual household, cattle farms, milk collection centers, and milk vendors**	***E. coli* (n=38)**	**Resistance % Ampicillin: 100% Amoxy-clav: 42.11% Chloramphenicol: 5.26% Co-trimoxazole: 13.16% Streptomycin: 57.89% Oxytetracycline: 47.5%**
Lalzampuia et al. 2013	**Pigs**	**2011–2012, Mizoram**	**Fecal samples (53 samples)**	**E. coli (n=102), *Salmonella* species (n=26) *Klebsiella pneumoniae* (n=10)**	**ESBL producers *E. coli*: 5.8% *K. pneumoniae*: 0% *Salmonella* species: 0%**
Samanta et al. 2015	**Pigs**	**2012, West Bengal**	**Rectal swabs (200 samples) 4 organized farms (n=100) 10 backyard farms (n=100)**	***E. coli* (organized, n=48, backyard, n=28)**	**ESBL Producers Organized farms: 8% Backyard farms: 28%**

3.2.3. Antibiotic-resistant bacteria in aquaculture

A limited number of studies examining resistance in fish and shrimp were conducted. A study from Cochin and Mumbai coast (Visnuvinayagam 2014) involving 252 *S. aureus* isolates from 105 fish samples identified only one MRSA isolate, whereas resistance to tetracycline, TMP-SMX, and vancomycin was 3.2%, 4.8%, and 0%, respectively (Table 3.8). In a study involving tilapia fish obtained from urban lakes and rivers in Karnataka, 42% of Enterobacteriaceae isolates obtained from the gut of tilapia fish were ESBL producers (Marathe et al. 2016). In another study, *Vibrio* species associated with food poisoning were identified among shrimp, shellfish, and clams obtained from retail markets in Kerala. These *Vibrio* species were 100% resistant to ampicillin but remained highly sensitive to chloramphenicol (Sudha et al. 2014).



Study	Fishery animal	Year(s) of data collection and state	Source	Organism	Findings
Visnuvinayagam et al., 2015	Fish (commercial fishery outlets)	Year not mentioned, Kerala, Maharashtra	Skin and muscle tissue of fish (105 samples)	*S. aureus* (n=252)	Resistance % Oxacillin: 0.4% Tetracycline: 3.2% Co-trimoxazole: 4.8% Vancomycin: 0%
Marathe et al. 2016	Tilapia fish (lakes and rivers)	Year not mentioned, Maharashtra	Gut content of the fish	Entero-bacteriaceae strains (n=34)	ESBL producers: 42%
Sudha et al. 2014	Shellfish: shrimp, crabs, clams (retail markets)	2010–2011, Kerala	Gut of shellfish (110 samples)	*Vibrio* species (n=72) *V. parahem-olyticus* (n=24)	Resistance % *Vibrio* species Ampicillin: 100% Ceftazidime: 67% Chloramphenicol: 0% Tetracycline: 0% *V. parahemolyticus* Ampicillin: 100% Ceftazidime: 96% Chloramphenicol: 0% Ciprofloxacin: 0%

Table 3.8:

Antibiotic resistance in aquaculture in various studies in India

3.3. Antibiotic Resistance in the Environment

With the interconnectedness of ecosystems, the role of the environment, particularly water, in the spread of antibiotic-resistant bacteria is increasingly gaining attention (Andremont and Walsh 2015). Antibiotic-resistant bacteria along with antibiotic residues are increasingly contaminating the environment through ineffective industrial effluent and sewage management and subsequently recontaminating humans and animals through drinking water and food (Andremont and Walsh 2015). The national water quality monitoring results from 1995 to 2011 indicate gradual degradation in water quality, with increasing bacterial contamination in critical water bodies across the country (CPCB 2013). Accordingly, published studies, although limited in number, indicate high levels of antibiotic-resistant bacteria and antibiotic resistance genes (ARGs) in various water bodies.

3.3.1. Antibiotic-resistant bacteria and genes in sewage and hospital wastewater

Hospital wastewater has high levels of antibiotic-resistant organisms. A study examining wastewater samples in 2013 from three different sewage treatment plants (STPs) in South India showed that hospital wastewater inflow significantly increased the prevalence of third-generation cephalosporin-resistant *E. coli* (Akiba et al. 2015). In this study, *E. coli* resistance to cefotaxime (third-generation cephalosporin) was 25%, 70%, and 95%

in STP with an inlet of domestic water, in STP with an inlet of hospital and domestic waste, and in STP that had an inlet of only hospital wastewater, respectively (Akiba et al. 2015) (Figure 3.3). However, *E. coli* resistance to imipenem was approximately 10% in all three sources. Similarly, wastewater treatment plants (WWTPs) receiving wastewater from bulk drug production facilities are observed to have high levels of MDR organisms and could act as breeding grounds for transfer of ARGs (Marathe et al. 2013).

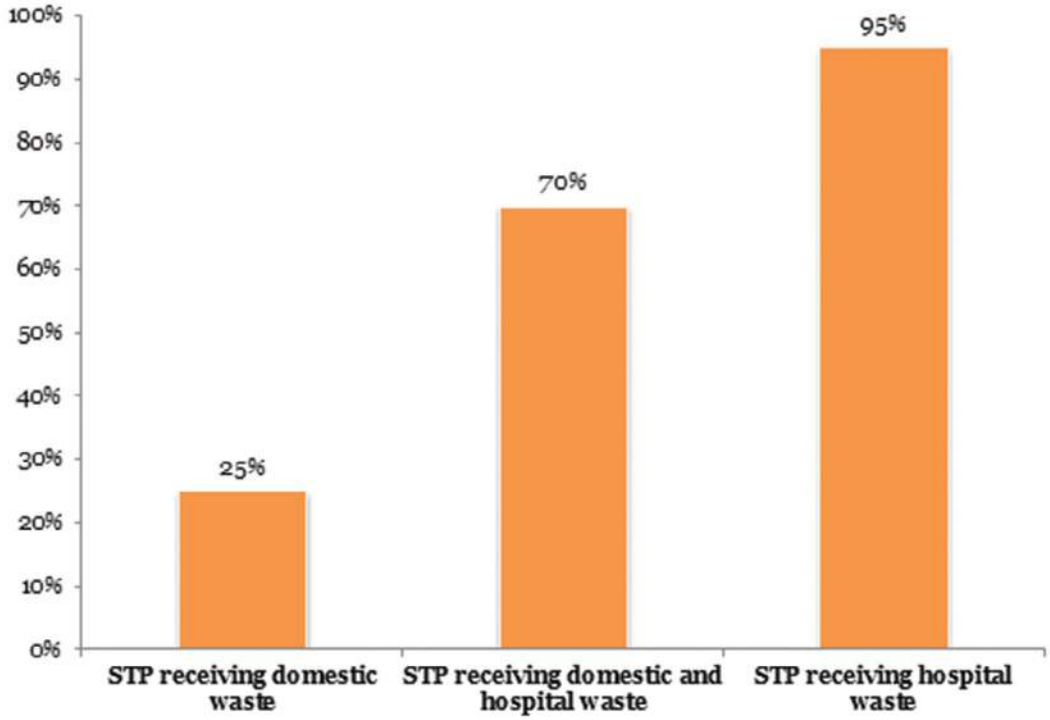


Figure 3.3:

***E. coli* resistance to third-generation cephalosporins among sewage treatment plants (STPs) receiving waste from various sources**

Source: *Akiba et al. (2015).*

3.3.2. Antibiotic-resistant bacteria and genes in rivers

Major rivers in India have bacteria with high levels of resistance to broad-spectrum antibiotics such as third-generation cephalosporins. In a study involving River Cauvery in Karnataka in 2011–2012, 100% of 283 *E. coli* isolates were found to be resistant to third-generation cephalosporins (Skariyachan et al. 2015) (Table 3.9). In a second study involving River Yamuna conducted in 2012–2014, out of a total of 230 nonduplicate bacterial isolates, 17.4% (40) isolates belonging to different groups of gram-negative bacteria were found to be extended-spectrum beta-lactamase (ESBL) producers (Azam et al. 2016). Another study involving water samples collected from rivers and sewage treatment plants (STPs) from the five Indian states of Bihar, Goa, Karnataka, Tamil Nadu, and Telangana between 2013 and 2014 showed that 37.9% (169) of 446 *E. coli* isolates were resistant to extended spectrum cephalosporins (ESC) (Akiba et al. 2015) (Table 3.9). In addition

Table 3.9:

Antibiotic-resistant bacteria in various rivers in India

River	Study	Years of study	Organisms	Organism
Cauvery	Skariyachan et al. 2015	2011–2012	*E. coli* (n=283)	Ampicillin: 100% Cefotaxime: 100% Ciprofloxacin: 75% Imipenem: 15%
Yamuna	Azam et al. 2016	2012–2014	Gram-negative bacteria (n=230)	Ampicillin: 100% Cefotaxime: 75% Ciprofloxacin: 58% Imipenem: 8%
Rivers from 5 states	Akiba et al. 2015	2013–2014	*E. coli* (n=446)	Extended spectrum cephalosporins: 37.9%

to resistant organisms, ARGs that confer resistance to broad-spectrum antibiotics including last-resort agents were detected in major rivers of India (Table 3.10). These include the bla_{CTX-M} gene (Azam et al. 2016; Akiba et al. 2016; Devarajan et al. 2016), bla_{NDM-1} gene (Ahammad et al. 2014; Devarajan et al. 2016; Marathe et al. 2017), and *mcr-1* gene (Marathe et al. 2017) (Table 3.10).

Table 3.10:

Presence of carbapenemases and colistin resistance genes in Indian rivers

River	Study	Year(s) of study	Antibiotic resistance genes
Ganga, Yamuna	Ahammad et al. 2014	2012	bla_{NDM-1}, bla_{OXA-48}
Cauvery	Devarajan et al. 2016	2012–2013	bla_{NDM-1}
Mutha	Marathe et al. 2017	Unknown	bla_{NDM-1}, bla_{OXA-48}, *mcr-1*

3.3.3. Antibiotic-resistant bacteria and genes in surface water and groundwater

Studies have also shown potable water sources apart from rivers to have bacteria with high levels of resistance to broad-spectrum antibiotics (Table 3.11). A study involving water from drinking and recreational sources in the Ayodhya-Faizabad area, located on the bank of the River Saryu, collected from the river, kunds (holy ponds), ponds, tube well, hand pumps, piped supply, and dug wells showed that 17% of E.coli and 13% of *Klebsiella* species were resistant to third-generation cephalosporins (Kumar et al. 2013) (Table 3.11). Another study involving water sources from streams, lake, tube wells, and community supply water in Kashmir in 2009–2010 showed that 7% of the *E. coli* were resistant to third-generation cephalosporins (Rather et al. 2013). A third study involving natural sources of water from East Sikkim in 2011–2012 showed that 50% of *E. coli* and 72% of *Klebsiella* species were resistant to third-generation cephalosporins (Poonia et al. 2014).

Another study involving four tap water samples, one bore-hole water sample, and 23 environmental water samples in the Hyderabad area looked for the presence of Enterobacteriaceae and other gram-negative bacteria (Lübbert et al. 2017). The environmental samples were obtained from rivers, lakes, groundwater, water sources contaminated by sewage treatment plants, and surface water in the vicinity of bulk drug manufacturing units. Of the four tap water samples, the study did not detect any bacteria in two. One tap water sample had Enterobacteriaceae and other gram-negative bacteria that produced ESBL and carbapenemase (bla_{OXA-48}) genes. All 23 environmental water samples had Enterobacteriaceae and other gram-negative bacteria. Alarmingly, 100% of the bacteria isolated from the 23 environmental samples were ESBL producers, and more than 95% were carbapenemase producers, with bla_{OXA-48} being detected in 22 samples (Table 3.11).

Table 3.11:

Antibiotic resistance in surface water and groundwater sources in various studies in India

Place	Study	Water sources	Organisms (selected list)	Resistance (%)
Ayodhya-Faizabad	Kumar et al. 2013	River, kunds (holy ponds), ponds, tube well, hand pumps, piped supply, dug wells	*E. coli* (n=72) *Klebsiella* species (n=30)	*E. coli* Cefotaxime: 17% Norfloxacin: 35% Klebsiella species Cefotaxime: 14%
Srinagar	Rather et al. 2013	Streams, Dal lake, tube well	*E. coli* (n=60) *Salmonella* species (n=12) *Salmonella* species (n=12)	*E. coli* Ciprofloxacin: 0% Cefotaxime: 7% Gentamicin: 9% *Salmonella* species Nalidix acid: 100% Ciprofloxacin: 9% Cefotaxime: 17%
Sikkim District	Poonia et al. 2014	Streams and springs	*E. coli* (n=122) *Klebsiella* species (n=106)	*E. coli* Ampicillin: 69% Cefixime: 50% Gentamicin: 0% *Klebsiella* species Cefixime: 41.5% Gentamicin: 0%
Hyderabad area	Lübbert et al. 2017	Total of 28 samples: 4 tap water samples, 1 bore-hole water sample, and 23 environmental water samples in the vic inity of bulk drug manufacturing units (rivers, lakes, water sources contaminat ed by sewage treatment plants, surface water)	Enterobacteriaceae Other gram-negative bacteria	Findings: In 2 (tap water) of 28 water samples, Enterobacteriaceae and other gram-negative bacteria were not detected 1 of 4 tap water samples contained ESBL and carbapenemase-producing bacteriaOf the 23 environmental samples, 100% of the isolates were ESBL positive, and >95% of the isolates were carbapenemase producers

3.4. Factors Driving Antibiotic Resistance in India

3.4.1. Antibiotic consumption in humans

Based on antibiotic sales data, in 2014, India was the highest consumer of antibiotics, followed by China and the United States. However, the per capita consumption of antibiotics in India is much lower than in several other high-income countries (Laxminarayan et al. 2016). Why are resistance rates high in India? Some possible reasons for the high ABR rates are discussed in this section.

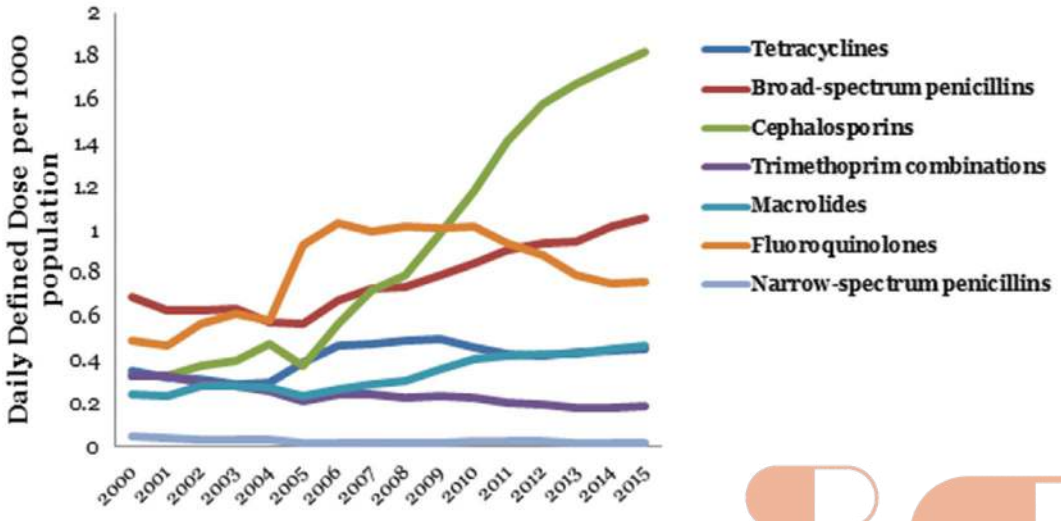
3.4.1.1. High consumption of broad-spectrum antibiotics

Broad-spectrum antibiotics are those that are effective against a wide range of disease causing bacteria, in contrast to narrow-spectrum antibiotics, which are effective against specific families of bacteria. Broad-spectrum antibiotics are generally prescribed empirically when there is a wide range of possible illnesses and a potentially serious illness would result if treatment were delayed. However, unnecessary use of broad-spectrum antibiotics leads to increased prevalence of MDR bacteria (Asensio et al. 2011). From 2000 to 2015, cephalosporin and broad-spectrum penicillin consumption increased rapidly, whereas narrow-spectrum penicillin consumption was low and decreasing (Figure 3.4).

Use of broad-spectrum antibiotics, particularly third-generation cephalosporins, has increased considerably. Between 2000 and 2015, the proportion of third-generation cephalosporins among the total antibiotics increased significantly, while penicillin consumption remained constant and the use of fluoroquinolones decreased (Figure 3.5). This increased use of third-generation cephalosporins is consistent with the high prevalence of third-generation cephalosporin-resistant *E. coli* in India. Use of narrow-spectrum antibiotics where possible is an important strategy of antimicrobial stewardship activity in overcoming

Figure 3.4:

Trends in antibiotic consumption in India, 2000–2015
Source: *QuintilesIMS.*



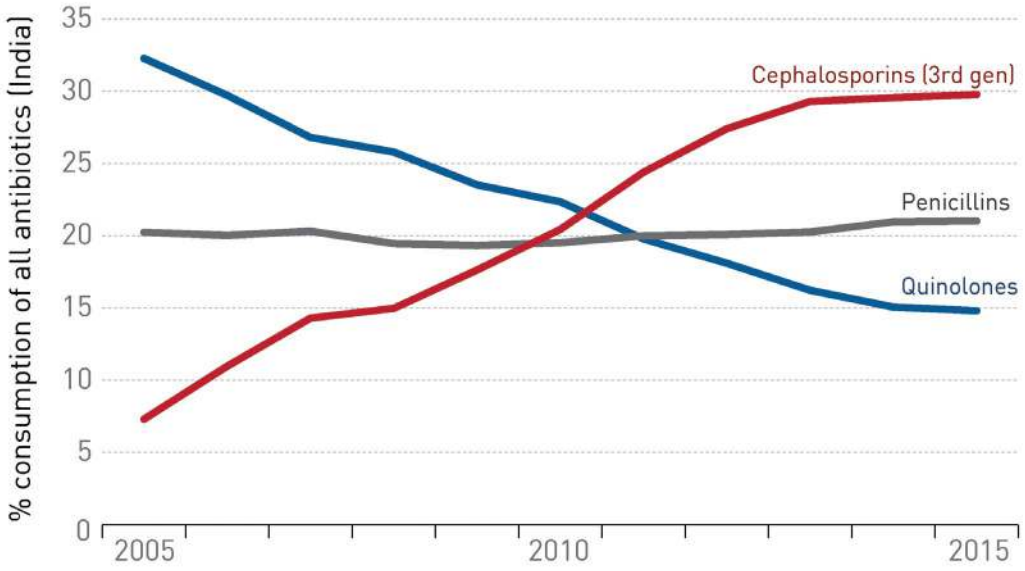


Figure 3.5:

Trends in proportion of three antibiotic classes among total antibiotics in India, 2005–2015

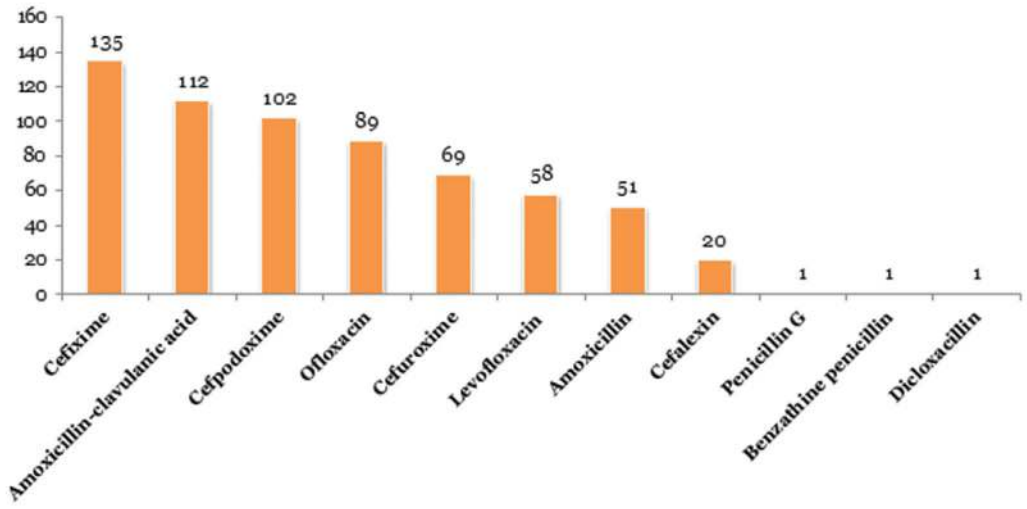
Source: *QuintilesIMS.*

The increasing use of third-generation cephalosporins could be due to multiple factors. First, fluoroquinolones have been the mainstay of treatment for enteric fever and bacterial dysentery, but with increasing quinolone resistance, third-generation cephalosporins are used as empiric treatment choices for these two common infections (Taneja 2007; Mukherjee et al. 2013; Gandra et al. 2016). The second reason is changing prescribing practices among healthcare providers. Third-generation cephalosporins are being substituted for penicillins in the treatment of upper respiratory tract infections in outpatient settings and lower respiratory tract infections in inpatient settings (Gandra et al. 2017; Kotwani and Holloway 2014; Kotwani et al. 2015). The third reason is the lack of widespread availability of narrow-spectrum agents such as first-generation penicillins (penicillin G, benzathine penicillin) in contrast to third-generation cephalosporins in the pharmacies (Kotwani and Holloway 2013). Accordingly, a review of the April–July 2017 edition of the Current Index of Medical Specialties (CIMS) INDIA shows that only one formulation company is making penicillin G or benzathine penicillin, whereas 135 companies are manufacturing cefixime (third-generation cephalosporin) (Figure 3.6).

Figure 3.6:

Number of formulation companies manufacturing various antibiotics for human use

Source: *CIMS INDIA, April–July 2017 edition.*



3.4.1.2. Increasing faropenem consumption

With the increasing prevalence of community-acquired and healthcare-associated third-generation cephalosporin-resistant bacterial infections, penem and carbapenem consumption increased in India (Gandra et al. 2016). However, the consumption of faropenem , which is an oral penem, a broad-spectrum antibiotic, increased 150% between 2010 and 2014. In India, faropenem is approved for treatment of a variety of common infections, including respiratory tract, urinary tract, skin and soft tissue, and gynecological infections. The sharp increase in use of faropenem is of concern because of the potential for cross-resistance to carbapenems. At present, susceptibility testing against faropenem is not routinely performed in microbiology laboratories due to a lack of guidelines from the Clinical & Laboratory Standards Institute (CLSI) or the European Committee on Antimicrobial Susceptibility Testing (EUCAST). There is currently a lack of understanding regarding the resistance situation and selection potential of faropenem with carbapenems.

3.4.1.3. Antibiotic fixed-dose combinations

Antibiotic fixed-dose combinations (FDCs) are combinations of two or more active antibiotics in a single dosage form. Antibiotic FDCs should be prescribed when the combination has a proven advantage over single compounds administered separately in therapeutic effect, safety, or compliance (Gautam and Saha 2008). However, in India, antibiotic FDCs are heavily prescribed even without the knowledge of a proven advantage over single compounds. In 2012, about 15% of total drug sales were attributed to dual anti-infectives.[2] Lack of diagnostic precision due to unavailability of diagnostic laboratory services has led to increased use of antibiotic FDCs in India (Gautam and Saha 2008). Injudicious use of antibiotic FDCs could lead to emergence of bacterial strains resistant to multiple antibiotics. Approximately 118 antibiotic FDCs are available in India (Ahmad et al. 2016; Shankar et al. 2016). These FDCs include dual oral

[2] http://www.pa2online.org/abstracts/vol13issue3abst135p.pdf.

broad-spectrum antibiotics such as third-generation cephalosporins and last-resort antibiotics such as linezolid. The following are some of the common FDCs available in India:

- azithromycin-cefixime
- cefixime-ofloxacin
- cefixime-levofloxacin
- cefixime-linezolid
- azithromycin-levofloxacin

3.4.2. Social factors

Several social factors have been associated with inappropriate antibiotic use in India among the general public and formal healthcare providers. Among the general public, such factors include self-medication, access to antibiotics without prescription, use of pharmacies and informal healthcare providers as sources of healthcare, and lack of knowledge about when to use antibiotics (Barker et al. 2017; Shet et al. 2015; Chandy et al. 2013; GARP India 2011; Sahoo et al. 2014; Salunkhe et al. 2013). Self-medication is mainly to avoid the financial burden of expensive allopathic medical visits and is compounded by the availability of drugs without a prescription (Barker et al. 2017; Keche et al. 2012). The major sources of self-medication are previous doctors' prescriptions and leftover medicines from previous illnesses (Kotwani et al. 2010; Keche et al. 2012). Self-medication with antibiotics is a common practice for infections such as the common cold, indicating a lack of knowledge of when to use antibiotics (Nair et al. 2015; Sahoo et al. 2014; Chandy et al. 2013). In rural areas, when there is a lack of healthcare services in their village, people may want to avoid the travel cost to get allopathic services and instead approach informal healthcare providers and chemists or pharmacists at pharmacy stores. In urban areas, doctor fees and diagnostic investigation charges may prevent people from visiting formal healthcare providers (Barker et al. 2017; Chandy et al. 2013).

Factors associated with inappropriate antibiotic prescribing among formal healthcare providers depend on whether they provide care in the public or private sector. Among those in the private sector, several factors are associated with inappropriate antibiotic prescribing. First, doctors may perceive that they are compelled to give antibiotics as patients come with preconceived ideas and demand quick relief (Chandy et al. 2013; GARP India 2011). As patients pay out of pocket for services, doctors may fear that if they do not give antibiotics and instead request diagnostic investigations, the patients will never return to them and thus they will lose their costumers (Chandy et al. 2013; GARP India 2011; Kotwani and Holloway 2013). Second, the diagnostic uncertainty due to the inability to perform investigations leads physicians to prescribe broad-spectrum antibiotics because of the fear of clinical failure (GARP India 2011). Third, pharmaceutical companies put pressure on doctors and pharmacists to prescribe new antibiotics, and in return they receive incentives (Chandy et al. 2013; GARP India 2011; Kotwani and Holloway 2013).

Physicians in the public sector have to see a huge number of patients in a limited time period. Thus these physicians do not have enough time

to counsel patients against the use of antibiotics and instead prescribe them (Kotwani et al. 2010; Kotwani and Holloway 2013). Second, primary care facilities and secondary care hospitals in the public sector do not have microbiology diagnostic laboratory services. Patients visiting public sector physicians cannot afford investigations in private labs, thus compelling physicians to prescribe antibiotics (Kotwani et al. 2010). Third, the medicine supply in the public sector could be erratic, with no supply during some months and oversupply during other months, and could have drugs near their expiration. To dispose of the medicines before they expire, doctors in the public sector may prescribe antibiotics even though they are not required for the patient (Kotwani et al. 2010).

Some factors are common to both public and private sector healthcare providers. One such factor is varying knowledge among healthcare providers on the problem of AMR and lack of continuing medical education on this problem (Kotwani et al. 2010; Chandy et al. 2013).

3.4.3. Cultural activities

One of the major cultural activities associated with potential acquisition and spread of antibiotic-resistant bacteria or ARGs is mass bathing in rivers as part of religious mass gathering occasions. One study compared the fecal coliform and bla_{NDM-1} abundances in waters and sediments before and during the pilgrimage season in Upper Ganges (Ahammad et al. 2014). In this particular study, the bla_{NDM-1} was found to be over 20 times greater in the river during pilgrimage season than at other times of year, indicating that pilgrimage areas may act as hot spots for the broader transmission of bla_{NDM-1} and other ARGs. The study highlights the need for improvement of waste handling at the time of pilgrimages.

3.4.4. Antibiotic consumption in food animals

Although direct antibiotic sales data in food animals are not available for India, it is estimated that India was the fifth-largest consumer of antibiotics in food animals (poultry, pigs, and cattle) in 2010, after China, the United States, Brazil, and Germany, based on livestock density (Van Boeckel et al. 2015). Changing patterns of affluence and dietary preferences mean that there is increasing demand for animal protein, which is driving antibiotic use in food animals. Accordingly, antibiotic consumption in food animal production in India is projected to grow by 312%, making India the fourth-largest consumer of antibiotics in animals in 2030 (Van Boeckel et al. 2015).

Use of antibiotics as growth promoters in food animals in poultry is a common practice; however, the true extent of this practice is unknown. Antibiotics such as colistin, tetracycline, doxycycline, and ciprofloxacin, which are critical to human health, are commonly used for growth promotion in poultry (Brower et al. 2017; CSE 2014). A recent study examining antimicrobial residues in chicken meat sold for human consumption found that of the 70 chicken meat samples tested, 40% contained antimicrobial residues. The most common antimicrobials

detected were enrofloxacin (20%), ciprofloxacin (14.3%), doxycycline (14.3%), oxytetracycline (11.4%), and chlortetracycline (1.4%) (Sahu and Saxena 2014). Similarly, antibiotic residues of chloramphenicol, sulphonamides, and erythromycin were detected in various shrimp samples collected from major shrimp farms of Andhra Pradesh, Karnataka, Kerala, and Tamil Nadu (Swapna et al. 2012).

A more concerning issue is the use of polymyxins (colistin) for growth promotion, prophylaxis, and therapeutic purposes in poultry, as this class of drugs is the last-resort medicine to treat serious infections in humans (CSE 2014). Because of the emergence of plasmid mediated resistance (*mcr-1* gene) with use of polymyxins in food animals (Liu et al. 2016) and potential transfer of this gene to humans, there is an urgent need to ban the use of antibiotics that are critically important to humans for growth promotion in food animals. Whereas only one antibiotic formulation company manufactures benzathine penicillin for human use, at least six companies manufacture benzathine penicillin for animal use (Figure 3.7).

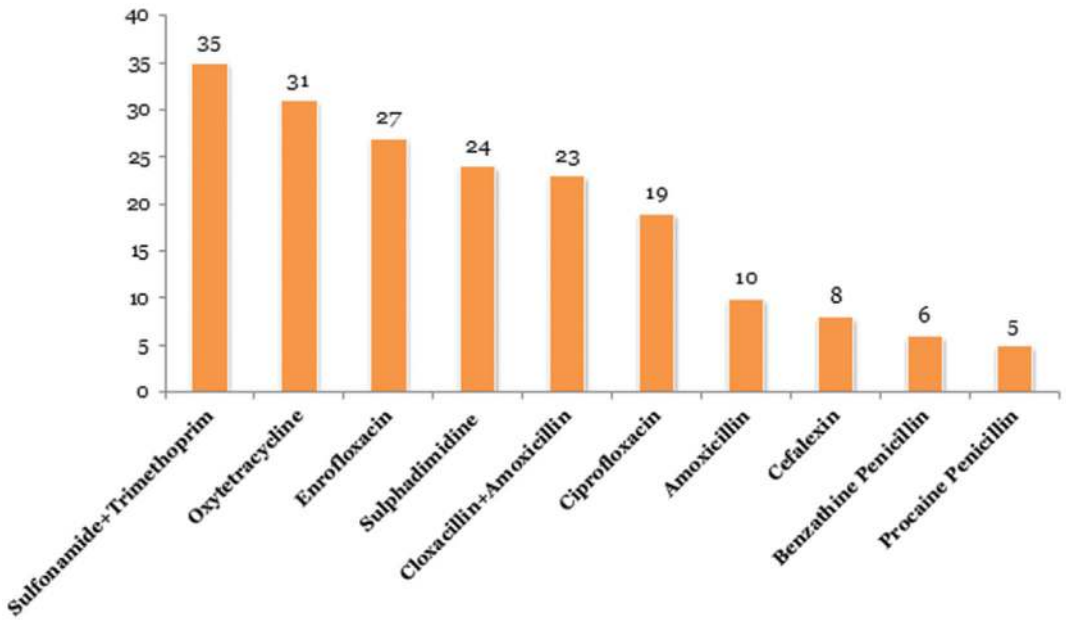


Figure 3.7:

Number of formulation companies manufacturing various antibiotics for animal use

Source: *VETNDEX Issue VII (2016).*

3.4.5. Pharmaceutical industry pollution

The Indian pharmaceutical industry supplies 20% of generic drugs, with an estimated US$15 billion in revenue in 2014 (Nordea Asset Management 2015). It is estimated that 80% of the antibiotics sold by multinational pharmaceutical companies on the global market are manufactured in India and China (Sum of Us 2015). However, the wastewater effluents from the antibiotic manufacturing units contain a substantial amount of antibiotics, leading to contamination of rivers and lakes (Larsson et al. 2007; Lübbert et al. 2017; Gothwal

and Shashidhar 2017). The existing good manufacturing practices (GMP) framework (WHO 2016) is restricted to drug safety and does not include environmental safeguards. GMP ensures that products are consistently produced and controlled according to quality standards to minimize the risks involved in any pharmaceutical production. GMP covers all aspects of production, from the starting materials, premises, and equipment to the training and personal hygiene of the staff. Many countries have formulated their own requirements based on the WHO GMP, and others have harmonized their requirements. However, regulation of environmental discharges from the manufacturing units is left to the local governments.

Pharmaceutical companies can be broadly classified as active pharmaceutical ingredient (API) manufacturers and formulation companies. API manufacturers produce antibiotics in bulk that are then sold to formulation companies to produce finished products like tablets, syrups and vials. Some companies manufacture both APIs and formulation products. Effluents coming from both types of manufacturing units contain antibiotic residues but significantly higher amount of residues are expected in the effluents of API manufacturing units. However, the huge number and the diversity of the antibiotic product range in the formulation companies could cause significant environmental contamination.

In India, the Central Pollution Control Board (CPCB) established effluent standards for pharmaceutical industry waste, and all state pollution control boards use the same standards. The current standards do not include antibiotic residues, and thus they are not monitored in the pharmaceutical industry effluents (CPCB Effluent Standards 2013). The current parameters monitored in the pharmaceutical industrial effluents are listed in Table 3.12. However, there are no consensus guidelines on the antibiotic residue discharge limits in industrial waste even outside India and one research group recently proposed discharge limits for various antibiotics (Bengtsson-Palme, Larsson 2016).

Table 3.12:

Pharmaceutical industry effluent standards in India

Source: *Central Pollution Control Board Effluent Standards (2013).*
Note: *BOD = biochemical oxygen demand;*
**The BOD limit shall be 30mg/l and 250mg/l, respectively, if treated effluent is discharged directly into a freshwater body.*

Compulsory parameters	Tolerance limits in mg/l except for pH
pH	6.0–8.5
Oil & grease	10
BOD (3 days 27°C)	100*
Total suspended solids	100
Bioassay test	90% survival of fish after first 96 hours in 100% effluent
Additional parameters	**Tolerance limits in mg/l except for pH**
Mercury	0.01
Arsenic	0.2
Chromium	0.1
Lead	0.1
Cyanide	0.1
Phenolics	1
Sulfides	2
Phosphate	5

Two studies (Larsson et al. 2007; Lübbert et al. 2017), which examined the effluents coming from antibiotic manufacturing units conducted 10 years apart (2006 and 2016) in the same industrial area near the city of Hyderabad, India, have shown excessive amount of antibiotics critical for human health. In 2006, the concentration of ciprofloxacin in the effluents was extremely high (31,000 micrograms/ml), a discharge equivalent to 45 kilograms of ciprofloxacin per day. In 2016, in addition to ciprofloxacin, several other antibiotics, such as moxifloxacin, levofloxacin, linezolid, ampicillin, doxycycline, and sulfamethoxazole, were abundant in the effluents, indicating the widening of the antibiotic portfolio of these manufacturing units. This inappropriate disposal of antibiotics has led to the contamination of the aquatic environment of Musi River, which flows through the city of Hyderabad. Fluoroquinolone concentrations higher than 1,000 times the usual concentrations found in rivers of developed countries were observed in Musi River in 2015 (Gothwal and Shashidhar 2017). Although, pharmaceutical industrial wastewater effluents are apparent source of antibiotic residues, it is important to acknowledge the possibility of antibiotic environmental contaminants through solid waste and possibly even by air pollution (Larsson 2014).

There are at least 40 human antibiotic API manufacturers in India (Table 3.13). In contrast, there are at least 250 pharmaceutical formulation companies manufacturing at least one antibiotic for human use and at least 94 pharmaceutical formulation companies manufacturing at least one antibiotic

Table 3.13:

List of human antibiotic active pharmaceutical ingredient (API) manufacturing companies#

Note: # This list includes major antibiotic API manufacturers in India and not a complete list
** Both API and formulation companies*

Manufacturer	Manufacturer
Aarti Drugs Ltd*	Kopran*
Abbott*	Lee Pharma Ltd
Ajanta Pharma Ltd*	Lupin Ltd*
Alembic Pharmaceuticals*	Mankind*
Arch Pharmalabs	Meck Pharmaceuticals & Chemicals
Aurobindo Pharma*	Mehta Pharmaceutical Ltd.
Calyx Pharma	Mylan Labs*
Century Pharmaceuticals Limited	Nectar Lifesciences Ltd*
Chromo Labs	Neuland Laboratories Limited*
Cipla*	Orange Pharma Private Limited
Covalent Laboratories*	Orchid Chem & Pharma*
Dalas Biotech Limited	Panchsheel Organics*
Dishman Pharmaceuticals	Penam Laboratories Ltd
Dr Reddys labs*	Pravah Laboratories Pvt Ltd
DSM Sinochem	Smruthi Organics Limited
Glenmark Labs*	Srini Pharmaceuticals
Granules India*	Sun Pharma*
Hetero Labs*	Unimark Remedies
Ind-Swift*	Vardhman Chemtech Ltd
Indoco*	Wockhardt*
Jubilant Pharma*	Zydus Cadila*

The leading antibiotic formulation companies for human and animal use in India are displayed in Figures 3.8 and 3.9. Complete list of antibiotic formulation companies in India are listed in Appendix Tables A.1 and A.2.

Figure 3.8:

Leading antibiotic formulation companies and the number of antibiotics they manufacture (excluding antituberculosis agents) for human use in India

Source: *CIMS INDIA, April–July 2017 edition.*

Note: AHPL = Ahaan Healthcare Private Limited; Hetero HC = Hetero Healthcare; FDC = Fairdeal Corporation Private Limited

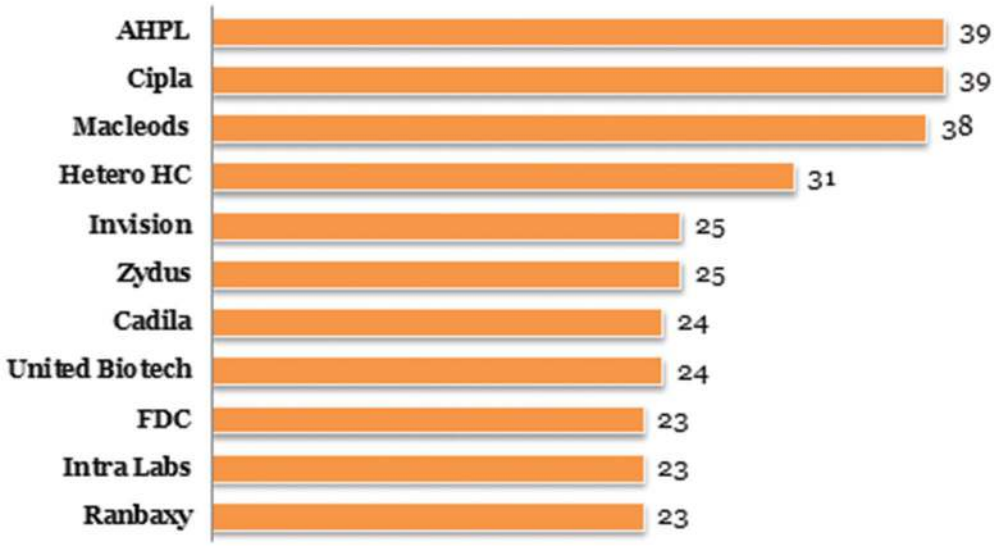
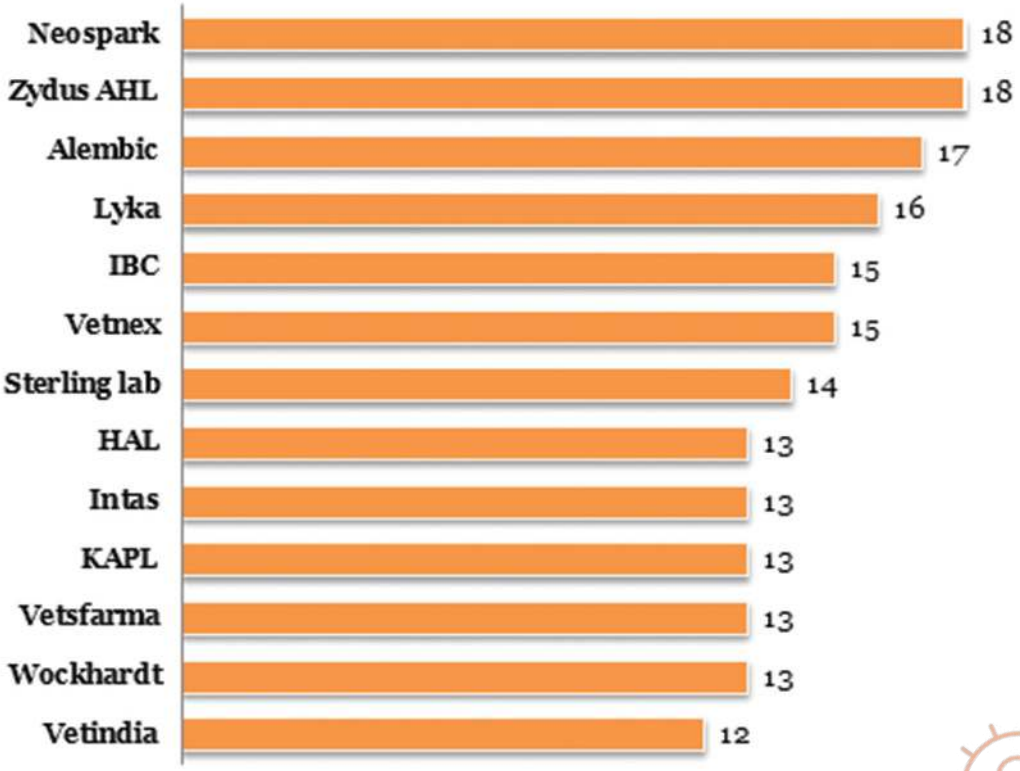


Figure 3.9:

Leading companies and the number of antibiotics they manufacture for animal use in India

Source: *VETNDEX Issue VII (2016).*

Note: Zydus AHL = Zydus Animal Health Limited; HAL = Hindustan Antibiotics Limited; KAPL = Karnataka Antibiotics & Pharmaceuticals Limited. The list of manufacturers is not complete, as the information gathered in VETNDEX was based on voluntary response from the companies to a survey conducted by the author of VETNDEX. Not all companies responded to the author's survey.



Although published studies on antibiotic pollution have been restricted to the Hyderabad area in the state of Telangana, the number of pharmaceutical companies involved in manufacturing antibiotics suggests the potential possibility of environmental antibiotic pollution in several other locations in India as well (Figure 3.10 and Figure 3.11). Some of the antibiotic API manufacturer hot spots include, Ankleshwar and Karkhadi in state of Gujarat, Aurangabad, Mumbai area, and Tarapur in the state of Maharashtra, Baddi and Paonta Sahib in the state of Himachal Pradesh, Derabassi in the state of Punjab and Hyderabad area in the state of Telangana (Figure 3.10). Similarly, some of the antibiotic formulation companies' hot spots include Ahmedabad in the state of Gujarat, Aurangabad in the state of Maharashtra, Bengaluru in the state of Karnataka, Hyderabad in the state of Telangana, Verna in the state of Goa, and Sikkim (Figure 3.11).

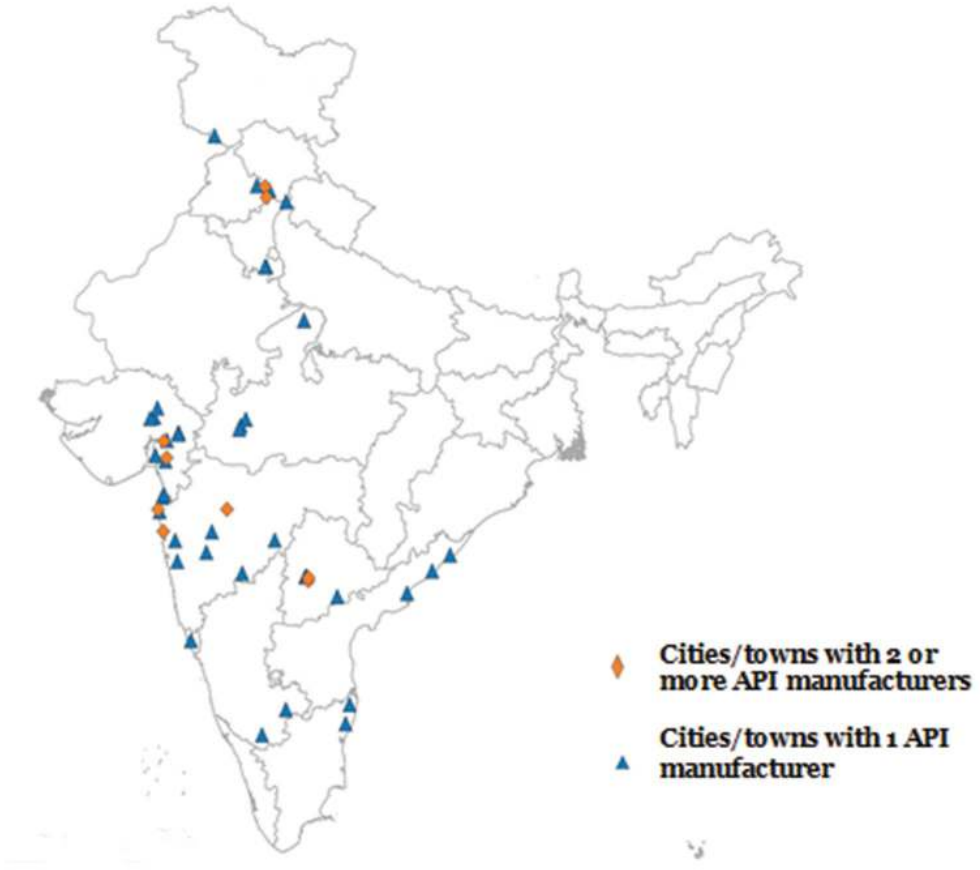


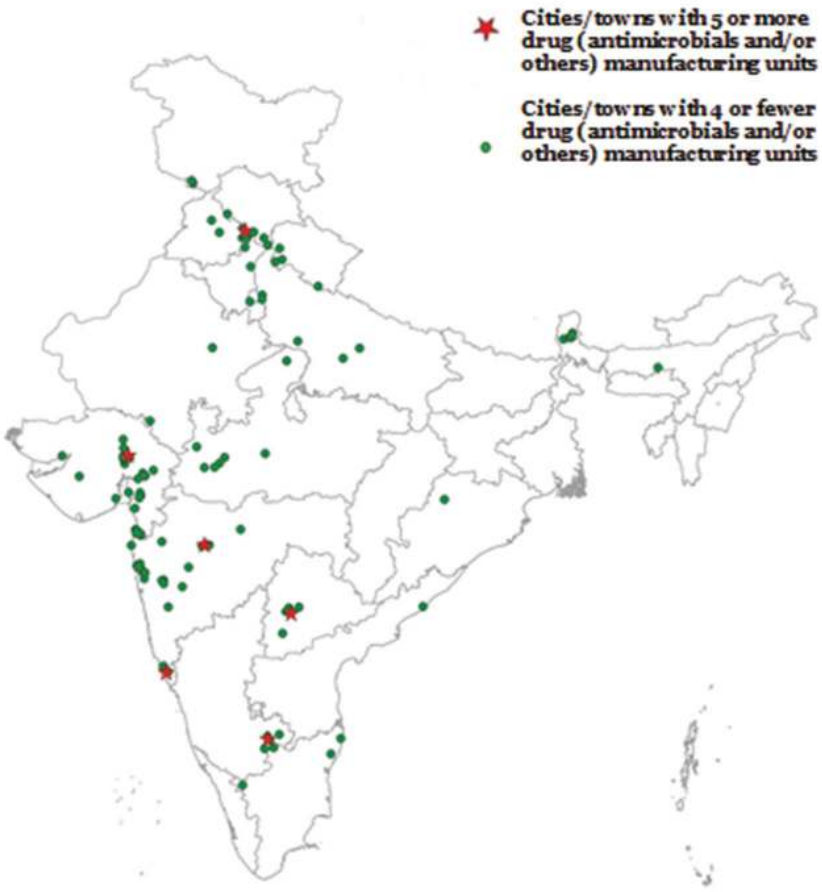
Figure 3.10:

Sites of human antibiotic active pharmaceutical ingredient (API) manufacturing companies in India
Note: Manufacturing unit locations were identified by reviewing websites of individual companies.

Figure 3.11:

Sites of human and animal antibiotic formulation manufacturing units in India

Note: Manufacturing unit locations were identified by reviewing websites of individual companies (manufacturers of antibiotics for both human and animal use). However, it is unknown whether antibiotics are manufactured at all these locations. There are also several companies for which manufacturing location was not mentioned on the company website.



3.4.6. Environmental sanitation

Antibiotic selection pressure is a prerequisite for the emergence of resistance; however, poor sanitation plays a major role in the spread of antibiotic-resistant bacteria and ARGs. According to the World Bank, more than 50% of the Indian population does not have access to sanitation facilities for safe disposal of human waste (World Bank 2017). In addition, a large proportion of sewage is disposed untreated into receiving water bodies, leading to gross contamination of rivers with antibiotic residues, antibiotic-resistant organisms, and ARGs (Marathe et al. 2017). As a result, recreational travel to India is recognized as an important risk factor for acquisition of ARGs such as ESBLs. In one study, the risk of asymptomatic intestinal colonization with ESBL-producing *E. coli* among Swiss travelers visiting India was 87% (Kuenzli et al. 2014).

3.4.7. Infection control practices in healthcare settings

The prevalence of various healthcare-associated infections (HAIs) among Indian hospitals ranges from 11% to 83%, in contrast to the WHO estimate of about 7% to 12% of the HAI burden among hospitalized patients globally (Ramasubramanian et al. 2014). Only a few multicenter studies have been conducted assessing infection control practices in India. A study involving eight hospitals, including one nursing

home in the city of Mangalore, assessed hand-washing practices of nurses and doctors and found that only 31.8% of them washed hands after contact with patients (Dileep 2013). A multicenter study involving a single operation theater in each of six tertiary care hospitals in Delhi showed a hand hygiene compliance of 80.5% (Kumar et al. 2014).

Another study in Gujarat that assessed infection control practices in 20 delivery care units showed that surgical gloves were reused in over 70% of facilities, only 15% of the facilities reported wiping of surfaces immediately after delivery in labor rooms, and one-third of facilities did not have wash basins with hands-free taps (Mehta et al. 2011). These poor infection prevention practices in delivery care units reflect the types of organisms seen in early onset neonatal sepsis cases. In a recent large prospective study involving three NICUs, *Acinetobacter* species (a common healthcare-acquired pathogen) was the most common organism causing early onset neonatal sepsis (occurring within 72 hours of birth) (Figure 3.11).

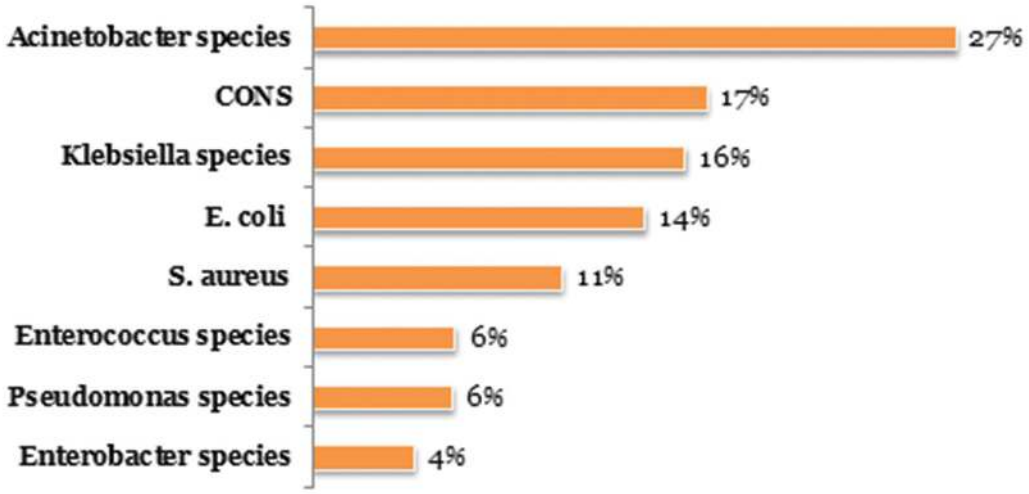


Figure 3.12:

Causes of early onset neonatal sepsis in three NICUs in Delhi

Source: *Chaurasia et al. (2016).*

Note: CONS = coagulase-negative Staphylococci

3.5. AMR Policy Situation in India

In India, the issue of AMR came to the attention of policymakers with the 2010 discovery of NDM-1 and the controversy[3] over its name. Subsequently, AMR-related policies were initiated in 2011 by publishing the National Policy on Containment of AMR. In addition, other nongovernmental initiatives such as the Chennai Declaration were published to create a roadmap to tackle the AMR problem. Over the last seven years, several policies were enacted, and in April 2017, a comprehensive National Action Plan for Containment of AMR was launched and the Delhi Declaration on AMR was pledged. Table 3.13 provides a timeline of AMR policy-related activities, which are described in detail below.

3.5.1 AMR-related policies for human health

The Ministry of Health and Family Welfare (MoHFW) is responsible for developing policies related to human health. In 2010, a working group on

3 https://timesofindia.indiatimes.com/india/Lancet-says-sorry-for-Delhi-bug-/articleshow/7261135.cms?referral=PM

Table 3.14:

Timeline of AMR policy-related activities in India

Year	Activity
2010	Establishment of the National Task Force on AMR Containment
2011	Publication of the Situation Analysis on AMR
2011	Publication of National Policy on AMR Containment
2011	Jaipur Declaration on AMR Containment
2011	The Food Safety and Standards (Contaminants, Toxins and Residues) Regulations, by FSSAI
2011	Establishment of the National Programme on AMR Containment under the Twelfth Five Year Plan (2012–2017)
2012	National Program on Antimicrobial Stewardship, Prevention of Infection and Control (ASPIC) by ICMR
2013	Establishment of a National AMR Surveillance Network by NCDC and ICMR
2014	Inclusion of antibiotics in Schedule H1 category to avoid nonprescription sales of antibiotics
2016	Launch of the Red Line Campaign on Antibiotics to create awareness regarding rational usage of antibiotics
2016	Publication of National Treatment Guidelines for Antimicrobial Use in Infectious Diseases by NCDC
2016	National address by prime minister on the issue of antibiotic resistance in his *Man Ki Baat* (a radio program hosted by the honorable prime minister of India) in August
2017	Publication of the National Action Plan for Containment of AMR and Delhi Declaration
2017	The Food Safety and Standards (Contaminants, Toxins and Residues) Regulations in food animals

AMR, with the support of the Global Antimicrobial Resistance Partnership (GARP), was formed to conduct a situational analysis for the country and suggest the way forward for combating the AMR problem (GARP India 2011). Subsequently, the National Policy for Containment of AMR for India was published in 2011 (Directorate General of Health Services 2011).

In September 2011, the Health Ministers of Member States of the South-East Asian Region of WHO, including India, signed the Jaipur Declaration on containment of AMR (Jaipur Declaration 2011). Subsequently, a joint meeting of Medical Societies in India was organized in Chennai in August 2012, which ended in the Chennai Declaration, drafting a roadmap by and for stakeholders to tackle the challenge of AMR (Ghafur et al. 2013). It recognized the need that although a ban on the sale of antibiotics without prescriptions would be the ideal step, this was not practical to implement, and instead recommended a step-by-step regulation, beginning immediately with controls on sales of third- and fourth-generation antibiotics and anti-TB agents, and then gradually expanding the list. Additional recommendations encompassing accreditation, hospital antibiotic usage policies, veterinary practices, strengthening diagnostic laboratories, education, training, and research were made with the aim to provide "an implementable antibiotic policy" and not "a perfect policy."

The National Programme on the Containment of Antimicrobial Resistance was launched under the aegis of the National Centre for Disease

Control (NCDC) under the 12th Five Year Plan (2012–2017).[4] The objectives of this program were to establish AMR surveillance system with 30 network laboratories, generating quality data on AMR pathogens of public health importance; strengthen infection control guidelines and practices; promote appropriate use of antibiotics; and generate awareness about the use of antibiotics both among healthcare providers and in the community. The policy focus included situational analysis regarding the manufacture, use, and misuse of antimicrobials; creation of a national surveillance system; identification of prescription patterns and establishment of a monitoring system for the same; enforcement of enhanced regulatory provisions with respect to marketing of antimicrobials; development of specific intervention measures such as antibiotic policies for healthcare facilities; and development of diagnostic aids related to monitoring AMR. Ten network laboratories have been identified in the first phase of the program, in which four pathogens of public health importance are being tracked: *Klebsiella* species, *E. coli*, *S. aureus*, and *Enterococcus* species. More recently, *P. aeruginosa* and *Acinetobacter* species were also included.

In 2012, ICMR launched the Antimicrobial Stewardship, Prevention of Infection and Control (ASPIC) program through collaboration among the office of the National Chair of Clinical Pharmacology, ICMR, and the Christian Medical College, Vellore (Chandy et al. 2014). A national workshop was hosted as a part of a one-year program to develop the capacity of key stakeholders in antibiotic stewardship.

In 2013, ICMR established a national network on surveillance of AMR in laboratories based at tertiary care academic centers, targeting medically important bacterial pathogens identified by WHO. The Antimicrobial Resistance Surveillance and Research Network (AMRSN), established by ICMR, started with six reference labs located in four tertiary care medical institutions. The network is being expanded to include 15 more medical colleges and private hospitals. The AMRSN also includes in-depth understanding of molecular mechanisms of drug-resistant pathogens and the transmission dynamics to enable better understanding of AMR in the Indian context and devise suitable interventions. The AMRSN is currently limited to the human health side, but there are plans to broaden its scope to a national scale and to include samples from a wider spectrum of sources, including animal, environmental, and food samples, to reflect the principles of a one health based surveillance system.

In March 2014, to prevent sales of important antibiotics without prescriptions, the Central Drugs Standard Control Organization (CDSCO) implemented Schedule H1. The H1 list includes 24 antibiotics, such as third- and fourth-generation cephalosporins, carbapenems, antituberculosis drugs, and newer fluoroquinolones. Schedule H1 specifies that the drugs on this list must carry a prominent Rx symbol in red and a

[4]http://dghs.gov.in/WriteReadData/userfiles/file/National_Programme_on_Containment_of_Anti_Microbial_Resistance.pdf.

printed warning inside a box with red borders. Moreover, drugs included in Schedule H1 may be sold only with a prescription from a registered medical practitioner, and the pharmacist must maintain a separate register with the patient's name, contact details of the prescribing doctor, and the name and dispensed quantity of the drug. The register has to be retained for at least three years and is subject to audit by the government.

In November 2014, the WHO Regional Committee meeting advocated with member states for acceleration of national efforts to build capacities to implement the Jaipur Declaration on AMR and the South-East Asia Regional Strategy on AMR.

In February 2016, the government of India conducted a three-day international conference on AMR during which the Red Line Campaign on Antibiotics was launched to create awareness regarding rational usage of antibiotics among the general public. It emphasized the following issues:

- Raising awareness about how to identify a drug that should be dispensed only with a prescription from a licensed doctor
- Limiting the practice of self-medication
- Making the public aware of the potential harms that may result from the misuse of antibiotics

During the same month, NCDC published the National Treatment Guidelines for Antimicrobial Use in Infectious Diseases, which served as a reference guide for hospitals and healthcare providers in the country (NCDC 2016). The Indian prime minister, Shri Narendra Modi, recently reaffirmed the joint Indo-US commitment to the Global Health Security Agenda (GHSA) and the timely implementation of its objectives. The prime minister noted India's role on the Steering Group of GHSA and its leadership in AMR arena. He also addressed the nation on the issue of antibiotic resistance in his radio program *Mann ki Baat* in August 2016, calling on everyone to practice responsible use of antibiotics. Both ICMR and NCDC released guidelines on infection control for healthcare facilities, noting the need to establish functional hospital infection control committees (HICCs) to provide leadership to the infection prevention and control (IPC) programs at the institutional level and to integrate these within the institutional setups. Establishing IPC focal experts at the policymaking levels and linking IPC programs to AMR and nosocomial infection surveillance were identified as key policy integrations to drive more successful IPC programs in India.

In March 2017, the National Health Policy 2017 (MoHFW 2017) highlighted the problem of AMR and called for rapid standardization of guidelines regarding antibiotic use, limiting the use of antibiotics as over-the-counter medications, banning or restricting the use of antibiotics as growth promoters in livestock, and practicing pharmacovigilance, including prescription audits inclusive of antibiotic usage in the hospital and the community.

In April 2017, the National Action Plan for Containment of AMR was

released and Delhi Declaration on AMR was pledged. In August 2017, a review meeting was held to discuss the next steps, including indicators for implementation of the National Action Plan.

3.5.2 AMR-related policies for animal health

The Food Safety and Standards Authority of India (FSSAI) set standards for antibiotics in fisheries in 2011 (FSSAI 2011) and for honey in 2014 (FSSAI 2014). Use of the following antibiotics is prohibited in any unit processing seafoods including shrimp, prawns, or any other variety of fish and fishery products (FSSAI 2011):

- all nitrofurantoins, including furaltadone, furazolidone, furylfuramide, nifuratel, nifuroxime, nifurprazine, nitrofurnatoin, nitrofurazone, chloramphenicol, neomycin, nalidixic acid
- sulfamethoxazole, *Aristolochia* species and preparations thereof
- chloroform, chloropromazine, colchicine, dapsone, dimetridazole, metronidazole
- ronidazole, ipronidazole
- other nitromidazoles, clenbuterol, diethylstibestrol
- sulfanoamide drugs (except approved sulfadimethoxine, sulfabromomethazine, and sulfaethoxypyridazine)
- fluoroquinolones, glycopeptides
- In addition to prohibition of the above antibiotics, tolerance limits were set for certain antibiotics in seafoods (Table 3.14).

In 2014, FSSAI set tolerance limits for following antibiotics in honey (FSSAI In February 2016, FSSAI held a workshop on Fixation of Maximum Residue Levels (MRLs) for Pesticides, Veterinary Drugs and Antibiotics in Foods Prepared from Animals, Poultry, Fish and Processed Foods (FSSAI 2016). Following are some of the key recommendations that emerged from the workshop:

- Antibiotics used in human population are best avoided for use

Table 3.15:

Tolerance limits for antibiotics in seafood

Name of antibiotic	Tolerance limit in mg/kg (ppm)
Tetracycline	0.1
Oxytetracycline	0.1
Trimethoprim	0.05
Oxolinic acid	0.3

Table 3.16:

Tolerance limits for antibiotics in honey

Name of antibiotic	Tolerance limit (mcg/kg)
Chloramphenicol	0.3
Nitrofurans and its metabolites	0.5
Sulphonamides and its metabolites	5.0
Streptomycin	5.0
Tetracycline	5.0
Oxytetracycline	5.0
Chlortetracycline	5.0
Ampicillin	5.0
Enrofloxacin	5.0
Ciprofloxacin	5.0
Erythromycin	5.0
Tylosin	5.0
	5.0

in food-producing animals.

- There is a need to have approved label claims for pesticides, antimicrobials, and veterinary drugs, to be duly authorized by a competent regulatory authority.
- For processed foods from agricultural commodities, there is a need for fixation of MRLs.
- National Good Aquaculture Practices should be developed to limit the usage of antibiotics and pesticides during farming operations.
- Because there are data gaps regarding residues of veterinary drugs in foods originating from meat, milk, and fish, and data are available only in scattered form from various research institutes, laboratories, individuals, and industries, FSSAI may initiate a coordinated Network Project to develop a central repository database.
- With the help of the Drug Controller General of India (DCGI), manufacturers of veterinary drugs must submit the required data with the approved method (guidelines need to be developed) to FSSAI for fixation of MRLs in edible animal products.

Accordingly, in June 2017, FSSAI published the MRLs for antibiotics in various food animals (FSSAI 2017).

3.5.3. AMR policies related to the environment

Policies specifically aimed at AMR aspects of the environment have not been formulated. However, the Swacch Bharat Abhiyan (Clean India Program), launched in October 2014 to achieve universal sanitation coverage, could play a vital role in containment of AMR. The goals of the Swacch Bharat Abhiyan are to promote cleanliness and hygiene, eliminate open defecation, and improve waste management.

3.5.4. Launch of National Action Plan for Containment of AMR (NAP-AMR) and Delhi Declaration on AMR

The National Action Plan for Containment of AMR (NAP-AMR) was released in April 2017.[5] On the same day, an interministerial group pledged to adapt a holistic and collaborative approach for the containment of AMR, which resulted in the Delhi Declaration on AMR.[6] The NCDC is the focal point for implementation and coordination of the NAP-AMR program. The NAP-AMR assigned coordinated tasks to multiple government agencies involving health, education, the environment, and livestock to change prescription practices and consumer behavior and to scale up infection control and antimicrobial surveillance.

The strategic objectives of India's NAP-AMR are aligned with the WHO's Global Action Plan on AMR (GAP-AMR). In addition, India has a sixth priority, which is dealing with India's leadership on AMR, including international, national, and subnational collaborations on AMR. Six strategic priorities have been identified under the NAP-AMR:

- Improve awareness and understanding of AMR through effective communication, education, and training.
- Strengthen knowledge and

[5]http://ncdc.gov.in/writereaddata/mainlinkFile/File645.pdf
[6]http://ncdc.gov.in/writereaddata/mainlinkFile/File670.pdf

evidence through surveillance by strengthening laboratories in human, animal, food, and environmental sectors, as well as ensuring surveillance of AMR in these sectors.

- Reduce the incidence of infection through effective IPC to reduce the burden of infection, in animal health and food to reduce the spread of AMR and antimicrobials through animals and food, and in community and environment to reduce the spread of AMR and antimicrobials in the environment.
- Optimize the use of antimicrobial agents in human health, animals, and food by strengthening regulations, ensuring access and surveillance of antimicrobial use, and providing antimicrobial stewardship in healthcare as well as animal health and agriculture.
- Promote investments for AMR activities, research, and innovations through new medicines and diagnostics, innovations to develop alternative approaches to manage infectious diseases, and sustainable financing to ensure adequate resources for containment of AMR.
- Strengthen India's leadership on AMR through international collaborations to ensure India's contributions toward global efforts to contain AMR and national collaborations to facilitate collaborations among vertical disease control programs.

Within each strategic priority and focus area, strategic interventions, key activities, and outputs have been defined with tentative responsibility and timelines: short-term (within 1 year), medium (between 1 and 3 years), and long-term (between 3 and 5 years). A stakeholder consultation to operationalize the NAP-AMR was conducted to develop indicators for implementation of the NAP-AMR in August 2017.

3.5.5. Effectiveness of the AMR policies

Although several policies and programs have been developed, the effectiveness of these initiatives on AMR containment or antimicrobial consumption is unknown and was not systematically examined. In addition, the extent of enforcement of the enacted policies is also unknown. For example, antibiotics that were part of Schedule H1 are still available without prescription (Satyanarayana et al. 2016). Similarly, the impact of the Red Line Campaign on Antibiotics on antibiotic awareness in general public is unknown.

SECTION 4

THE ANTIMICROBIAL RESISTANCE RESEARCH LANDSCAPE IN INDIA

4.1. Overall Summary of Studies

A total of 2,152 studies published by researchers based in Indian institutions were identified and extracted into our database. The breakdown of these publications into major categories was as follows (Figure 4.1):

- Humans: 1,040 (48.3%)
- Novel agents: 379 (17.6%)
- Reviews or editorial articles: 287 (13.3%)
- Miscellaneous: 254 (11.8%)
- Environment: 90 (4.2%)
- Animals: 70 (3.3%)
- Diagnostics: 19 (0.9%)

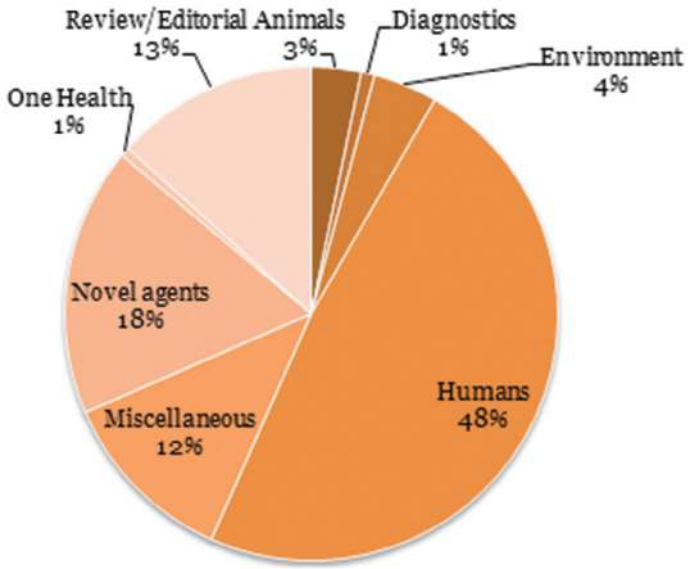


Figure 4.1:

Number of publications in each of the seven categories of AMR research (N=2,152)

There were approximately 630 institutions with at least one publication on AMR. Christian Medical College, Vellore, accounted for 3.1% of the total publications (excluding review studies), followed by All India Institute of Medical Sciences, New Delhi, with 2.5% of the total publications. Following are the top 10 institutes that published AMR-related research studies (Figure 4.2):

- Christian Medical College, Vellore, Tamil Nadu
- All India Institute of Medical Sciences (AIIMS), New Delhi, Delhi
- Manipal University, Mangalore, Karnataka
- Aligarh Muslim University, Aligarh, Uttar Pradesh
- Banaras Hindu University, Varanasi, Uttar Pradesh
- Panjab University, Chandigarh
- National Institute of Cholera and Enteric Diseases (NICED), Kolkata, West Bengal
- Post Graduate Institute of Medical Education and Research (PGIMER), Chandigarh
- Assam University, Silchar, Assam
- Vellore Institute of Technology (VIT), Vellore, Tamil Nadu

A complete list of institutions that published at least one study related to AMR appears in Appendix Table A.3

4.2. Results by Category of Studies

4.2.1. Humans

Overall 1040 studies were conducted on AMR in humans. Of these, 83% (864) were on surveillance, 12.8% (132) were clinical, and 4.2% (44) concerned the social aspect of AMR in humans (Figure 4.3). Transmission-based studies were absent.

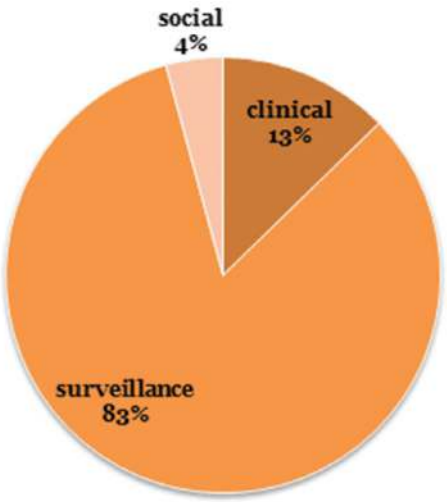


Figure 4.3:

Distribution of human studies by three categories of AMR research (N=1,040)

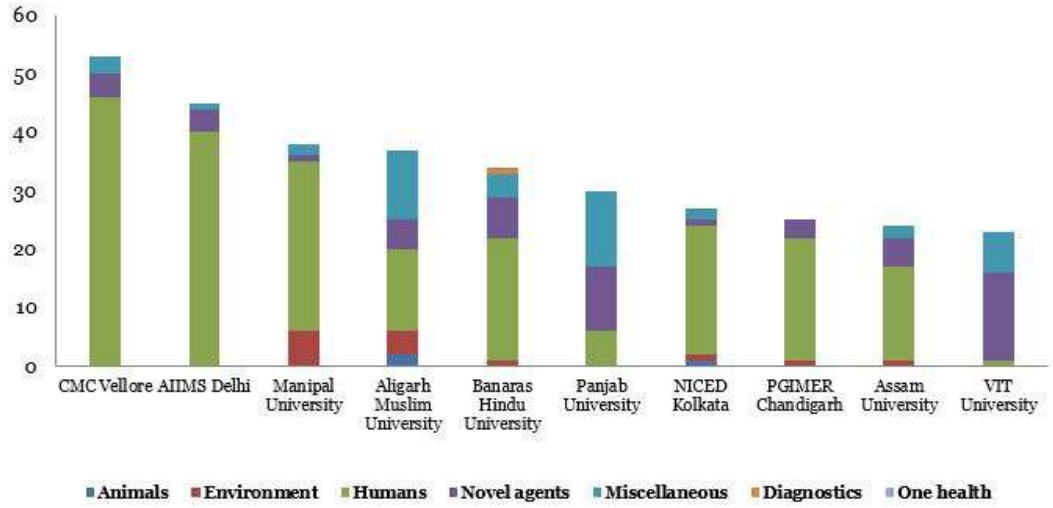


Figure 4.2:

Top 10 institutions with AMR publications by category (excluding review publications)

There were approximately 380 institutions with at least one publication on AMR. The top 10 institutions that published AMR-related research in humans are listed in Table 4.1. A complete list of institutions that published at least one study related to AMR in humans appears in Appendix Table A.4.

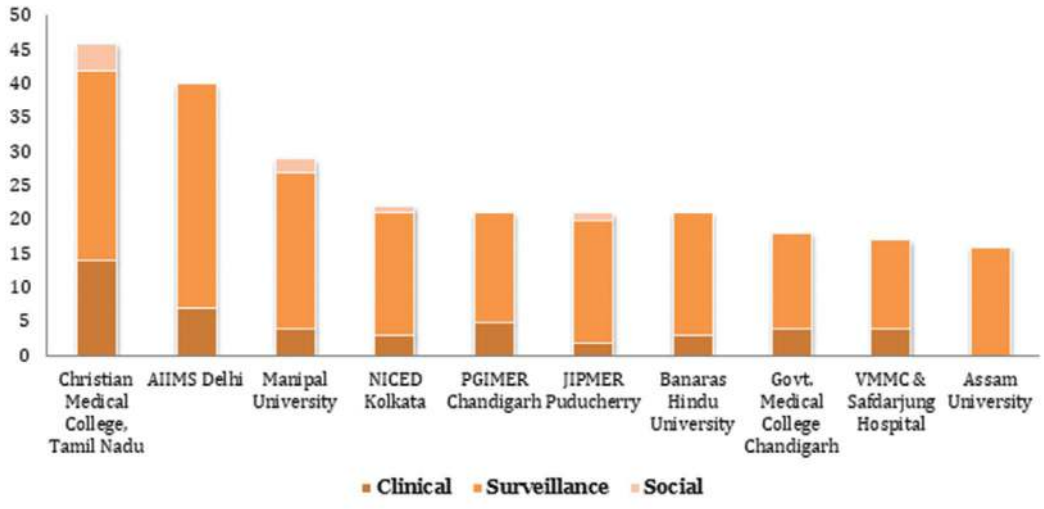
Table 4.1:

Top 10 institutions that published AMR-related research in humans in India, 2012–2017

Institution	State	Total publications
Christian Medical College	Tamil Nadu	46
All India Institute of Medical Sciences	Delhi	40
Manipal University	Karnataka	29
National Institute of Cholera and Enteric Diseases	West Bengal	22
Post Graduate Institute of Medical Education & Research	Chandigarh	21
Jawaharlal Institute of Postgraduate Medical Education & Research	Puducherry	21
Banaras Hindu University	Uttar Pradesh	21
Government Medical College	Chandigarh	18
Vardhman Mahavir Medical College–Safdarjung Hospital	Delhi	17
Assam University	Assam	16

Figure 4.4:

Top 10 institutions with publications on AMR in humans by category



4.2.2. Animals

Overall, 70 studies were conducted on AMR in animals, of which 30% (21) were in livestock, 24.3% (17) were in poultry, 15.7% (11) were in fish, and 30% (21) were classified as other (Figure 4.5).

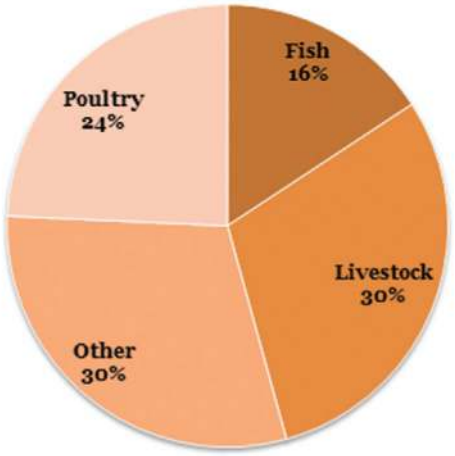


Figure 4.5:

Distribution of AMR research studies in animals (N=70)

The institutions that conducted AMR research in animals and published more than one study are listed in Table 4.2. A complete list of institutions that published at least one study related to AMR in animals appears in Appendix Table A.5.

4.2.3. Environment

A total of 90 studies were environmental, of which 22% (20) were conducted on river water, 11% (10) concerned freshwater, and 13% (12) concerned sewage , 10% (9) concerned hospital effluent, 7% (6) concerned industry effluent and

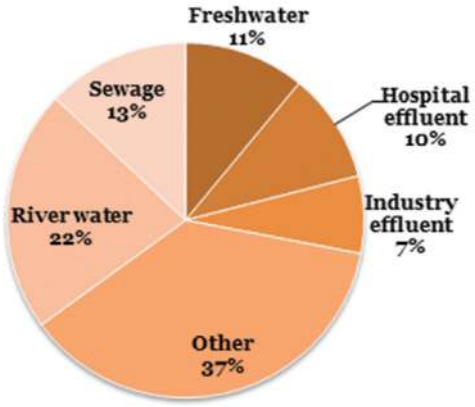
Institutions	State	Total publications
Anand Agricultural University	Gujarat	4
ICAR Research Complex for NEH Region	Meghalaya	4
West Bengal University of Animal and Fishery Sciences	West Bengal	4
Cochin University of Science and Technology	Kerala	3
ICAR–National Research on Pig	Assam	3
Central Institute of Fisheries Technology Kerala	Kerala	2
Chhattisgarh Kamdhenu Vishwavidyalaya	Chattisgarh	2
College of Veterinary Science	Assam	2
Dr. G. R. Damodaran College of Science	Tamil Nadu	2
ICAR–Indian Veterinary Research Institute	Uttar Pradesh	2
Indian Veterinary Research Institute, Uttar Pradesh	Uttar Pradesh	2
Indian Veterinary Research Institute, West Bengal	West Bengal	2
Karnataka Veterinary Animal and Fisheries Sciences University	Karnataka	2
Sher-e-Kashmir University	Jammu & Kashmir	2

Table 4.2:

Institutions that published more than one AMR research study in animals in India, 2012–2017

Figure 4.6:

Distribution of AMR research studies on the environment (N=90)



37% (34) constituted others (Figure 4.6). The institutions that conducted AMR research on the environment and published more than one study are listed in Table 4.3. A complete list of institutions that published at least one study related to AMR in the environment appears in Appendix Table A.6.

Table 4.3:

Institutes that published more than one AMR research study on the environment in India, 2012–2017

Institutions	State	Total publications
Indian Institute of Technology Delhi	Delhi	6
Manipal University	Karnataka	6
Aligarh Muslim University	Uttar Pradesh	4
Cochin University of Science and Technology	Kerala	4
RD Gardi Medical College	Madhya Pradesh	4
Bharathidasan University	Tamil Nadu	3
Anand Agricultural University	Gujarat	2
Annamalai University	Tamil Nadu	2
CSIR–Indian Institute of Toxicology Research	Uttar Pradesh	2
Dayananda Sagar Institutions	Karnataka	2
Integral University	Uttar Pradesh	2
Jamia Millia Islamia	Delhi	2
National Centre for Cell Science	Maharashtra	2
National Institute of Science Education	Odisha	2
Sher-e-Kashmir University	Jammu & Kashmir	2
University of Delhi	Delhi	2
Veer Narmad South Gujarat University	Gujarat	2

4.2.4. Novel agents

Overall, 379 studies focused on identifying new compounds with antimicrobial activity. Among these, 145 (38%) identified compounds active against gram-negative bacteria, 114 (30%) identified compounds active against both gram-negative and gram-positive bacteria, 91(24%) identified compounds active against gram-positive bacteria, 7(2%) identified compounds against MDR gram-negative bacteria, 2(0.5%) identified compounds active against MDR gram-positive bacteria and 20 (5%) identified compounds active against non-bacterial pathogens (Figure 4.7).

The institutions that conducted AMR research on novel agents and published more than five studies are listed in Table 4.4. A complete list of institutions that published at least one study related to AMR in novel agents appears in Appendix Table A.7.

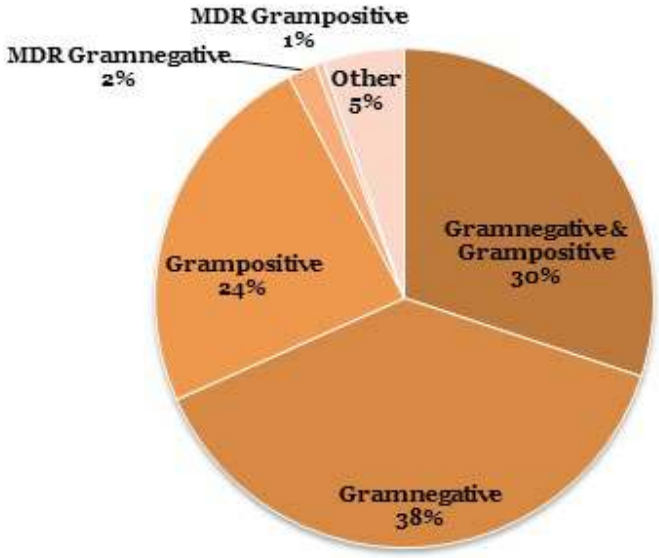


Figure 4.7:

Antibacterial spectrum of novel agent studies (N=379)

Institute	State	Total publications
Jawaharlal Nehru Centre for Advanced Scientific Research	Karnataka	18
Alagappa University	Tamil Nadu	14
Panjab University	Chandigarh	13
Aligarh Muslim University	Uttar Pradesh	12
Indian Institute of Technology Kharagpur	West Bengal	10
Institute of Nuclear Medicine and Allied Sciences	Delhi	8
IMS & Sum Hospital	Odisha	7
Jadavpur University	West Bengal	7
Vellore Institute of Technology University	Tamil Nadu	7

Table 4.4:

Institutions that published more than five AMR research studies on novel agents in India, 2012–2017

Anna University	Tamil Nadu	5
CSIR–Central Institute of Medicinal and Aromatic Plants	Uttar Pradesh	5
Jaypee Institute of Information Technology, UP	Himachal Pradesh	5
Karnataka Veterinary Animal and Fisheries Sciences University	Karnataka	2
Sher-e-Kashmir University	Jammu & Kashmir	2

4.2.5. Miscellaneous

Overall, 254 studies were published that fell into the miscellaneous category. The studies focused on several aspects, such as molecular biology, biofilm formation, genetics, immunology, biochemistry, and mathematical modeling. The institutions that conducted research on miscellaneous aspects of AMR and published five or more studies are listed in Table 4.5. A complete list of institutions that published at least one study related to miscellaneous aspects of AMR appears in Appendix Table A.8.

Table 4.5:

Institutions that published more than five studies on miscellaneous aspects of AMR in India, 2012–2017

Institution	State	Total publications
Vellore Institute of Technology University	Tamil Nadu	15
CSIR–Institute of Microbial Technology	Chandigarh	11
Panjab University	Chandigarh	11
Banaras Hindu University	Uttar Pradesh	7
Jaypee Institute of Information Technology	Himachal Pradesh	7
University of Delhi	Delhi	7
Indian Institute of Technology Kharagpur	West Bengal	6
Indian Institute of Technology Bombay	Maharashtra	6
Aligarh Muslim University	Uttar Pradesh	5
Assam University	Assam	5
National Dairy Research Institute	Haryana	5

4.2.6. Diagnostics

Overall, 19 studies were published in the category of diagnostics. The majority of the studies were focused on novel diagnostics to identify resistance mechanism in bacteria. The institutions that published studies on diagnostics are listed in Table 4.6.

Institute	State	Total publications
Aligarh Muslim University	Uttar Pradesh	2
Amity University	Uttar Pradesh	1
Animal and Fisheries Sciences University	Karnataka	1
Anna University	Tamil Nadu	1
Dr. M.G.R. Educational and Research Institute	Tamil Nadu	1
Government Medical College Hospital Chandigarh	Chandigarh	1
Indian Institute of Technology Delhi	Delhi	1
KEM Hospital	Maharashtra	1
National Dairy Research Institute	Haryana	1
National Institute of Cholera and Enteric Diseases	West Bengal	1
Nizam Institute of Medical Sciences	Telangana	1
P.D. Hinduja Hospital & Medical Research Centre	Maharashtra	1
Sant Gadge Baba Amravati University	Maharashtra	1
SRM University	Tamil Nadu	1
Subharti Medical College	Uttar Pradesh	1
Swami Vivekanand Subharti University	Uttar Pradesh	1
Tamil Nadu Veterinary and Animal Sciences University	Tamil Nadu	1
Tata Medical Center	West Bengal	1

Table 4.6:

Institutions that published AMR research studies on diagnostics in India, 2012–2017

4.2.7. One health

Overall, 11 studies were published in the one health category. The majority of the studies focused on the bacterial resistance profile isolated from humans and/or animals and/or the environment. The institutions that published studies in the one health category are listed in Table 4.7.

Table 4.7:

Institutions that published AMR research studies on one health in India, 2012–2017

Institution	State	Total publications
Banaras Hindu University	Uttar Pradesh	1
Chhattisgarh Kamdhenu Vishwavidyalaya	Chattisgarh	1
ICAR–Indian Veterinary Research Institute	Uttar Pradesh	1
Indian Veterinary Research Institute, Uttar Pradesh	Uttar Pradesh	2
Karnataka Veterinary Animal and Fisheries Sciences University	Karnataka	1
Lovely Professional University	Punjab	1
National Centre for Cell Science	Maharashtra	1
National Salmonella Centre	Uttar Pradesh	1
North-Eastern Hill University	Meghalaya	1
RD Gardi Medical College	Madhya Pradesh	1
University of Pune	Maharashtra	1
West Bengal University of Animal and Fishery Sciences	West Bengal	1

4.3. Prominent researchers in AMR field in India

Table 4.8:

Prominent researchers in AMR field in humans

Note: AIIMS- All India Institute of Medical Sciences; BHU- Banaras Hindu University; CMC- Christian Medical College; GMC- Government Medical college; HAIs- Healthcare Associated Infections; JIPMER- Jawaharlal Institute of Postgraduate Medical Education & Research; NICED- National Institute of Cholera and Enteric Diseases; PGIMER- Post Graduate Institute of Medical Education & Research

Researcher	Institution	AMR related Publications (2012-2017)	Major area of work
Dr. Balaji Veeraraghavan	CMC, Vellore	37	Medical microbiology, studying phenotypic and molecular mechanisms of resistance, HAIs
Dr. Amitabha Bhattacharjee Dr. Deep Jyotipaul	Assam University, Silchar	20 16	
Dr. Arti Kapil	AIIMS, Delhi	17	
Dr. Jagdish Chander	GMC, Chandigarh	16	
Dr. Ramamurthy Thandavarayan	NICED, Kolkata (now in THSTI, Faridabad)	13	Epidemiology, phenotypic and molecular mechanisms of resistance among dysentery causing bacteria
Dr. Belgode N Harish Dr. Subhash C Parija	JIPMER, Puducherry	11 10	Medical microbiology, examining phenotypic and molecular mechanisms of resistance, HAIs
Dr. Shampa Anupurba Dr. Tuhina Banerjee	BHU, Varanasi	10 10	
Dr. Neelam Taneja Dr. Vikas Gautam	PGIMER, Chandigarh	9 8	

4.4 Survey Responses

The questionnaire asking for current research activities was sent to 264 individuals, of whom 50 responded (19%). Considering humans, animals, and the environment, they indicated the following areas of current research activity (Figure 4.8):

Researcher	Institution	AMR related Publications (2012-2017)	Major area of work
Dr. Samiran Bandyopadhyay Dr. Sandeep Ghatak	Indian Veterinary Research Institute, Kolkata	8 3	Studying phenotypic and molecular mechanisms of resistance in livestock and poultry
Dr. Indranil Samanta Dr. Achintya Mahanti Dr. Siddhartha N Joardar	West Bengal University of Animal and Fishery Sciences, Kolkata	8 5 4	
Dr. Ashok J Tamhankar Dr. Vishal Diwan Dr. Ashish Pathak	RD Gardi Medical College, Ujjain	9 7 7	EOne-health research, social aspects of antibiotic use, AMR spread with human activities
Dr. Yogesh S Shouche	National Centre for Cell Science, Pune	7	Pharmaceutical industry effluents and impact on AMR
Dr. Atul Mittal Dr. Ziaddin S Ahammad	Indian Institute of Technology, Delhi	3 2	Environmental AMR aspects and AMR spread with human activities
Dr. Asad U Khan Dr. Mohammad A Ansari	Aligarh Muslim University, Aligarh	13 6	Understanding molecular mechanisms of resistance, development of novel agents, diagnostics
Dr. Jayanta Haldar Dr. Chandradhish Ghosh	JNCASR Bengaluru	18 10	Novel agents research
Dr. S. Karutha Pandian	Alagappa University	11	
Dr. Sudha Ramaiah	VIT, Vellore	9	Molecular biology, biofilm formation, genetics, immunology, biochemistry aspects of AMR
Dr. Kusum Harjai	Panjab University, Chandigarh	8	
Dr. Govindan Rajamohan Dr. Vijaya B Srinivasan	CSIR-IMTECH, Chandigarh	6 6	
Dr. Jayashree Ramana	Jaypee Institute of Information Technology, Noida	6	

Table 4.9:

Prominent researchers in AMR field in animals, environment, novel agents, miscellaneous, one health and diagnostics

Note: CSIR-IMTECH-Council of Scientific & Industrial Research

Institute of Microbial Technology; JNCASR-Jawaharlal Nehru Centre for Advanced Scientific Research; VIT- Vellore Institute of Technology

- 23% on surveillance/epidemiology
- 21% on drug discovery
- 19% on diagnostics
- 14% clinical
- 5% on policy
- 5% on sanitation
- 4% on social aspects
- 9% on other areas

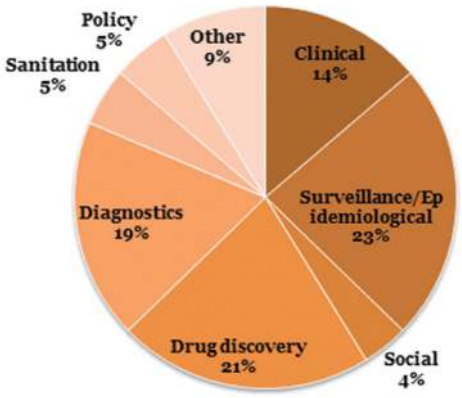


Figure 4.8:

Areas of current research activities in all three areas (human, animal, environment), based on responses from 50 researchers

SECTION 5

DISCUSSION AND RECOMMENDATIONS

5.1. Humans

The majority of the human studies were surveillance-based, examining the prevalence of phenotypic resistance and molecular characterization of resistance for various pathogens. The majority of these surveillance studies were retrospective single-center studies and focused on infected patients. There were very few multicenter large prospective cohort-based or population-based epidemiological studies. The majority of the clinical studies were single center studies focusing on clinical outcomes and risk factors associated with antibiotic-resistant infections and case reports of emerging antibiotic-resistant infections. A limited number of studies examined the impact of infection prevention measures or antimicrobial stewardship activities, but none of them were multicenter studies. There were no studies focusing on transmission dynamics of bacteria either in hospitals or in the community.

The studies categorized as social were mainly focused on understanding the knowledge, attitudes, practices, and ethical issues involving antibiotic use in the general public and among healthcare providers, chemists, and healthcare trainees. There were no studies focusing on the impact of behavioral or policy change on antibiotic use in the community.

Recommendations for future research in humans include the following:

- Understanding transmission mechanisms by which antibiotic resistance spreads in hospitals and in the community
- Developing and studying the impact of various antimicrobial stewardship activities and infection control measures in healthcare facilities with varying resources and in the community
- Examining the impact of behavioral interventions on antibiotic use in healthcare

settings and in the community
- Developing methods for communicating the issue of antibiotic resistance to the general public and healthcare workers and studying their impact on antibiotic use
- Focusing on the burden of antibiotic resistance in various groups (neonates, children, young adults, the elderly) in the community and in various levels of healthcare settings
- Studying supply systems and market dynamics of antibiotic production to understand the lack of availability of narrow-spectrum antibiotics or old antibiotics such as penicillin

5.2. Animals

The majority of animal studies examined the resistance profiles of bacteria isolated from livestock, poultry, and aquaculture; however, the frequency of antibiotic use and reasons for use during animal rearing are poorly represented in the published literature. There were no qualitative studies on farmers' knowledge, attitudes, and practices regarding antibiotic use in food animals.

Recommendations for future research in animals include the following:

- Conducting large-scale studies on surveillance of antibiotic resistance in food animals
- Conducting large-scale studies on antibiotic use for various purposes (growth promotion, prophylaxis, treatment) among food animals, especially in poultry
- Understanding the social aspects of antibiotic use in food animals and subsequent behavioral interventions
- Studying variations in antibiotic use in different farming practices, such as industrial and backyard farming
- Examining alternative practices of food animal rearing and their economic impacts
- Focusing on supply systems and market dynamics of antibiotic production for animal use
- Understanding transmission mechanisms by which antibiotic resistance spreads from food animals to humans

5.3. Environment

The majority of studies examined the prevalence of phenotypic resistance of various bacteria, the presence of ARGs, or the presence of antimicrobial residues in various environmental sources such as rivers, recreational water, sewage treatment plants, hospital effluents, and industrial effluents. Studies examining antibiotic pollution from pharmaceutical industry effluents were confined to Hyderabad city; however, several hot spots of potential antibiotic pollution have been identified (Figure 3.10 and Figure 3.11). A limited number of studies examined the impact of religious mass gathering occasions on contamination of rivers with antibiotic-resistant bacteria and ARGs and the impact of new technologies in STPs in removing antibiotic-resistant bacteria and ARGs.

Recommendations for future research on the environment include the following:

- Studying the extent of environmental antibiotic pollution through pharmaceutical industrial waste (wastewater, solid waste and air) in various parts of India
- Developing standards and detection tools for antibiotic residues in pharmaceutical industrial effluents
- Examining acquisition of antibiotic-resistant bacteria during religious mass gatherings in rivers
- Focusing on waste management to reduce the contamination of rivers during religious mass gatherings
- Developing novel technologies to remove antibiotic-resistant bacteria and ARGs from STPs and hospital wastewater
- Examining behavioral aspects of human waste disposal and its contribution to the problem of antibiotic resistance

5.4. Other (Novel Agents, Diagnostics, One Health, Miscellaneous)

The majority of studies categorized as novel agents focused on compounds with antimicrobial activity, characterization of antimicrobial properties of natural or synthetic compounds, and development of nanoparticle-based antimicrobial agents. Although several compounds have been shown to have antimicrobial activity, these were limited to in vitro experiments, and none of them progressed to clinical evaluation. In the miscellaneous category, studies focused on several aspects such as molecular biology, biofilm formation, genetics, immunology, biochemistry, and mathematical modeling concerning antibiotic resistance. However, studies concentrating on comprehensive understanding of molecular mechanisms of emerging resistance among various pathogens were lacking. A limited number of studies focused on diagnostics and one health. Studies categorized as one health were merely surveillance studies looking at the percentages of resistance in various bacteria isolated from humans, animals, and the environment.

Recommendations for future research in these other areas include the following:

- Studying novel diagnostics and their impact on antibiotic use and clinical outcomes in humans
- Understanding molecular mechanisms of bacterial resistance
- Focusing on the one health approach to understand the transmission mechanisms by which antibiotic resistance can spread between different (animal, human, environmental) reservoirs
- Studying the relative contribution of different reservoirs to antibiotic resistance

5.5. Limitations of the Current Study

There are some limitations to our scoping exercise. First, we focused on published literature that was indexed in PubMed and Google Scholar, which limited our ability to capture research projects that were not indexed, that were completed but have not been published, or that are currently ongoing. Although we attempted to assess current research activities through a survey, the response rate

was poor, at only 19%. However, we observed an increased concentration of research in diagnostics in the survey results. Second, there is a possibility that we might have missed a few studies in our literature search.

5.6. Conclusion

The mapping exercise determined the AMR research landscape, with a particular focus on ABR research in India. This report identifies the future AMR research priorities to be considered in India for various funding agencies, including DBT and RCUK.

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APPENDIX

Table A.1:

Formulation companies manufacturing antibiotics for human use (excluding antituberculosis agents) in India

Manufacturer	Number of antibiotics manufactured	Manufacturer	Number of antibiotics manufactured	Manufacturer	Number of antibiotics manufactured
Aarpik	3	Arlak Biotech	15	Daksh	4
Abbott	4	Assure Aplomb	9	Dallas	1
ABS	3	Asterik	3	Divine Savior	4
Accilex	3	Astra Zeneca	2	DML	2
Acinom HC	9	Astrica	10	Docventures	3
Acinta	4	Auris	1	Dr. Alson Labs	6
Active HC	12	Ausler Snovy	2	Dr. Reddy's	11
Aden Healthcare	8	Azine	5	Drukst Biotech	9
Adley	7	Baroda	1	DWD	6
Aglowmed	3	Baxter	4	Dycine	3
AHPL	39	Bayer	2	East West	3
Akesiss	7	Bestochem	10	Eclipser	1
Alb David	1	Beulah	9	Elder	1
Alde Medi	1	Bharat Serum	1	Elkos	7
Alembic	3	Biochem	5	Elmex	1
Alkem	20	Biocon	14	Eltis	6
Allenge	2	Biomax	7	Emcure	1
Almed	1	Biomiicron	2	Emenox	7
Alna Bio	4	Blubell	5	Encore	2
Ambit	4	Blue Cross	19	Epitome	8
Ancalima	6	Bristol Myers	2	Exeltis	2
Andic	8	Brostin	2	FDC	23
Ankare	5	Cadila	24	Fenestra	1
Anvik Biotech	6	Cipla	39	Finecure	16
Apex	2	Citadel	1	Fitwel	6
Aprique	5	Cross Berry	3	Floreat Medica	4
Aqualife	1	Cubit	4	Forgo Pharma	4
Arist	1	Curex	1	Franco Indian	1
Aristo	1	D.S. Labs	3	Fulford	3

Source: *: Current Index of Medical Specialties (CIMS) INDIA, April–July 2017 edition.*

Manufacturer	Number of antibiotics manufactured	Manufacturer	Number of antibiotics manufactured	Manufacturer	Number of antibiotics manufactured
Future	7	Jenburkt	3	Micro Gratia	2
Galpha	11	Jpee	3	Micro Labs	3
Gen-Biotech	4	Juggat	2	Micro Nova	3
Genesis	2	KAPL	7	Minova	6
Genesis Ram	4	Kepler	3	MNW	6
Gentech HC	4	Konverge	1	Molekule	10
Gladcare	9	Koye	1	MSD	2
Glenmark (Maj)	21	Kusum HC	3	Nanocea Biotec	7
Group	3	Laksun	5	NeeSee	1
GSK	15	Leben Labs	16	Neiss	11
Gujarat Terce	8	Levitas	2	NGS	1
Health Biomed	5	Lexus	5	Nidus	5
Healthkind	8	Lifecare	2	Novagen	2
Helplab	6	Lifestyle	1	Novalab	5
Hetero HC	31	Lincoln	5	Novartis Sandoz	11
Hiral	3	Little Greave	2	Octane	1
HLL Lifecare	2	Lividus	4	Orchid	6
ICARUS	4	Lupin	20	Organic labs	5
Ikon	20	Maan Pharma	5	Orion	9
Indchemie	5	Macleods	38	Pax Healthcare	7
Indus Drugs	2	Madhav Biotech	8	Pfizer	4
Inga	2	Malody	12	Pharmed	2
Intas	3	Maneesh H.care	4	Pharmtech HC	4
Intra Life	9	Mankind	8	Plus India	8
Intra Labs	23	Marc Lab	5	Pranshu	14
Invida	1	Marquess	3	Prime Meditek	6
Invision	25	MDC	2	Procure	2
IPCA	12	Medihealth	4	Progressive	4
Iscon	7	Medopharm	3	Psycorem	6
ISIS	1	Medtronix	2	Q Check	2
Jainik	2	Merck	5	Quality	4
Jaiwik	4	Micro B & B	5	Radicura	13
Jb chemicals	3	Micro Eros	3	Ranbaxy	23

Source: *: Current Index of Medical Specialties (CIMS) INDIA, April–July 2017 edition.*

Manufacturer	Number of antibiotics manufactured	Manufacturer	Number of antibiotics manufactured
Rass HC	14	Vensat	11
Regardia	1	Vinca	1
Reliance	2	Wallace	2
Rhine Biogenics	1	Wezen	5
Rishab	7	Win medicare	5
Rowan	1	Winsome	4
Rowez	2	Wintech	2
Saffron	3	Wockhardt Orion	8
Sanat	1	Wonder HC	8
Sanify (7 Bio)	5	World wide	2
Sanofi Aventis	17	Wyeth	12
Santiago	2	Zanetus	1
Sarian	5	Zee Lab	12
Schon (Reco)	4	Zenacts	5
Serum Institute	1	Zenon	9
Shinto Biotech	7	Zodak	13
Signova	13	Zota	11
Soigner	9	Zubin	13
Solitaire Radix	11	Zubit	10
Solvay	1	Zuventus	15
SRK	5	Zydus	25
Stadmed	2		
Svizera	6		
Systemic	1		
Tablets	2		
Talent	4		
Themis MedC	4		
Theo Pharma	2		
TNT	2		
Treatwell	1		
Tulip	6		
Unilex	6		
United Biotech	24		
United Lifecare	1		
USV	1		

Source: *: Current Index of Medical Specialties (CIMS) INDIA, April–July 2017 edition.*

Table A.2:

Formulation companies manufacturing antibiotics for animal use in India

Manufacturer	Number of antibiotics manufactured	Manufacturer	Number of antibiotics manufactured	Manufacturer	Number of antibiotics manufactured
AHP	1	IBC-Bayer	1	Stallen	5
Alembic	17	ICI/BE	1	Stancare	2
Alved	8	IDPL	1	Sterling lab	14
Ar-Ex	1	Indian Imlogics	7	Themis	4
Aristo	5	Intas	13	Theodor	2
Astra-IDL	1	Intervet	3	Torrent	6
AVR	2	IPCL	1	Trichem	3
BE	2	Jeps	7	TTK	7
Biochem	3	KAPL	13	Unichem	4
Boehringer Mannheim	1	Lyka	16	Universal Medikit	5
Brihans	8	Marc	5	USV	5
Brilliant	6	Max	1	Varsha labs	4
Burrough's-Wellcome	1	Megacare	1	Venky's	6
Cadila HC	4	Micro	7	Vesper	1
Cadila pharma	7	Micro Labs	1	Vetcare	6
Carevet	7	Morvel	9	Vetindia	12
Cattle remedies	7	Neon Labs	1	Vetnex	15
Century	6	Neospark	18	Vetsfarma	13
Chemeck	1	Novartis	7	Virbac	5
Cipla	2	Osco	4	VIRBEC	2
Core	2	Parke-Davis	1	Wallace	1
Cyanamid	1	Pfizer	8	Wockhardt	13
Dabur	4	Piramal	1	Wyeth lederle	1
Denis	5	Piya	2	Zeita	1
Dey's	1	Pranav	4	Zydus AHL	18
Divine lab	3	Prima Vetcare	6	Venky's	6
DOSCH	8	Rajan	5	Vesper	1
Eli Lily	1	Redeem	3		
Fulford	1	Rexcel	3		
G-Loucatos	4	Saideep	1		
GSK Pharma	1	Salus	3		
HAL	13	Sam Browns	1		
Hoechst Marion Roussel	1	Smith-Kline-Beecham	3		
IBC	15	Sarabhai	4		

Source: *:VETNDEX Issue VII (2016).*

Table A.3:

Institutions with at least one publication on AMR in India

Institution	State	Animals	Diagnostics	Environment	Humans	Miscellaneous	Novel agents	One health	Total
A.J. Institute of Medical Sciences and	Karnataka	0	0	0	1	0	0	0	1
A.V. Medical College	Puducherry	0	0	0	1	0	0	0	1
AECS Maaruti College of Dental Sciences	Karnataka	0	0	0	1	0	0	0	1
AFMC	Maharashtra	0	0	0	7	0	0	0	7
AIIMS Chattisgarh	Chattisgarh	0	0	0	1	0	0	0	1
AIIMS Delhi	Delhi	0	0	0	40	4	1	0	45
AIIMS Karnataka	Karnataka	0	0	0	2	0	0	0	2
AIIMS Odisha	Odisha	0	0	0	3	0	0	0	3
Acharya & B.M Reddy College of Pharmacy	Karnataka	0	0	0	1	0	0	0	1
Adichunchanagiri Biotechnology and Cancer	Karnataka	0	0	0	0	0	3	0	3
Agartala Government Medical College	Tripura	0	0	0	1	0	0	0	1
Agharkar Research Institute	Maharashtra	0	0	0	1	0	0	0	1
Alagappa University	Tamil Nadu	0	0	1	4	3	14	0	22
Aligarh Muslim University	Uttar Pradesh	0	2	4	14	5	12	0	37
Amity University	Uttar Pradesh	0	1	0	1	0	2	0	4
Amrita Institute of Medical Sciences	Kerala	0	0	0	6	0	0	0	6
Amrita Vishwa Vidyapeetham University	Kerala	0	0	0	0	1	0	0	1
Anand Agricultural University	Gujarat	4	0	3	0	2	0	0	8
Anand Diagnostics Laboratory	Karnataka	0	0	0	1	0	0	0	1
Animal Sciences University	Punjab	0	0	0	0	1	0	0	1
Animal and Fisheries Sciences University	Karnataka	0	1	0	1	0	0	0	2

Institution	State	Animals	Diagnostics	Environment	Humans	Miscellaneous	Novel agents	One health	Total
Anna University	Tamil Nadu	0	1	1	0	0	5	0	7
Annamalai University	Tamil Nadu	0	0	2	3	0	0	0	5
Apollo Cancer Institute	Tamil Nadu	0	0	0	1	0	0	0	1
Apollo Hospitals	Maharashtra	0	0	0	9	0	0	0	9
Apollo Institute of Medical Sciences	Telangana	0	0	0	3	1	0	0	4
Aravind Eye Care Coimbatore	Tamil Nadu	0	0	0	1	0	0	0	1
Aravind Eye Care Madurai	Tamil Nadu	0	0	0	2	1	0	0	3
Aravind Eye Hospital and Postgraduate Institute	Tamil Nadu	0	0	0	2	0	0	0	2
Army College of Dental Sciences	Telangana	0	0	0	1	0	0	0	1
Army Hospital (R&R)	Delhi	0	0	0	1	0	0	0	1
Artemis Health Institute	Haryana	0	0	0	2	0	0	0	2
Arts, Commerce and Science College	Maharashtra	0	0	0	0	0	1	0	1
Ashok Laboratory Clinical Testing Centre	West Bengal	0	0	0	1	0	0	0	1
Ashok and Rita Patel Institute of Integrated Study	Gujarat	1	0	0	0	0	0	0	1
Asian Institute of Public Health	Odisha	0	0	0	1	0	0	0	1
Assam Medical College	Assam	0	0	0	2	0	0	0	2
Assam University	Assam	0	0	1	16	5	2	0	24
Aurigene Discovery Technologies Ltd	Karnataka	0	0	0	0	0	1	0	1
Azeezia Medical College	Kerala	0	0	0	2	0	0	0	2
B.J. Medical College	Gujarat	0	0	0	2	0	0	0	2
B.J. Wadia Hospital for Childrens	Maharashtra	0	0	0	1	0	0	0	1
B.J.B. Autonomous College	Odisha	0	0	0	1	0	1	0	2
B.Y.L. Nair Charitable Hospital	Maharashtra	0	0	0	1	0	0	0	1
BIS Group of Institutions	Punjab	0	0	1	0	0	0	0	1

Institution	State	Animals	Diagnostics	Environment	Humans	Miscellaneous	Novel agents	One health	Total
BLDEU's Shri B M Patil Medical College	Karnataka	0	0	0	2	0	0	0	2
BLK Superspeciality Hospital	Delhi	0	0	0	2	0	0	0	2
BPS GMC (Women)	Haryana	0	0	0	1	0	0	0	1
Baba Farid University of Health Sciences	Punjab	0	0	0	0	0	1	0	1
Baba Saheb Ambedkar Hospital	Delhi	0	0	0	1	0	0	0	1
Banaras Hindu University	Uttar Pradesh	0	0	1	21	7	4	1	34
Bangalore Baptist Hospital	Karnataka	0	0	0	1	0	0	0	1
Bangalore Medical College	Karnataka	0	0	0	1	0	0	0	1
BarodaMedical College	Gujarat	0	0	0	0	0	1	0	1
Base Hospital	Delhi	0	0	0	1	0	0	0	1
Belagavi Institute of Medical Sciences	Delhi	0	0	0	1	0	0	0	1
Belgaum Institute of Medical Sciences	Karnataka	0	0	0	1	0	0	0	1
Berhampur University	Odisha	0	0	0	3	0	0	0	3
Bhabha Atomic Research Centre	Maharashtra	0	0	0	0	2	1	0	3
Bharat Institute of Technology	Telangana	0	0	0	1	0	0	0	1
Bharath University	Tamil Nadu	0	0	0	1	0	0	0	1
Bharathi College of Pharmacy	Karnataka	0	0	0	1	0	0	0	1
Bharathiar University	Tamil Nadu	0	0	0	3	0	2	0	5
Bharathidasan University	Tamil Nadu	1	0	3	0	2	1	0	7
Bharati Vidyapeeth Deemed University	Maharashtra	0	0	0	2	0	0	0	2
Biju Patnaik University of Technology	Odisha	0	0	1	0	0	0	0	1
Birla Institute of Technology & Science	Jharkhand	0	0	0	0	1	1	0	2
Birla Institute of Technology & Science	Telangana	0	0	0	1	1	1	0	3

Institution	State	Animals	Diagnostics	Environment	Humans	Miscellaneous	Novel agents	One health	Total
Birla Institute of Technology and Science	Goa	0	0	0	0	0	1	0	1
Bombay College of Pharmacy	Maharashtra	0	0	0	0	0	2	0	2
Bose Institute	West Bengal	0	0	0	0	2	2	0	4
Browns College of Pharmacy	Telangana	0	0	0	1	0	0	0	1
Burdwan Medical College	West Bengal	0	0	0	2	0	0	0	2
Burdwan University	West Bengal	0	0	0	0	1	0	0	1
Byramjee Jeejeebhoy Government Medical C	Maharashtra	0	0	0	2	0	0	0	2
C.B.S.H., G. B. Pant University of Agric	Uttarakhand	0	0	0	0	0	1	0	1
CHILDS Trust Medical Research Foundation	Tamil Nadu	0	0	0	1	0	0	0	1
CSIR - National Environmental Engineerin	Maharashtra	0	0	0	0	1	1	0	2
CSIR Institute of Genomics and Integrated Biology	Delhi	0	0	0	0	2	2	0	2
CSIR-CSMCRI	Gujarat	1	0	0	0	0	0	0	1
CSIR-Central Drug Research Institute	Uttar Pradesh	0	0	0	0	1	1	0	2
CSIR-Central Food Technological Research	Karnataka	1	0	1	0	4	1	0	7
CSIR-Central Institute of Medicinal and Aromatic Plants	Uttar Pradesh	0	0	0	0	0	5	0	5
CSIR-Indian Institute of Chemical Technology	Telangana	0	0	0	0	1	0	0	1
CSIR-Indian Institute of Integrative Medicine	Jammu and Kashmir	0	0	0	0	2	4	0	6
CSIR-Indian Institute of Toxicology Research	Uttar Pradesh	0	0	2	0	0	0	0	2
CSIR-Institute of Microbial Technology	Chandigarh	0	0	0	3	11	4	0	18
CSIR-National Botanical Research Institu	Uttar Pradesh	0	0	0	0	0	1	0	1
CSIR-National Chemical Laboratory	Maharashtra	0	0	0	0	0	1	0	1

Institution	State	Animals	Diagnostics	Environment	Humans	Miscellaneous	Novel agents	One health	Total
CSIR-National Environmental Engineering	Maharashtra	0	0	0	0	0	1	0	1
CSIR-National Institute of Oceanography	West Bengal	0	0	1	0	0	0	0	1
CU Shah Medical College	Gujarat	0	0	0	1	0	0	0	1
Calcutta School of Tropical Medicine	West Bengal	0	0	0	4	0	2	0	6
Cancer Institute	Tamil Nadu	0	0	0	1	0	0	0	1
Center for Disease Dynamics, Economics & Policy	Delhi	1	0	0	5	0	0	0	6
Center for Science and Environment	Delhi	1	0	0	0	0	0	0	1
Central Agricultural University	Mizoram	1	0	0	2	0	0	0	3
Central Avian Research Institute	Uttar Pradesh	1	0	0	0	0	0	0	1
Central Institute of Fisheries Education	Maharashtra	0	0	0	0	1	0	0	1
Central Institute of Fisheries Technolog	Kerala	2	0	0	0	0	0	0	2
Central Institute of Fisheries Technolog	Maharashtra	1	0	0	0	0	0	0	1
Central Institute of Freshwater Aquacul	Odisha	0	0	0	0	0	1	0	1
Central Institute of Medicinal and Aroma	Uttar Pradesh	0	0	0	0	0	3	0	3
Central Leather Research Institute	Tamil Nadu	0	0	1	0	0	1	0	2
Central Leprosy-Teaching and Research Ins	Tamil Nadu	0	0	0	1	0	0	0	1
Central Marine Fisheries Research Instit	Kerala	0	0	1	0	0	0	0	1
Central Research Institute	Himachal Pradesh	0	0	0	4	0	0	0	4
Central Tuber Crops Research Institute	Kerala	0	0	0	0	0	2	0	2

Institution	State	Animals	Diagnostics	Environment	Humans	Miscellaneous	Novel agents	One health	Total
Central University of Rajastan Ajmer	Rajasthan	0	0	0	1	1	2	0	4
Centre for Cellular and Molecular Biology	Telangana	0	0	0	0	1	0	0	1
Centre for DNA Fingerprinting and Diagno	Telangana	0	0	0	0	2	0	0	2
Centre for Materials for Electronics Tec	Maharashtra	0	0	0	0	1	0	0	1
Centre of Advanced Study	Uttar Pradesh	1	0	0	0	0	0	0	1
Chacha Nehru Bal Chikitsalaya	Delhi	0	0	0	2	0	0	0	2
Chaudhary Charan Singh (C.C.S.) Universi	Gujarat	1	0	0	0	0	0	0	1
Chettinad Hospital and Research Institut	Tamil Nadu	0	0	0	3	1	0	0	4
Chhatrapati Shahuji Maharaj Medical Univ	Uttar Pradesh	0	0	0	1	0	0	0	1
Chhattisgarh Dental College and Research	Chattisgarh	0	0	0	0	0	1	0	1
Chhattisgarh Kamdhenu Vishwavidyalaya	Chattisgarh	2	0	0	0	0	0	1	3
Chirayu Medical College and Hospital	Madhya Pradesh	0	0	0	1	0	0	0	1
Choithram Hospital & Research Centre	Madhya Pradesh	0	0	0	1	0	0	0	1
Christ College	Gujarat	0	0	0	0	1	0	0	1
Christian Dental College	Punjab	0	0	0	1	0	0	0	1
Christian Medical College, Punjab	Punjab	0	0	0	4	0	0	0	4
Christian Medical College, Tamil Nadu	Tamil Nadu	0	0	0	46	4	3	0	53
Civil Hospital	Rajasthan	0	0	0	1	0	0	0	1
Cochin University of Science and Technol	Kerala	3	0	4	0	1	1	0	9
College of Pharmacy, SRIPMS	Tamil Nadu	0	0	0	1	0	0	0	1

Institution	State	Animals	Diagnostics	Environment	Humans	Miscellaneous	Novel agents	One health	Total
College of Veterinary Science	Assam	2	0	0	0	0	0	0	2
College of Veterinary and Animal Husband	Uttar Pradesh	1	0	1	0	0	0	0	2
College of Veterinary and Animal Science	Kerala	1	0	0	0	0	0	0	1
College of Veterinary and Animal Science	Uttarakhand	1	0	0	0	0	0	0	1
Command Hospital	Maharashtra	0	0	0	3	0	0	0	3
Coorg Institute of Dental Sciences	Karnataka	0	0	0	0	0	1	0	1
Council of Scientific and Industrial Res	Kerala	0	0	0	0	0	1	0	1
DHAFMS	Delhi	0	0	0	1	0	0	0	1
DUVASU, Mathura	Uttar Pradesh	0	0	0	1	0	0	0	1
Damodaran College of Science	Tamil Nadu	0	0	0	1	0	0	0	1
Dayanand Medical College and Hospital	Punjab	0	0	0	1	0	0	0	1
Dayananda Sagar Institutions	Karnataka	0	0	2	0	1	2	0	5
Deccan College of Medical Sciences	Telangana	0	0	0	1	0	0	0	1
Deemed University Tamil Nadu	Tamil Nadu	0	0	0	0	1	0	0	1
Deemed University Uttar Pradesh	Uttar Pradesh	0	0	0	0	1	0	0	1
Defence Institute of Physiology and Alli	Delhi	0	0	0	0	0	1	0	1
Defence Research & Development Establish	Madhya Pradesh	0	0	0	3	0	0	0	3
Delhi State Cancer Institute	Delhi	0	0	0	6	0	0	0	6

Institution	State	Animals	Diagnostics	Environment	Humans	Miscellaneous	Novel agents	One health	Total
Department of Science & Technology	Gujarat	0	0	0	0	1	0	0	1
Department of Veterinary Microbiology an	Uttar Pradesh	1	0	0	0	0	0	0	1
Department of Veterinary Pharmacology an	Uttar Pradesh	0	0	1	0	0	0	0	1
Dhanalakshmi Srinivasan Medical College	Tamil Nadu	0	0	0	1	0	0	0	1
Dibrugarh University	Assam	0	0	0	0	0	1	0	1
Division of Avian Genetics and Breeding	West Bengal	0	0	0	0	1	0	0	1
Doctors Diagnostic Centre	Tamil Nadu	0	0	0	0	0	1	0	1
Dr MGR Educational and Research Institut	Tamil Nadu	0	1	0	1	0	0	0	2
Dr Shankarrao Chavan Government Medical	Maharashtra	0	0	0	1	0	0	0	1
Dr. B C Roy Post Graduate Institute of B	West Bengal	0	0	0	1	0	0	0	1
Dr. B.R Ambedkar Medical College	Karnataka	0	0	0	2	0	0	0	2
Dr. B.R. Ambedkar University	Uttar Pradesh	0	0	0	0	0	1	0	1
Dr. Baba Saheb Ambedkar Hospital	Delhi	0	0	0	1	1	0	0	2
Dr. D.Y Patil Medical College	Maharashtra	0	0	0	2	0	0	0	2
Dr. G. R. Damodaran College of Science	Tamil Nadu	2	0	0	0	0	0	0	2
Dr. H.S. Gour Central University	Madhya Pradesh	0	0	0	0	0	2	0	2
Dr. Harvansh Singh Judge Institute of De	Chandigarh	0	0	0	1	0	0	0	1
Dr. N.G.P Arts and Science College	Tamil Nadu	0	0	0	1	0	0	0	1

Institution	State	Animals	Diagnostics	Environment	Humans	Miscellaneous	Novel agents	One health	Total
Dr. Pinnamaneni Siddhartha Institute of	Andhra Pradesh	0	0	0	1	0	0	0	1
Dr. RPGMC	Himachal Pradesh	0	0	0	1	0	0	0	1
Dr. Ram Manohar Lohia Avadh University	Uttar Pradesh	0	0	1	0	0	0	0	1
Dr. Somervell Memorial CSI Medical Colle	Kerala	0	0	0	2	0	0	0	2
Dr. V. P. Medical College, Hospital & Research Centre	Maharashtra	0	0	0	1	0	0	0	1
Dr. Yewale's Multispeciality Hospital for Children	Maharashtra	0	0	0	1	0	0	0	1
ESI-PGIMSR, ESIC Medical College and ESI	West Bengal	0	0	0	1	0	0	0	1
ESIC MC & PGIMSR	Karnataka	0	0	0	2	0	0	0	2
ESIC Medical College and ESIC Hospital	West Bengal	0	0	0	1	0	0	0	1
East-West College of Science	Karnataka	0	0	0	0	0	1	0	1
Eminent Biosciences	Madhya Pradesh	0	0	0	0	1	0	0	1
Entomology Research Institute	Tamil Nadu	0	0	0	0	0	1	0	1
Eras Lucknow Medical College and Hospital	Uttar Pradesh	0	0	0	2	0	0	0	2
Father Muller Medical College	Karnataka	0	0	0	3	0	0	0	3
Fernandez Hospital	Telangana	0	0	0	1	0	0	0	1
Fortis Escorts Hospital	Rajasthan	0	0	0	5	0	0	0	5
G. B. Pant Institute of Postgraduate Medical Education	Delhi	0	0	0	4	0	0	0	4
GADVASU	Punjab	1	0	0	1	0	0	0	2
GHR Micro Diagnostics	Telangana	0	0	0	1	0	0	0	1

Institution	State	Animals	Diagnostics	Environment	Humans	Miscellaneous	Novel agents	One health	Total
GITAM University	Andhra Pradesh	0	0	0	0	2	1	0	3
GMERS Medical College	Gujarat	0	0	0	1	0	0	0	1
GSK Pharmaceuticals Ltd	Karnataka	0	0	0	1	0	0	0	1
GSL Medical College & General Hospital	Andhra Pradesh	0	0	0	1	0	0	0	1
Gandhi Medical College and Hospital	Telangana	0	0	0	2	0	0	0	2
Gangagen Biotechnologies Pvt. Ltd	Karnataka	0	0	0	0	1	2	0	3
Gangasaras Diagnostic and Research Centre	Tamil Nadu	0	0	0	1	0	0	0	1
Garhwal University	Uttarakhand	0	0	0	0	0	1	0	1
Gauhati Medical College	Assam	0	0	0	2	0	0	0	2
Gauhati University	Assam	0	0	0	6	1	0	0	7
Glenmark Pharmaceuticals Ltd	Maharashtra	0	0	0	1	0	0	0	1
Goa Dental College and Hospital	Goa	0	0	0	1	0	0	0	1
Goa University	Goa	0	0	0	0	1	0	0	1
Gold Field Institute of Medical Sciences	Haryana	0	0	0	1	0	0	0	1
Golden Jubilee Biotech Park for Women	Tamil Nadu	0	0	0	1	0	0	0	1
Government Degree College Baramulla	Jammu and Kashmir	0	0	0	1	0	0	0	1
Government Dental College and Research Institute	Karnataka	0	0	0	1	0	0	0	1
Government Medical College Gujarat	Gujarat	0	0	0	7	0	0	0	7
Government Medical College Haldwani	Uttarakhand	0	0	0	1	0	0	0	1
Government Medical College Hospital	Chandigarh	0	1	0	18	0	0	0	19

Institution	State	Animals	Diagnostics	Environment	Humans	Miscellaneous	Novel agents	One health	Total
Government Medical College Hospital Tami	Tamil Nadu	0	0	0	1	0	0	0	1
Government Medical College Jammu and Kashmir	Jammu and Kashmir	0	0	0	2	0	0	0	2
Government Medical College Kerala	Kerala	0	0	0	4	0	0	0	4
Government Medical College Punjab	Punjab	0	0	0	2	0	0	0	2
Government Medical College Uttarakhand	Uttarakhand	0	0	0	4	0	0	0	4
Government Medical College, Latur	Maharashtra	0	0	0	1	0	0	0	1
Government Medical College, Nagpur	Maharashtra	0	0	0	1	0	0	0	1
Government Postgraduate College	Uttarakhand	0	0	0	1	0	0	0	1
Government Cancer Hospital	Maharashtra	0	0	0	1	0	0	0	1
Govt. Kilpauk Medical College	Tamil Nadu	0	0	0	2	0	0	0	2
Grant Government Medical College	Maharashtra	0	0	0	1	0	0	0	1
Grant Medical College	Maharashtra	0	0	0	0	1	0	0	1
Greater Kailash Hospital	Madhya Pradesh	0	0	0	1	0	0	0	1
Gujarat University	Gujarat	0	0	0	0	0	1	0	1
Gulbarga University	Karnataka	0	0	0	2	2	1	0	5
Guru Angad Dev Veterinary and Animal Sciences	Delhi	1	0	0	0	0	0	0	1
Guru Gobind Singh Indraprastha University	Delhi	0	0	0	0	0	1	0	1
Guru Gobind Singh Medical College and Hospital	Punjab	0	0	0	1	0	0	0	1
Guru Jambheshwer University of Science & Technology	Haryana	0	0	0	0	0	3	0	3

Institution	State	Animals	Diagnostics	Environment	Humans	Miscellaneous	Novel agents	One health	Total
Guru Nanak Dev University	Punjab	0	0	0	0	0	2	0	2
Gurukul Kangri University	Uttarakhand	0	0	0	0	0	1	0	1
Haldia Institute of Technology	West Bengal	0	0	0	0	0	2	0	2
Hamdard University	Delhi	0	0	0	0	0	1	0	1
Herbicure Healthcare Bio-Herbal Foundation	Not Applicable	0	0	0	0	0	1	0	1
Himachal Pradesh University	Himachal Pradesh	0	0	0	1	0	0	0	1
Himalayan Institute of Medical Sciences	Uttarakhand	0	0	0	4	0	0	0	4
Hindu Rao Hospital	Delhi	0	0	0	1	0	0	0	1
Holy Cross College	Tamil Nadu	0	0	0	0	1	0	0	1
Holy Spirit Hospital	Maharashtra	0	0	0	1	0	0	0	1
ICAR Research Complex for NEH Region	Meghalaya	4	0	0	0	1	0	0	5
ICAR-Indian Veterinary Research Institut	Uttar Pradesh	2	0	0	0	0	0	1	3
ICARE Eye Hospital and Postgraduate Institute	Uttar Pradesh	0	0	0	1	0	0	0	1
IFTM University	Uttar Pradesh	0	0	0	0	0	1	0	1
IIT Delhi	Delhi	0	1	6	0	0	0	0	7
IIT Guwahati	Assam	0	0	1	0	1	4	0	6
IIT Hyderabad	Telangana	0	0	0	0	1	1	0	2
IIT Kanpur	Uttar Pradesh	0	0	0	0	2	0	0	2
IIT Kharagpur	West Bengal	0	0	0	1	6	10	0	17
IIT Madras	Tamil Nadu	0	0	0	1	0	0	0	1
IIT Roorkee	Uttarakhand	0	0	0	0	3	4	0	7
IMS & Sum Hospital Medical College, S 'O	Odisha	0	0	0	7	0	7	0	14
IPGME&R and SSKM Hospital	West Bengal	0	0	0	3	0	1	0	4
IPGMER & SSKM Hospital	West Bengal	0	0	0	1	0	0	0	1
IT University	Tamil Nadu	0	0	0	0	1	0	0	1

Institution	State	Animals	Diagnostics	Environment	Humans	Miscellaneous	Novel agents	One health	Total
ITS Dental College	Uttar Pradesh	0	0	0	1	0	0	0	1
Dr G R Damodaran College of Science	Tamil Nadu	0	0	0	0	1	0	0	1
M M College of Pharmacy	Haryana	0	0	0	0	0	1	0	1
Indian Academy Degree College	Karnataka	0	0	0	1	0	0	0	1
Indian Agricultural Research Institute	Delhi	0	0	0	0	0	1	0	1
Indian Association for the Cultivation of Science	West Bengal	0	0	0	0	0	1	0	1
Indian Council of Agricultural Research	Assam	4	0	0	0	0	0	0	4
Indian Council of Medical Research	Delhi	0	0	1	2	1	0	0	4
Indian Council of Medical Research	Andaman & Nicobar Islands	0	0	0	7	1	0	0	8
Indian Council of Medical Research	Assam	0	0	0	1	0	0	0	1
Indian Council of Medical Research,	Karnataka	0	0	0	5	0	1	0	6
Indian Council of Medical Research,	Odisha	0	0	0	2	0	0	0	2
Indian Institute of Advanced Research	Gujarat	0	0	0	4	1	0	0	5
Indian Institute of Chemical Technology	Telangana	0	0	0	0	0	1	0	1
Indian Institute of Science	Karnataka	0	0	0	0	4	1	0	5
Indian Institute of Science Education and Research	Madhya Pradesh	0	0	0	0	2	0	0	2
Indian Institute of Science Education and Research	Maharashtra	0	0	0	0	1	1	0	2
Indian Institute of Technology Bombay	Maharashtra	0	0	0	0	6	1	0	7

Institution	State	Animals	Diagnostics	Environment	Humans	Miscellaneous	Novel agents	One health	Total
Indian Institute of Technology Kharagpur	West Bengal	0	0	1	0	0	0	0	1
Indian Network for Surveillance of Antimicrobial Resistance	Multicenter	0	0	0	1	0	0	0	1
Indian Veterinary Research Institute	Arunachal Pradesh	1	0	0	0	0	0	0	1
Indian Veterinary Research Institute	Uttar Pradesh	2	0	0	0	0	1	2	5
Indian Veterinary Research Institute	West Bengal	2	0	0	0	0	1	0	3
Indian Institute of Soil Science	Madhya Pradesh	0	0	0	0	1	0	0	1
Indira Gandhi Government Medical College	Maharashtra	0	0	0	2	0	0	0	2
Indira Gandhi Krishi Vishwavidyalaya	Chattisgarh	0	0	0	0	1	0	0	1
Indira Gandhi Medical College	Himachal Pradesh	0	0	0	5	0	0	0	5
Indira Gandhi Medical College & Research	Puducherry	0	0	0	1	0	0	0	1
Institute for Research in Vision and Ophtholomology	Tamil Nadu	0	0	0	1	0	0	0	1
Institute of Advanced Study in Science and Technology	Assam	0	0	0	0	0	1	0	1
Institute of Bioresources and Sustainable Development	Manipur	0	0	0	0	0	1	0	1
Institute of Chemical Technology	Maharashtra	0	0	1	0	0	0	0	1
Institute of Child Health	West Bengal	0	0	0	1	0	0	0	1
Institute of Life Sciences	Odisha	0	0	0	2	2	0	0	4
Institute of Liver & Biliary Sciences	Delhi	0	0	0	1	0	0	0	1
Institute of Minerals and Materials Technology	Odisha	0	0	1	0	0	0	0	1

Institution	State	Animals	Diagnostics	Environment	Humans	Miscellaneous	Novel agents	One health	Total
Institute of Nuclear Medicine and Allied Sciences	Delhi	0	0	0	1	1	8	0	10
Integral University	Uttar Pradesh	0	0	2	3	2	3	0	10
International Centre for Ecological Engineering	West Bengal	0	0	1	0	0	0	0	1
International Crops Research Institute for Semi-Arid Tropics	Telangana	0	0	0	0	1	0	0	1
J N Medical College	Uttar Pradesh	0	0	0	3	0	1	0	4
JIPMER	Puducherry	0	0	0	21	1	0	0	22
JJM Medical College	Karnataka	0	0	0	4	0	0	0	4
JSS Dental College and Hospital	Karnataka	0	0	0	0	1	0	0	1
JSS University	Karnataka	0	0	0	0	0	2	0	2
Jadavpur University	West Bengal	0	0	1	0	0	7	0	8
Jain Irrigation Systems Ltd	Maharashtra	0	0	0	1	0	0	0	1
Jain University	Karnataka	0	0	1	3	0	1	0	5
Jamal Mohamed College	Tamil Nadu	0	0	1	0	0	0	0	1
Jamia Hamdard	Delhi	0	0	0	1	0	0	0	1
Jamia Millia Islamia	Delhi	0	0	2	0	0	2	0	4
Janakpuri Super Speciality Hospital	Delhi	0	0	0	1	0	0	0	1
Jawaharlal Nehru Centre for Advanced Sciences	Karnataka	0	0	0	0	1	18	0	19
Jawaharlal Nehru Institute of Advanced Sciences	Telangana	1	0	0	0	0	0	0	1
Jawaharlal Nehru University, Delhi	Delhi	0	0	1	2	1	3	0	7
Jawaharlal Nehru University, Maharashtra	Karnataka	0	0	0	2	0	0	0	2
Jawaharlal Nehru University, Uttar Pradesh	Uttar Pradesh	0	0	1	2	0	3	0	6

Institution	State	Animals	Diagnostics	Environment	Humans	Miscellaneous	Novel agents	One health	Total
Jaypee Institute of Information Technology	Himachal Pradesh	0	0	1	0	7	5	0	13
Jaypee Institute of Information Technology	Uttar Pradesh	0	0	0	0	2	0	0	2
Jhalawar Medical College	Rajasthan	0	0	0	2	0	0	0	2
Joseph Eye Hospital	Tamil Nadu	0	0	0	1	0	0	0	1
Jubilant Chemsys Ltd	Uttar Pradesh	0	0	0	0	1	0	0	1
K.S.R. College of Arts and Science	Tamil Nadu	0	0	0	1	0	1	0	2
KEM Hospital	Maharashtra	0	1	0	0	0	0	0	1
KG Medical University	Uttar Pradesh	0	0	0	1	0	0	0	1
KIIT University	Odisha	0	0	0	0	1	3	0	4
KLE University	Karnataka	0	0	0	0	0	1	0	1
KLE VK Institute of Dental Sciences	Karnataka	0	0	0	0	0	2	0	2
KLE's JN Medical College, Belgaum	Karnataka	0	0	0	1	0	0	0	1
KVG Dental College and Hospital	Karnataka	0	0	0	1	0	0	0	1
Kakatiya Government Degree & P.G College	Telangana	0	0	0	0	0	1	0	1
Kalinga Institute of Medical Sciences	Odisha	0	0	0	2	0	0	0	2
Kamalnayan Bajaj Research Centre, Vision	Tamil Nadu	0	0	0	1	0	0	0	1
Kannur Dental College	Kerala	0	0	0	1	0	0	0	1
Karnatak University	Karnataka	0	0	0	0	0	1	0	1
Karnataka Institute of Medical Sciences	Karnataka	0	0	0	1	0	0	0	1
Karnataka Veterinary Animal and Fisherie	Karnataka	2	0	0	0	0	0	1	3

Institution	State	Animals	Diagnostics	Environment	Humans	Miscellaneous	Novel agents	One health	Total
Karpagam Faculty of Medical Sciences and	Tamil Nadu	0	0	0	2	0	0	0	2
Karunya University	Tamil Nadu	0	0	0	1	0	0	0	1
Kashibai Navale Medical College	Maharashtra	0	0	0	1	0	0	0	1
Kasturba Medical College	Karnataka	0	0	0	5	0	0	0	5
Katihar Medical College	Bihar	0	0	0	1	0	0	0	1
Kempegowda Institute of Medical Sciences	Karnataka	0	0	0	3	0	0	0	3
Kerala Institute of Medical Sciences	Kerala	0	0	0	1	0	0	0	1
Kerala Veterinary and Animal Sciences University	Kerala	0	0	0	0	1	0	0	1
Khadir Mohideen College	Tamil Nadu	0	0	0	1	0	0	0	1
Khaja Banda Nawaz institute of Medical Sciences	Karnataka	0	0	0	1	0	0	0	1
Kidwai Memorial Institute of Oncology,	Karnataka	0	0	0	1	0	0	0	1
King George Medical University	Uttar Pradesh	0	0	0	3	0	0	0	3
King Saud University	Tamil Nadu	0	0	1	0	0	0	0	1
Kokilaben Dhirubhai Ambani Hospital and	Maharashtra	0	0	0	2	0	0	0	2
Konaseema Institute of Medical Science &	Andhra Pradesh	0	0	0	1	0	0	0	1
Kovai Medical Center and Hospital	Tamil Nadu	0	0	0	1	0	1	0	2
Krishna Institute of Medical Sciences	Maharashtra	0	0	0	1	0	0	0	1
Kurukshetra University	Gujarat	1	0	0	0	0	0	0	1
L & T Microbiology Research Centre	Tamil Nadu	0	0	0	1	0	0	0	1
L. V. Prasad Eye Institute AP	Andhra Pradesh	0	0	0	5	0	0	0	5

Institution	State	Animals	Diagnostics	Environment	Humans	Miscellaneous	Novel agents	One health	Total
L. V. Prasad Eye Institute Odisha	Odisha	0	0	0	5	0	0	0	5
L. V. Prasad Eye Institute Telangana	Telangana	0	0	0	5	0	0	0	5
L.T.M. Medical College	Maharashtra	0	0	0	4	0	0	0	4
LBS College of Pharmacy	Rajasthan	0	0	0	0	0	1	0	1
LN Medical College & RC	Madhya Pradesh	0	0	0	2	0	0	0	2
Lady Doak College	Tamil Nadu	0	0	0	0	1	0	0	1
Lady Hardinge Medical College	Delhi	0	0	0	2	0	0	0	2
Lohia Hospital	Delhi	0	0	0	1	0	0	0	1
Lovely Professional University	Punjab	0	0	1	2	1	1	1	6
Loyola College (Autonomous)	Tamil Nadu	0	0	0	0	0	1	0	1
M. D. University	Haryana	0	0	0	0	0	1	0	1
M.M. Institute of Medical Sciences and R	Haryana	0	0	0	1	0	0	0	1
MES Medical College	Kerala	0	0	0	4	0	0	0	4
MES Ponnani College	Kerala	0	0	0	0	1	0	0	1
MGM Eye Institute	Chattisgarh	0	0	0	1	0	0	0	1
MGM Medical College and Hospital	Maharashtra	0	0	0	2	0	0	0	2
MIMER Medical College	Maharashtra	0	0	0	1	0	0	0	1
MS Ramaiah Medical College	Karnataka	0	0	0	2	0	0	0	2
Madha Medical College	Tamil Nadu	0	0	0	1	0	0	0	1
Madhav Institute of Technology and Sciences	Madhya Pradesh	0	0	1	0	1	1	0	3
Madras Medical College	Tamil Nadu	0	0	0	1	0	0	0	1
Madras Medical Mission	Tamil Nadu	0	0	0	1	0	0	0	1
Madurai Kamaraj University	Tamil Nadu	0	0	0	2	3	2	0	7
Maharajah's Institute of Medical Sciences	Andhra Pradesh	0	0	0	1	0	0	0	1

Institution	State	Animals	Diagnostics	Environment	Humans	Miscellaneous	Novel agents	One health	Total
Maharashtra Institute of Medical Education	Maharashtra	0	0	0	1	0	0	0	1
Maharishi Markandeshwar College of Dental Sciences & Research	Haryana	0	0	0	1	0	0	0	1
Maharshi Dayanand University	Haryana	0	0	0	0	1	1	0	2
Mahatma Gandhi Institute of Medical Sciences	Gujarat	0	0	0	1	0	0	0	1
Mahatma Gandhi Institute of Medical Sciences	Maharashtra	0	0	0	2	0	0	0	2
Mahatma Gandhi Medical College	Rajasthan	0	0	0	2	0	1	0	3
Mahatma Gandhi Medical College and Research Center	Puducherry	0	0	0	11	0	1	0	12
Mahatma Gandhi University	Kerala	0	0	0	2	0	2	0	4
Majeedia Hospital	Delhi	0	0	0	1	0	0	0	1
Malabar Medical College and Research Centre	Kerala	0	0	0	1	0	0	0	1
Malankara Catholic College	Tamil Nadu	0	0	0	0	0	1	0	1
Malda Medical College and Hospital	West Bengal	0	0	0	1	0	0	0	1
Manipal College of Pharmaceutical Sciencec	Karnataka	0	0	0	0	1	0	0	1
Manipal University	Karnataka	0	0	6	29	1	2	0	38
Manonmaniam Sundaranar University	Tamil Nadu	0	0	0	0	0	2	0	2
Maulana Azad Medical College	Delhi	0	0	0	13	0	0	0	13
Maulana Azad Medical College Uttar Pradesh	Uttar Pradesh	0	0	0	1	0	0	0	1
Max Super Speciality Hospital	Delhi	0	0	0	3	0	0	0	3
Mayo Institute of Medical Sciences	Uttar Pradesh	0	0	0	3	0	0	0	3
Medanta Hospital	Haryana	0	0	0	4	0	0	0	4
Medical College	Gujarat	0	0	0	1	0	1	0	2

Institution	State	Animals	Diagnostics	Environment	Humans	Miscellaneous	Novel agents	One health	Total
Medical Sciences and Research Institute	Uttarakhand	0	0	0	1	0	0	0	1
Medicinal Chemistry Department	Uttar Pradesh	0	0	0	0	0	1	0	1
Meenakshi Ammal Dental College	Tamil Nadu	0	0	0	1	1	0	0	2
Meerut College Gujarat	Gujarat	0	0	0	1	0	0	0	1
Meerut College Uttar Pradesh	Uttar Pradesh	0	0	0	1	0	0	0	1
Metropolis Healthcare Ltd	Maharashtra	0	0	0	1	0	0	0	1
Military Hospital Meerut	Uttar Pradesh	0	0	0	3	0	0	0	3
Mizoram University	Mizoram	0	0	1	0	0	0	0	1
Modern College of Arts	Maharashtra	0	0	0	0	0	1	0	1
Modern Dental College and Research Centre	Madhya Pradesh	0	0	0	2	0	0	0	2
Montessori Mahila Kalasala	Andhra Pradesh	0	0	0	1	0	0	0	1
Motilal Nehru Medical College	Uttar Pradesh	0	0	0	3	1	0	0	4
Motilal Nehru National Institute of Tech	Uttar Pradesh	0	0	0	0	2	1	0	3
Muljibhai Patel Urological Hospital	Gujarat	0	0	0	1	0	0	0	1
Multicenter study	Multicenter	0	0	0	1	0	0	0	1
Murshidabad Medical College	West Bengal	0	0	0	1	0	0	0	1
Muzaffarnagar Medical College and Hospital	Uttar Pradesh	0	0	0	1	0	0	0	1
NDMC & Hindu Rao Hospital	Delhi	0	0	0	1	0	0	0	1
NGO Gamana	Telangana	0	0	1	0	0	0	0	1
NHL Municipal Medical College	Gujarat	0	0	0	1	0	0	0	1
NIIT University	Rajasthan	0	0	0	3	0	0	0	3
NIMS Medical College & Hospital	Rajasthan	0	0	0	4	0	0	0	4

Institution	State	Animals	Diagnostics	Environment	Humans	Miscellaneous	Novel agents	One health	Total
NMIMS university	Maharashtra	0	0	0	0	0	1	0	1
NRI college of pharmacy	Andhra Pradesh	0	0	0	0	0	1	0	1
NRS Medical College	West Bengal	0	0	0	1	0	0	0	1
Nagpur University	Maharashtra	0	0	0	1	0	0	0	1
Nagpur Veterinary College	Maharashtra	1	0	0	0	0	0	0	1
Nanaji Deshmukh Veterinary Science University	Madhya Pradesh	1	0	0	0	0	0	0	1
Nandha College of Pharmacy and Research	Tamil Nadu	0	0	0	0	0	1	0	1
National AIDS Research Institute	Maharashtra	0	0	0	2	0	0	0	2
National Bureau of Fish Genetic Resource	Uttar Pradesh	1	0	0	0	1	0	0	2
National Centre for Cell Science	Maharashtra	1	0	2	1	1	1	1	7
National Centre for Compositional Characterisation of Materials	Telangana	0	0	0	0	0	1	0	1
National Centre for Veterinary Type Cultures	Haryana	0	0	0	0	1	0	0	1
National Chemical Laboratory	Maharashtra	0	0	0	0	0	3	0	3
National Dairy Research Institute	Haryana	0	1	0	0	5	2	0	8
National Environmental Engineering Research	Telangana	0	0	0	0	1	0	0	1
National Institute for Interdisciplinary	Kerala	0	0	0	1	0	1	0	2
National Institute for Research in Reproductive Health	Maharashtra	0	0	0	0	0	1	0	1
National Institute of Cholera and Enteric Diseases	West Bengal	0	1	1	22	1	2	0	27
National Institute of Epidemiology (ICMR)	Tamil Nadu	0	0	0	1	0	0	0	1

Institution	State	Animals	Diagnostics	Environment	Humans	Miscellaneous	Novel agents	One health	Total
National Institute of Immunohaemotology	Maharashtra	0	0	0	0	1	0	0	1
National Institute of Mental Health & Neurosciences	Karnataka	0	0	0	1	0	0	0	1
National Institute of Ocean Technology	Andaman & Nicobar Islands	0	0	0	1	0	0	0	1
National Institute of Pharmaceutical Education	Assam	0	0	0	1	0	0	0	1
National Institute of Pharmaceutical Education	Punjab	0	0	0	1	0	1	0	2
National Institute of Plant Genome Research	Delhi	0	0	0	0	1	0	0	1
National Institute of Science Education	Odisha	0	0	2	2	0	2	0	6
National Institute of Technology Gujarat	Gujarat	0	0	0	0	0	1	0	1
National Institute of Technology	Karnataka	0	0	0	0	1	0	0	1
National Institute of Technology	Odisha	0	0	0	0	1	1	0	2
National Institute of Unani Medicine	Karnataka	0	0	0	0	0	1	0	1
National JALMA Institute for Leprosy	Uttar Pradesh	0	0	0	1	0	0	0	1
National Research Centre on Yak	Arunachal Pradesh	1	0	0	0	0	0	0	1
National Salmonella Centre (Vet)	Uttar Pradesh	0	0	0	0	0	0	1	1
Natubhai V. Patel College of Pure and Applied Sciences	Gujarat	0	0	0	0	0	1	0	1
Navodaya Medical College	Karnataka	0	0	0	2	0	0	0	2
Netaji Subhas Institute of Technology	Delhi	0	0	0	0	2	0	0	2
Nilratan Sircar Medical College & Hospital	West Bengal	0	0	0	1	0	0	0	1
Nirma University	Gujarat	0	0	0	0	0	1	0	1

Institution	State	Animals	Diagnostics	Environment	Humans	Miscellaneous	Novel agents	One health	Total
Nitte University	Karnataka	0	0	0	2	0	0	0	2
Nizam Institute of Medical Sciences	Telangana	0	1	0	1	0	0	0	2
North Eastern Indira Gandhi Regional Institute	Meghalaya	0	0	0	3	0	0	0	3
North Maharashtra University	Maharashtra	0	0	0	1	1	1	0	3
North Orissa University	Odisha	0	0	0	0	0	4	0	4
North-Eastern Hill University	Meghalaya	0	0	0	0	1	0	1	2
Orchid Chemicals and Pharmaceuticals Ltd	Tamil Nadu	0	0	0	1	0	0	0	1
P. M. N. M. Dental College and Hospital	Karnataka	0	0	0	0	1	0	0	1
P.D. Hinduja Hospital & Medical Research	Maharashtra	0	1	0	4	0	0	0	5
P.D.U. Govt. Medical College	Gujarat	0	0	0	1	0	0	0	1
PDM College of Pharmacy	Haryana	0	0	0	0	0	1	0	1
PGIMER	Chandigarh	0	0	1	21	3	0	0	25
PGIMSR	Karnataka	0	0	0	1	0	0	0	1
PRIST University	Tamil Nadu	0	0	0	0	0	1	0	1
PSG College of Arts and Science	Tamil Nadu	0	0	0	0	1	0	0	1
PSG Institute of Medical Sciences & Research	Tamil Nadu	0	0	0	2	0	0	0	2
Pachaiyappa's College	Tamil Nadu	0	0	0	1	0	0	0	1
Padmashree Institute of Management and Sciences	Karnataka	0	0	0	0	0	1	0	1
Pandit Bhagwat Dayal Sharma Post Graduation	Delhi	0	0	0	0	1	0	0	1
Panineeya Dental College	Telangana	0	0	0	1	0	0	0	1
Panjab University	Chandigarh	0	0	0	6	11	13	0	30
Patel College of Paramedical Science and	Gujarat	0	0	0	1	0	0	0	1
Patna Womens College	Bihar	1	0	0	0	0	0	0	1

Institution	State	Animals	Diagnostics	Environment	Humans	Miscellaneous	Novel agents	One health	Total
Periyar Maniammai University	Tamil Nadu	0	0	0	0	0	1	0	1
Periyar University	Tamil Nadu	0	0	1	1	0	0	0	2
Piramal Enterprises Ltd	Maharashtra	0	0	0	0	1	1	0	2
Pondicherry Institute of Medical Science	Puducherry	0	0	0	3	0	0	0	3
Pondicherry University	Puducherry	0	0	0	3	1	2	0	6
Post Graduate Institute of Veterinary Education	Rajasthan	1	0	0	0	0	0	0	1
Pramukh Swami Medical College and Hospit	Gujarat	0	0	0	2	0	0	0	2
Pramukh Swami Science and H. D. Patel Arts College	Gujarat	0	0	1	0	0	0	0	1
Prathima Institute of Medical Sciences	Telangana	0	0	0	1	1	0	0	2
Presidency College	Tamil Nadu	0	0	0	1	0	0	0	1
Presidency University	West Bengal	0	0	0	1	1	0	0	2
Priti Medical Research and Charitable Trust	Uttar Pradesh	0	0	0	1	0	0	0	1
Pt. B D Sharma PGIMS	Haryana	0	0	0	6	0	0	0	6
Public Health Foundation of India	Delhi	0	0	0	1	0	0	0	1
Pune University	Maharashtra	0	0	1	0	0	1	0	2
Pushpagiri Institute of Medical Sciences	Kerala	0	0	0	2	0	0	0	2
Quaid-e-Millath Government Arts College	Tamil Nadu	0	0	0	1	0	0	0	1
R. G. Kar Medical College	West Bengal	0	0	0	4	0	0	0	4
RD Gardi Medical College	Madhya Pradesh	0	0	4	14	0	0	1	19
RIMS	Karnataka	0	0	0	2	0	0	0	2
RML Hospital	Delhi	0	0	0	4	0	0	0	4
RTM Nagpur University	Maharashtra	0	0	0	2	0	0	0	2
RVS College of Arts and Science	Tamil Nadu	1	0	0	0	0	0	0	1

Institution	State	Animals	Diagnostics	Environment	Humans	Miscellaneous	Novel agents	One health	Total
Raghavendra Institute of Pharmaceutical	Andhra Pradesh	0	0	0	2	0	0	0	2
Rainbow Childrens Hospital	Telangana	0	0	0	2	0	0	0	2
Rajah muthiah medical college and hospital	Tamil Nadu	0	0	0	1	0	0	0	1
Rajasthan University of Veterinary and Animal Sciences	Rajasthan	1	0	0	0	0	0	0	1
Rajendra Memorial Research Institute of Medical Sciences	Bihar	0	0	0	0	1	0	0	1
Rajiv Gandhi Centre for Biotechnology	Kerala	0	0	0	1	0	0	0	1
Rajiv Gandhi Institute of Medical Sciences	Telangana	0	0	0	1	0	0	0	1
Rajiv Gandhi Cancer Institute and Rese	Delhi	0	0	0	1	0	0	0	1
Rama Medical College	Uttar Pradesh	0	0	0	4	0	0	0	4
Ramananda College	West Bengal	0	0	0	0	1	0	0	1
Ranbaxy Research Laboratories	Haryana	0	0	0	0	0	3	0	3
Rohilkhand Medical College	Uttar Pradesh	0	0	0	1	0	0	0	1
Ruhs College of Medical Sciences	Rajasthan	0	0	0	1	0	0	0	1
Rungta College of science and Technology	Chattisgarh	0	0	0	1	0	0	0	1
Rural Development Trust Hospital	Andhra Pradesh	0	0	0	3	0	0	0	3
S L Raheja Hospital	Maharashtra	0	0	0	0	0	1	0	1
S. N. M. C. Bagalkot	Karnataka	0	0	0	1	0	0	0	1
S. S. Institute of Medical Sciences & Re	Karnataka	0	0	0	1	0	1	0	2
S.C.B Medical College	Odisha	0	0	0	1	0	0	0	1

Institution	State	Animals	Diagnostics	Environment	Humans	Miscellaneous	Novel agents	One health	Total
SASTRA University	Tamil Nadu	0	0	0	0	3	3	0	6
SDM College of Medical Sciences and Hospital	Karnataka	0	0	0	1	0	0	0	1
SGB Amravati University	Maharashtra	0	0	0	0	0	3	0	3
SGT University	Haryana	0	0	0	0	0	1	0	1
SHIATS	Uttar Pradesh	0	0	0	0	1	2	0	3
SRL Ltd, S. V. Road	Maharashtra	0	0	0	1	0	0	0	1
SRM University	Tamil Nadu	0	1	0	0	0	1	0	2
SRNMN College of Applied Sciences	Karnataka	0	0	0	0	0	1	0	1
SSN College of Engineering	Tamil Nadu	0	0	0	0	0	1	0	1
SVMCH &RC	Puducherry	0	0	0	2	0	0	0	2
SVS Medical College	Telangana	0	0	0	1	0	0	0	1
Saifee Hospital	Maharashtra	0	0	0	1	0	0	0	1
Sanjay Gandhi Post Graduate Institute of Medical Sciences	Uttar Pradesh	0	0	0	8	0	2	0	10
Sant Gadge Baba Amravati University	Maharashtra	0	1	0	0	0	1	0	2
Santosh University	Uttar Pradesh	0	0	0	1	0	0	0	1
Sapthagiri Institute of Medical Science	Karnataka	0	0	0	1	0	0	0	1
Saurashtra University	Gujarat	0	0	0	0	1	0	0	1
Saveetha Medical College & Hospital	Tamil Nadu	0	0	0	1	0	0	0	1
Savitribai Phule Pune University	Maharashtra	0	0	0	0	0	1	0	1
Sawai Man Singh Medical College	Rajasthan	0	0	0	3	1	0	0	4
School of Biosciences and Technology	Tamil Nadu	0	0	0	1	0	0	0	1
School of Tropical Medicine	West Bengal	0	0	0	4	0	0	0	4
Seth GS Medical College & KEM Hospital	Maharashtra	0	0	0	4	0	0	0	4

Institution	State	Animals	Diagnostics	Environment	Humans	Miscellaneous	Novel agents	One health	Total
Sher-e-Kashmir University	Jammu and Kashmir	2	0	2	2	0	0	0	6
Sher-i-Kashmir Institute of Medical Scie	Jammu and Kashmir	0	0	0	4	0	0	0	4
Sheth M.N.Science College	Gujarat	0	0	0	0	0	1	0	1
Shivaji University	Maharashtra	0	0	0	1	0	0	0	1
Shoolini University	Himachal Pradesh	0	0	0	1	0	0	0	1
Shri B. M. Patil Medical College	Karnataka	0	0	0	1	0	0	0	1
Shri Ram Murti Smarak Institute of Medical Sciences	Uttar Pradesh	0	0	0	1	0	0	0	1
Shri Shivaji Science College Department	Maharashtra	0	0	0	1	0	0	0	1
Shri Vasantrao Naik Government Medical College	Maharashtra	0	0	0	1	0	0	0	1
Siksha 'O' Anusandhan University	Odisha	0	0	0	1	0	1	0	2
Sindhu Mahavidyalaya Center for Biotechnology	Maharashtra	0	0	0	1	0	0	0	1
Sir Ganga Ram Hospital	Delhi	0	0	0	6	0	0	0	6
Smt Kashibai Navale Medical College and Hospital	Maharashtra	0	0	0	3	0	0	0	3
Sourashtra College	Maharashtra	0	0	0	1	0	0	0	1
Sree Chitra Tirunal Institute for Medical Sciences and Technology	Kerala	0	0	0	1	0	0	0	1
Sree Vidhyanikethan College of Pharmacy	Andhra Pradesh	0	0	0	0	0	1	0	1
Sri Aurobindo Institute of Medical Sciences	Madhya Pradesh	0	0	0	6	0	0	0	6
Sri Devaraj Urs Medical College	Karnataka	0	0	0	2	0	0	0	2
Sri Guru Ram Das Institute of Medical Sciences	Punjab	0	0	0	3	0	0	0	3

Institution	State	Animals	Diagnostics	Environment	Humans	Miscellaneous	Novel agents	One health	Total
Sri Krishnadevaraya University	Andhra Pradesh	0	0	0	0	0	1	0	1
Sri Narayani Hospital and Research Center	Tamil Nadu	0	0	0	1	0	0	0	1
Sri Ramachandra Medical College and Research Centre	Tamil Nadu	0	0	1	12	0	4	0	17
Sri Sathya Sai Institute of Higher Learning center	Andhra Pradesh	0	0	0	0	1	0	0	1
Sri Siddhartha Medical College	Karnataka	0	0	0	4	0	0	0	4
Sri Venkateswara Institute of Medical Sciences	Andhra Pradesh	0	0	0	5	0	0	0	5
Srimad Andavan Arts and Science College	Tamil Nadu	0	0	0	1	0	0	0	1
Sriram Chandra Bhanj Medical College	Odisha	0	0	0	1	0	0	0	1
St John's Medical College and Hospital	Karnataka	0	0	1	6	0	0	0	7
St. Gregorios Dental College	Kerala	0	0	0	0	0	1	0	1
St. Xavier's College Goa	Goa	0	0	0	0	0	1	0	1
St. Xavier's College Tamil Nadu	Tamil Nadu	0	0	0	0	0	1	0	1
Subbaiah Institute of Medical Sciences and Research Center	Karnataka	0	0	0	1	0	0	0	1
Subharti Medical College	Uttar Pradesh	0	1	0	2	0	0	0	3
Swami Ramanand Teerth Marathwada University	Maharashtra	0	0	0	0	1	0	0	1
Swami Vivekanand Subharti University	Uttar Pradesh	0	1	0	0	0	0	0	1
TATA Main Hospital	Jharkhand	0	0	0	2	0	0	0	2
Tamil Nadu Veterinary and Animal Sciences	Tamil Nadu	0	1	0	0	0	0	0	1
Tata Consultancy Services Ltd.	Maharashtra	0	0	0	1	0	0	0	1

Institution	State	Animals	Diagnostics	Environment	Humans	Miscellaneous	Novel agents	One health	Total
Tata Institute of Fundamental Research	Karnataka	0	0	0	0	2	0	0	2
Tata Medical Center	Maharashtra	0	1	0	5	0	0	0	6
Tata Memorial Hospital	Maharashtra	0	0	0	4	0	0	0	4
Teerthanker Mahaveer Medical College	Uttar Pradesh	0	0	0	1	0	0	0	1
Tejasvini Hospital and SSIOT	Karnataka	0	0	0	1	0	0	0	1
Tezpur University	Assam	0	0	0	0	1	1	0	2
Thapar University	Punjab	0	0	0	0	0	1	0	1
The Maharaja Sayajirao University of Baroda	Gujarat	0	0	0	0	1	0	0	1
The Tamil Nadu Dr MGR Medical University	Tamil Nadu	0	0	0	1	0	0	0	1
The West Bengal University of Health Sciences	West Bengal	0	0	0	1	0	0	0	1
Thiagarajar College	Tamil Nadu	0	0	0	0	0	1	0	1
Tripura University	Tripura	0	0	0	0	1	2	0	3
UNESCO MIRCEN for Marine Biotechnology	Karnataka	1	0	0	0	0	0	0	1
University College of Medical Sciences	Delhi	0	0	0	6	0	0	0	6
University of Allahabad	Uttar Pradesh	0	0	0	0	1	0	0	1
University of Calcutta	West Bengal	0	0	0	0	2	4	0	6
University of Delhi	Delhi	0	0	2	1	7	4	0	14
University of Hyderabad	Telangana	1	0	0	3	2	1	0	7
University of Kalyani	West Bengal	0	0	0	0	0	3	0	3
University of Lucknow	Uttar Pradesh	0	0	0	0	0	1	0	1
University of Madras	Tamil Nadu	0	0	0	12	3	2	0	17
University of Mysore	Karnataka	0	0	0	3	2	3	0	8
University of North Bengal	West Bengal	1	0	1	0	0	0	0	2
University of Pune	Maharashtra	0	0	0	1	0	3	1	5

Institution	State	Animals	Diagnostics	Environment	Humans	Miscellaneous	Novel agents	One health	Total
Unknown	Madhya Pradesh	0	0	0	6	1	3	0	10
VHNSN College	Tamil Nadu	0	0	0	0	0	1	0	1
VIT University	Tamil Nadu	0	0	0	1	15	7	0	23
Vallabhbhai Patel Chest Institute	Delhi	0	0	1	12	0	0	0	13
Vananchal Dental College and Hospital	Jharkhand	0	0	0	1	0	0	0	1
Vardhman Mahavir Medical College & Safdarjung Hospital	Delhi	0	0	0	17	0	0	0	17
Veer Bahadur Singh Purvanchal University	Uttar Pradesh	0	0	1	0	0	0	0	1
Veer Chandra Singh Garhwali Government Inst. Of Medical Sciences	Uttarakhand	0	0	0	4	0	0	0	4
Veer Narmad South Gujarat University	Gujarat	0	0	2	0	0	0	0	2
Veer Surendra Sai University of Technology	Odisha	0	0	0	0	1	0	0	1
Velammal Medical College Hospital	Tamil Nadu	0	0	0	0	1	0	0	1
Vels University	Tamil Nadu	0	0	0	1	0	0	0	1
Venus Medicine Research Centre	Himachal Pradesh	0	0	0	3	0	0	0	3
Venus Remedies	Haryana	0	0	0	0	0	1	0	1
Veterinary College and Research Institut	Tamil Nadu	1	0	0	0	0	0	0	1
Vidyasagar University	West Bengal	0	0	0	4	2	4	0	10
Vijaya Institute of Pharmaceutical Sciences	Andhra Pradesh	0	0	0	0	0	1	0	1
Vinayaka Missions University	Tamil Nadu	0	0	1	0	0	0	0	1
Vision Research Foundation	Tamil Nadu	0	0	0	2	0	0	0	2

Institution	State	Animals	Diagnostics	Environment	Humans	Miscellaneous	Novel agents	One health	Total
Visva-Bharati University	West Bengal	0	0	0	0	0	1	0	1
Visvesvaraya Technological University	Karnataka	0	0	0	0	1	1	0	2
Vivekananda College	Tamil Nadu	0	0	0	0	0	1	0	1
Vyas Dental College and Hospital	Rajasthan	0	0	0	1	0	0	0	1
Vydehi Institute of Medical Sciences	Karnataka	0	0	0	2	0	0	0	2
West Bengal University of Animal and Fishery Sciences	West Bengal	4	0	0	0	0	0	1	5
World Health Organization	Delhi	0	0	0	1	0	0	0	1
Yashoda Hospital	Telangana	0	0	0	1	0	0	0	1
Yashvantrao Chavan Institute of Science	Maharashtra	0	0	0	0	0	1	0	1
Yenepoya Medical College	Karnataka	0	0	0	2	0	0	0	2
Yenepoya University	Karnataka	0	0	0	0	2	1	0	3

Table A.4:

Institutions with at least one publication on AMR in humans

Institution	State	Clinical	Surveillance	Social	Total
A.J. Institute of Medical Sciences and	Karnataka	1	0	0	1
A.V. Medical College	Puducherry	0	1	0	1
AECS Maaruti College of Dental Sciences	Karnataka	0	0	1	1
AFMC	Maharashtra	0	7	0	7
AIIMS Chattisgarh	Chattisgarh	0	1	0	1
AIIMS Delhi	Delhi	7	33	0	40
AIIMS Karnataka	Karnataka	0	2	0	2
AIIMS Odisha	Odisha	0	3	0	3
Acharya & B.M Reddy College of Pharmacy	Karnataka	0	1	0	1
Agartala Government Medical College	Tripura	0	1	0	1
Agharkar Research Institute	Maharashtra	0	1	0	1
Alagappa University	Tamil Nadu	0	4	0	4
Aligarh Muslim University	Uttar Pradesh	4	10	0	14
Amity University	Uttar Pradesh	0	1	0	1
Amrita Institute of Medical Sciences	Kerala	1	5	0	6
Anand Diagnostics Laboratory	Karnataka	0	1	0	1
Animal and Fisheries Sciences University	Karnataka	0	1	0	1
Annamalai University	Tamil Nadu	0	1	2	3
Apollo Cancer Institute	Tamil Nadu	0	1	0	1
Apollo Hospitals	Maharashtra	8	8	0	9
Apollo Institute of Medical Sciences and	Telangana	1	2	0	3
Aravind Eye Care Coimbatore	Tamil Nadu	0	1	0	1
Aravind Eye Care Madurai	Tamil Nadu	0	2	0	2
Aravind Eye Hospital and Postgraduate In	Tamil Nadu	0	2	0	2
Army College of Dental Sciences	Telangana	0	1	0	1
Army Hospital (R&R)	Delhi	0	1	0	1
Artemis Health Institute	Haryana	1	1	0	2
Ashok Laboratory Clinical Testing Centre	West Bengal	0	1	0	1
Asian Institute of Public Health	Odisha	0	1	0	1
Assam Medical College	Assam	0	2	0	2
Assam University	Assam	0	16	0	16
Azeezia Medical College	Kerala	1	1	0	2

Institution	State	Clinical	Surveillance	Social	Total
B.J. Medical College	Gujarat	0	1	1	2
B.J. Wadia Hospital for Childrens	Maharashtra	0	1	0	1
B.J.B. Autonomous College	Odisha	0	1	0	1
B.Y.L. Nair Charitable Hospital	Maharashtra	0	1	0	1
BLDEU's Shri B M Patil Medical College	Karnataka	0	2	0	2
BLK Superspeciality Hospital	Delhi	1	1	0	2
BPS GMC (Women)	Haryana	0	1	0	1
Baba Saheb Ambedkar Hospital	Delhi	0	1	0	1
Banaras Hindu University	Uttar Pradesh	3	18	0	21
Bangalore Baptist Hospital	Karnataka	0	1	0	1
Bangalore Medical College	Karnataka	0	1	0	1
Base Hospital	Delhi	0	1	0	1
Belagavi Institute of Medical Sciences	Delhi	0	1	0	1
Belgaum Institute of Medical Sciences	Karnataka	0	1	0	1
Berhampur University	Odisha	0	3	0	3
Bharat Institute of Technology	Telangana	0	0	1	1
Bharath University	Tamil Nadu	0	1	0	1
Bharathi College of Pharmacy	Karnataka	0	0	1	1
Bharathiar University	Tamil Nadu	0	3	0	3
Bharati Vidyapeeth Deemed University	Maharashtra	0	1	1	2
Birla Institute of Technology & Science	Telangana	0	1	0	1
Browns College of Pharmacy	Telangana	0	1	0	1
Burdwan Medical College	West Bengal	0	2	0	2
Byramjee Jeejeebhoy Government Medical College	Maharashtra	0	2	0	2
CHILDS Trust Medical Research Foundation	Tamil Nadu	0	1	0	1
CSIR-Institute of Microbial Technology	Chandigarh	0	3	0	3
CU Shah Medical College	Gujarat	0	1	0	1
Calcutta School of Tropical Medicine	West Bengal	0	4	0	4
Cancer Institute	Tamil Nadu	0	1	0	1

Institution	State	Clinical	Surveillance	Social	Total
Center for Disease Dynamics, Economics & Policy	Delhi	0	4	1	5
Central Agricultural University	Mizoram	0	2	0	2
Central Leprosy-Teaching and Research	Tamil Nadu	0	1	0	1
Central Research Institute	Himachal Pradesh	0	4	0	4
Central University of Rajastan Ajmer	Rajasthan	1	0	0	1
Chacha Nehru Bal Chikitsalaya	Delhi	0	2	0	2
Chettinad Hospital and Research Institute	Tamil Nadu	0	3	0	3
Chhatrapati Shahuji Maharaj Medical Univ	Uttar Pradesh	0	1	0	1
Chirayu Medical College and Hospital	Madhya Pradesh	0	1	0	1
Choithram Hospital & Research Centre	Madhya Pradesh	0	1	0	1
Christian Dental College	Punjab	1	0	0	1
Christian Medical College, Punjab	Punjab	0	4	0	4
Christian Medical College, Tamil Nadu	Tamil Nadu	14	28	4	46
Civil Hospital	Rajasthan	1	0	0	1
College of Pharmacy, SRIPMS	Tamil Nadu	1	0	0	1
Command Hospital	Maharashtra	0	3	0	3
DHAFMS	Delhi	0	1	0	1
DUVASU, Mathura	Uttar Pradesh	0	1	0	1
Damodaran College of Science	Tamil Nadu	0	1	0	1
Dayanand Medical College and Hospital	Punjab	0	1	0	1
Deccan College of Medical Sciences	Telangana	0	1	0	1
Defence Research & Development Establishment	Madhya Pradesh	0	3	0	3
Delhi State Cancer Institute	Delhi	0	6	0	6
Dhanalakshmi Srinivasan Medical College	Tamil Nadu	0	1	0	1
Dr MGR Educational and Research Institute	Tamil Nadu	0	1	0	1
Dr Shankarrao Chavan Government Medical College	Maharashtra	0	0	1	1

Institution	State	Clinical	Surveillance	Social	Total
Dr. B C Roy Post Graduate Institute	West Bengal	0	1	0	1
Dr. B.R Ambedkar Medical College	Karnataka	0	2	0	2
Dr. Baba Saheb Ambedkar Hospital	Delhi	0	1	0	1
Dr. D.Y Patil Medical College	Maharashtra	0	2	0	2
Dr. Harvansh Singh Judge Institute of Dental Sciences	Chandigarh	0	1	0	1
Dr. N.G.P Arts and Science College	Tamil Nadu	0	1	0	1
Dr. Pinnamaneni Siddhartha Institute of Medical Sciences	Andhra Pradesh	0	1	0	1
Dr. RPGMC	Himachal Pradesh	0	1	0	1
Dr. Somervell Memorial CSI Medical College	Kerala	0	1	1	2
Dr. V. P. Medical College, Hospital & RC	Maharashtra	0	1	0	1
Dr. Yewale's Multispeciality Hospital for Children	Maharashtra	0	0	1	1
ESI-PGIMSR, ESIC Medical College and ESI	West Bengal	0	1	0	1
ESIC MC & PGIMSR	Karnataka	0	2	0	2
ESIC Medical College and ESIC Hospital	West Bengal	0	1	0	1
Era's Lucknow Medical College and Hospital	Uttar Pradesh	0	2	0	2
Father Muller Medical College	Karnataka	0	3	0	3
Fernandez Hospital	Telangana	1	0	0	1
Fortis Escorts Hospital	Rajasthan	1	4	0	5
G. B. Pant Institute of Postgraduate Medicine	Delhi	2	2	0	4
GADVASU	Punjab	0	1	0	1
GHR Micro Diagnostics	Telangana	0	1	0	1
GMERS Medical College	Gujarat	0	1	0	1
GSK Pharmaceuticals Ltd	Karnataka	0	1	0	1
GSL Medical College & General Hospital	Andhra Pradesh	0	1	0	1
Gandhi Medical College and Hospital	Telangana	0	1	1	2
Gangasaras Diagnostic and Research Centre	Tamil Nadu	0	1	0	1
Gauhati Medical College	Assam	1	1	0	2

Institution	State	Clinical	Surveillance	Social	Total
Gauhati University	Assam	1	5	0	6
Glenmark Pharmaceuticals Ltd	Maharashtra	0	1	0	1
Goa Dental College and Hospital	Goa	1	0	0	1
Gold Field Institute of Medical Sciences	Haryana	0	1	0	1
Golden Jubilee Biotech Park for Women	Tamil Nadu	0	1	0	1
Government Degree College Baramulla	Jammu and Kashmir	0	1	0	1
Government Dental College and Research Institute	Karnataka	1	0	0	1
Government Medical College Gujarat	Gujarat	1	6	0	7
Government Medical College Haldwani	Uttarakhand	0	1	0	1
Government Medical College Hospital Chan	Chandigarh	4	14	0	18
Government Medical College Hospital	Tamil Nadu	0	1	0	1
Government Medical College	Jammu and Kashmir	0	2	0	2
Government Medical College Kerala	Kerala	3	1	0	4
Government Medical College Punjab	Punjab	0	2	0	2
Government Medical College Uttarakhand	Uttarakhand	0	4	0	4
Government Medical College, Latur	Maharashtra	0	1	0	1
Government Medical College, Nagpur	Maharashtra	0	1	0	1
Government Postgraduate College	Uttarakhand	1	0	0	1
Government Cancer Hospital	Maharashtra	0	1	0	1
Govt. Kilpauk Medical College	Tamil Nadu	0	2	0	2
Grant Government Medical College	Maharashtra	0	1	0	1
Greater Kailash Hospital	Madhya Pradesh	0	1	0	1
Gulbarga University	Karnataka	0	2	0	2
Guru Gobind Singh Medical College	Punjab	0	1	0	1
Himachal Pradesh University	Himachal Pradesh	0	1	0	1
Himalayan Institute of Medical Sciences	Uttarakhand	1	3	0	4
Hindu Rao Hospital	Delhi	0	1	0	1

Institution	State	Clinical	Surveillance	Social	Total
Holy Spirit Hospital	Maharashtra	0	1	0	1
ICARE Eye Hospital and Postgraduate Inst.	Uttar Pradesh	1	0	0	1
IIT Kharagpur	West Bengal	0	1	0	1
IIT Madras	Tamil Nadu	0	1	0	1
IMS & Sum Hospital Medical College, S 'O	Odisha	0	7	0	7
IPGME&R and SSKM Hospital	West Bengal	0	3	0	3
IPGMER & SSKM Hospital	West Bengal	1	0	0	1
ITS Dental College	Uttar Pradesh	1	0	0	1
Indian Academy Degree College	Karnataka	0	1	0	1
Indian Council of Medical Research	Delhi	0	2	0	2
Indian Council of Medical Research	Andaman & Nicobar Islands	0	7	0	7
Indian Council of Medical Research	Assam	0	1	0	1
Indian Council of Medical Research	Karnataka	0	5	0	5
Indian Council of Medical Research	Odisha	0	2	0	2
Indian Institute of Advanced Research	Gujarat	0	4	0	4
Indian Network for Surveillance of AMR	Multicenter	0	1	0	1
Indira Gandhi Government Medical College	Maharashtra	0	2	0	2
Indira Gandhi Medical College	Himachal Pradesh	2	3	0	5
Indira Gandhi Medical College & Research	Puducherry	0	1	0	1
Institute for Research in Vision and Ophtholmology	Tamil Nadu	0	1	0	1
Institute of Child Health	West Bengal	0	1	0	1
Institute of Life Sciences	Odisha	0	2	0	2
Institute of Liver & Biliary Sciences	Delhi	1	0	0	1
Institute of Nuclear Medicine and Allied Sciences	Delhi	0	1	0	1
Integral University	Uttar Pradesh	0	3	0	3
J N Medical College	Uttar Pradesh	0	3	0	3
JIPMER	Puducherry	2	18	1	21
JJM Medical College	Karnataka	1	3	0	4
Jain Irrigation Systems Ltd	Maharashtra	0	1	0	1

Institution	State	Clinical	Surveillance	Social	Total
Jain University	Karnataka	0	3	0	3
Jamia Hamdard	Delhi	0	1	0	1
Janakpuri Super Speciality Hospital	Delhi	0	1	0	1
Jawaharlal Nehru University, Delhi	Delhi	0	2	0	2
Jawaharlal Nehru University, Maharashtra	Karnataka	0	2	0	2
Jawaharlal Nehru University	Uttar Pradesh	0	2	0	2
Jhalawar Medical College	Rajasthan	0	2	0	2
Joseph Eye Hospital	Tamil Nadu	0	1	0	1
K.S.R. College of Arts and Science	Tamil Nadu	0	1	0	1
KG Medical University	Uttar Pradesh	0	1	0	1
KLE's JN Medical College, Belgaum	Karnataka	0	1	0	1
KVG Dental College and Hospital	Karnataka	1	0	0	1
Kalinga Institute of Medical Sciences	Odisha	0	2	0	2
Kamalnayan Bajaj Research Centre, Vision	Tamil Nadu	0	1	0	1
Kannur Dental College	Kerala	0	0	1	1
Karnataka Institute of Medical Sciences	Karnataka	0	1	0	1
Karpagam Faculty of Medical Sciences	Tamil Nadu	1	1	0	2
Karunya University	Tamil Nadu	0	1	0	1
Kashibai Navale Medical College	Maharashtra	0	1	0	1
Kasturba Medical College	Karnataka	1	4	0	5
Katihar Medical College	Bihar	0	1	0	1
Kempegowda Institute of Medical Sciences	Karnataka	0	3	0	3
Kerala Institute of Medical Sciences	Kerala	1	0	0	1
Khadir Mohideen College	Tamil Nadu	0	1	0	1
Khaja Banda Nawaz institute of Medical Sciences	Karnataka	0	1	0	1
Kidwai Memorial Institute of Oncology,	Karnataka	0	1	0	1
King George Medical University	Uttar Pradesh	0	3	0	3
Kokilaben Dhirubhai Ambani Hospital	Maharashtra	0	2	0	2

Institution	State	Clinical	Surveillance	Social	Total
Konaseema Institute of Medical Science	Andhra Pradesh	0	1	0	1
Kovai Medical Center and Hospital	Tamil Nadu	0	1	0	1
Krishna Institute of Medical Sciences	Maharashtra	0	1	0	1
L & T Microbiology Research Centre	Tamil Nadu	0	1	0	1
L. V. Prasad Eye Institute AP	Andhra Pradesh	1	4	0	5
L. V. Prasad Eye Institute Odisha	Odisha	3	2	0	5
L. V. Prasad Eye Institute Telangana	Telangana	0	5	0	5
L.T.M. Medical College	Maharashtra	1	3	0	4
LN Medical College & RC	Madhya Pradesh	1	1	0	2
Lady Hardinge Medical College	Delhi	1	1	0	2
Lohia Hospital	Delhi	0	1	0	1
Lovely Professional University	Punjab	0	2	0	2
M.M. Institute of Medical Sciences and R	Haryana	0	1	0	1
MES Medical College	Kerala	1	2	1	4
MGM Eye Institute	Chattisgarh	1	0	0	1
MGM Medical College and Hospital	Maharashtra	0	1	1	2
MIMER Medical College	Maharashtra	0	1	0	1
MS Ramaiah Medical College	Karnataka	0	2	0	2
Madha Medical College	Tamil Nadu	0	1	0	1
Madras Medical College	Tamil Nadu	1	0	0	1
Madras Medical Mission	Tamil Nadu	0	1	0	1
Madurai Kamaraj University	Tamil Nadu	0	2	0	2
Maharajah's Institute of Medical Sciences	Andhra Pradesh	0	1	0	1
Maharashtra Institute of Medical Education	Maharashtra	0	1	0	1
Maharishi Markandeshwar College of Denta	Haryana	0	1	0	1
Mahatma Gandhi Institute of Medical Sciences	Gujarat	0	1	0	1
Mahatma Gandhi Institute of Medical Sciences	Maharashtra	0	2	0	2
Mahatma Gandhi Medical College	Rajasthan	0	1	1	2

Institution	State	Clinical	Surveillance	Social	Total
Mahatma Gandhi Medical College and Research Center	Puducherry	8	8	1	11
Mahatma Gandhi University	Kerala	0	2	0	2
Majeedia Hospital	Delhi	0	1	0	1
Malabar Medical College and Research Centre	Kerala	0	1	0	1
Malda Medical College and Hospital	West Bengal	0	1	0	1
Manipal University	Karnataka	4	23	2	29
Maulana Azad Medical College	Delhi	0	13	0	13
Maulana Azad Medical College	Uttar Pradesh	0	1	0	1
Max Super Speciality Hospital	Delhi	0	3	0	3
Mayo Institute of Medical Sciences	Uttar Pradesh	0	3	0	3
Medanta Hospital	Haryana	1	1	2	4
Medical College	West Bengal	0	1	0	1
Medical Sciences and Research Institute	Uttarakhand	0	1	0	1
Meenakshi Ammal Dental College	Tamil Nadu	0	1	0	1
Meerut College Gujarat	Gujarat	0	1	0	1
Meerut College Uttar Pradesh	Uttar Pradesh	0	1	0	1
Metropolis Healthcare Ltd	Maharashtra	0	1	0	1
Military Hospital Meerut	Uttar Pradesh	0	3	0	3
Modern Dental College and Research Centre	Madhya Pradesh	1	1	0	2
Montessori Mahila Kalasala	Andhra Pradesh	0	1	0	1
Motilal Nehru Medical College	Uttar Pradesh	0	3	0	3
Muljibhai Patel Urological Hospital and	Gujarat	0	1	0	1
Multicenter study	Multicenter	0	1	0	1
Murshidabad Medical College	West Bengal	0	1	0	1
Muzaffarnagar Medical College and Hospital	Uttar Pradesh	0	1	0	1
NDMC & Hindu Rao Hospital	Delhi	0	1	0	1
NHL Municipal Medical College	Gujarat	0	1	0	1
NIIT University	Rajasthan	0	3	0	3
NIMS Medical College & Hospital	Rajasthan	0	4	0	4

Institution	State	Clinical	Surveillance	Social	Total
NRS Medical College	West Bengal	0	1	0	1
Nagpur University	Maharashtra	0	1	0	1
National AIDS Research Institute	Maharashtra	0	2	0	2
National Centre for Cell Science	Maharashtra	0	1	0	1
National Institute for Interdisciplinary	Kerala	1	0	0	1
National Institute of Cholera and Enteri	West Bengal	3	18	1	22
National Institute of Epidemiology (ICMR	Tamil Nadu	0	1	0	1
National Institute of Mental Health & Ne	Karnataka	0	1	0	1
National Institute of Ocean Technology	Andaman & Nicobar Islands	0	1	0	1
National Institute of Pharmaceutical Edu	Assam	0	1	0	1
National Institute of Pharmaceutical Edu	Punjab	0	1	0	1
National Institute of Science Education	Odisha	0	2	0	2
National Institute of Cholera and Ente	West Bengal	0	2	0	2
National JALMA Institute for Leprosy and	Uttar Pradesh	0	1	0	1
Navodaya Medical College	Karnataka	0	2	0	2
Nilratan Sircar Medical College & Hospit	West Bengal	0	1	0	1
Nitte University	Karnataka	0	1	1	2
Nizam Institute of Medical Sciences	Telangana	1	0	0	1
North Eastern Indira Gandhi Regional Ins	Meghalaya	0	3	0	3
North Maharashtra University	Maharashtra	0	1	0	1
Orchid Chemicals and Pharmaceuticals Lt	Tamil Nadu	0	1	0	1
P.D. Hinduja Hospital & Medical Research	Maharashtra	1	3	0	4
P.D.U. Govt. Medical College	Gujarat	0	1	0	1
PGIMER	Chandigarh	5	16	0	21
PGIMSR	Karnataka	0	1	0	1
PSG Institute of Medical Sciences & Rese	Tamil Nadu	0	2	0	2
Pachaiyappa's College	Tamil Nadu	0	1	0	1
Panineeya Dental College	Telangana	0	1	0	1

Institution	State	Clinical	Surveillance	Social	Total
Panjab University	Chandigarh	0	6	0	6
Patel College of Paramedical Science and	Gujarat	0	1	0	1
Periyar University	Tamil Nadu	0	1	0	1
Pondicherry Institute of Medical Science	Puducherry	1	2	0	3
Pondicherry University	Puducherry	0	3	0	3
Pramukh Swami Medical College	Gujarat	1	1	0	2
Prathima Institute of Medical Sciences	Telangana	0	1	0	1
Presidency College	Tamil Nadu	0	1	0	1
Presidency University	West Bengal	0	1	0	1
Priti Medical Research and Charitable Trust	Uttar Pradesh	0	1	0	1
Pt. B D Sharma PGIMS	Haryana	0	6	0	6
Public Health Foundation of India	Delhi	0	0	1	1
Pushpagiri Institute of Medical Sciences	Kerala	0	2	0	2
Quaid-e-Millath Government Arts College	Tamil Nadu	0	1	0	1
R. G. Kar Medical College	West Bengal	2	2	0	4
RD Gardi Medical College	Madhya Pradesh	1	10	3	14
RIMS	Karnataka	0	2	0	2
RML Hospital	Delhi	2	2	0	4
RTM Nagpur University	Maharashtra	0	2	0	2
Raghavendra Institute of Pharmaceutical	Andhra Pradesh	0	1	1	2
Rainbow Childrens Hospital	Telangana	1	1	0	2
Rajah muthiah medical college and hospit	Tamil Nadu	0	1	0	1
Rajiv Gandhi Centre for Biotechnology	Kerala	0	1	0	1
Rajiv Gandhi Institute of Medical Scienc	Telangana	0	1	0	1
Rajiv Gandhi Cancer Institute and Rese	Delhi	0	1	0	1
Rama Medical College	Uttar Pradesh	0	4	0	4
Rohilkhand Medical College	Uttar Pradesh	0	1	0	1
Ruhs College of Medical Sciences	Rajasthan	0	1	0	1
Rungta College of science and Technology	Chattisgarh	0	1	0	1
Rural Development Trust Hospital	Andhra Pradesh	0	2	1	3

Institution	State	Clinical	Surveillance	Social	Total
S. N. M. C. Bagalkot	Karnataka	0	1	0	1
S. S. Institute of Medical Sciences & Re	Karnataka	0	1	0	1
S.C.B Medical College	Odisha	0	1	0	1
SDM College of Medical Sciences and Hosp	Karnataka	0	1	0	1
SRL Ltd, S. V. Road	Maharashtra	0	1	0	1
SVMCH &RC	Puducherry	0	1	1	2
SVS Medical College	Telangana	0	1	0	1
Saifee Hospital	Maharashtra	0	1	0	1
Sanjay Gandhi Post Graduate Institute of	Uttar Pradesh	8	8	0	8
Santosh University	Uttar Pradesh	1	0	0	1
Sapthagiri Institute of Medical Science	Karnataka	0	1	0	1
Saveetha Medical College & Hospital, Sa	Tamil Nadu	0	1	0	1
Sawai Man Singh Medical College	Rajasthan	0	3	0	3
School of Biosciences and Technology, An	Tamil Nadu	0	1	0	1
School of Tropical Medicine	West Bengal	0	4	0	4
Seth GS Medical College & KEM Hospital	Maharashtra	1	3	0	4
Sher-e-Kashmir University	Jammu and Kashmir	0	2	0	2
Sher-i-Kashmir Institute of Medical Sciences	Jammu and Kashmir	2	2	0	4
Shivaji University	Maharashtra	0	1	0	1
Shoolini University	Himachal Pradesh	0	1	0	1
Shri B. M. Patil Medical College	Karnataka	0	1	0	1
Shri Ram Murti Smarak Institute of Medical Sciences	Uttar Pradesh	0	1	0	1
Shri Shivaji Science College Department	Maharashtra	0	1	0	1
Shri Vasantrao Naik Government Medical College	Maharashtra	0	1	0	1
Siksha 'O' Anusandhan University	Odisha	0	1	0	1
Sindhu Mahavidyalaya Center for Biotechn	Maharashtra	0	1	0	1
Sir Ganga Ram Hospital	Delhi	1	4	1	6
Smt Kashibai Navale Medical College and	Maharashtra	0	2	1	3
Society for Innovation and Development,	Karnataka	0	1	0	1

Institution	State	Clinical	Surveillance	Social	Total
Sourashtra College	Maharashtra	0	1	0	1
Sree Chitra Tirunal Institute for Medica	Kerala	0	1	0	1
Sri Aurobindo Institute of Medical Sciences	Madhya Pradesh	1	5	0	6
Sri Devaraj Urs Medical College	Karnataka	0	2	0	2
Sri Guru Ram Das Institute of Medical Sciences	Punjab	0	3	0	3
Sri Narayani Hospital and Research Center	Tamil Nadu	0	1	0	1
Sri Ramachandra Medical College and Rese	Tamil Nadu	1	11	0	12
Sri Siddhartha Medical College	Karnataka	1	3	0	4
Sri Venkateswara Institute of Medical Sciences	Andhra Pradesh	0	5	0	5
Srimad Andavan Arts and Science College	Tamil Nadu	0	1	0	1
Sriram Chandra Bhanj Medical College and	Odisha	0	1	0	1
St John's Medical College and Hospital	Karnataka	0	5	1	6
Subbaiah Institute of Medical Sciences	Karnataka	0	1	0	1
Subharti Medical College	Uttar Pradesh	0	2	0	2
TATA Main Hospital	Jharkhand	0	2	0	2
Tata Consultancy Services Ltd.	Maharashtra	0	1	0	1
Tata Medical Center	Maharashtra	0	5	0	5
Tata Memorial Hospital	Maharashtra	0	4	0	4
Teerthanker Mahaveer Medical College	Uttar Pradesh	0	1	0	1
Tejasvini Hospital and SSIOT	Karnataka	0	1	0	1
The Tamil Nadu Dr MGR Medical University	Tamil Nadu	0	1	0	1
The West Bengal University of Health Sciences	West Bengal	0	0	1	1
University College of Medical Sciences	Delhi	1	5	0	6
University Tiruchirappalli	Puducherry	0	1	0	1
University of Delhi	Delhi	0	1	0	1
University of Hyderabad	Telangana	0	3	0	3
University of Madras	Tamil Nadu	0	12	0	12
University of Mysore	Karnataka	1	2	0	3

Institution	State	Clinical	Surveillance	Social	Total
University of Pune	Maharashtra	0	1	0	1
Unknown	Maharashtra	2	4	0	6
VIT University	Tamil Nadu	0	1	0	1
Vallabhbhai Patel Chest Institute	Delhi	3	5	4	12
Vananchal Dental College and Hospital	Jharkhand	1	0	0	1
Vardhman Mahavir Medical College & Safdarjung Hospital	Delhi	4	13	0	17
Veer Chandra Singh Garhwali Government	Uttarakhand	1	3	0	4
Vels University	Tamil Nadu	0	0	1	1
Venus Medicine Research Centre	Himachal Pradesh	2	1	0	3
Vidyasagar University	West Bengal	0	4	0	4
Vision Research Foundation	Tamil Nadu	1	1	0	2
Vyas Dental College and Hospital	Rajasthan	0	1	0	1
Vydehi Institute of Medical Sciences	Karnataka	0	2	0	2
World Health Organization	Delhi	0	1	0	1
Yashoda Hospital	Telangana	1	0	0	1
Yenepoya Medical College	Karnataka	0	2	0	2

Table A.5:

Institutions with at least one publication on AMR in animals

Institution	State	Total publications
Anand Agricultural University	Gujarat	4
ARIBAS	Gujarat	1
Bharathidasan University	Tamil Nadu	1
CSIR-CSMCRI	Gujarat	1
CSIR-Central Food Technological Research Institute	Karnataka	1
Center for Disease Dynamics, Economics & Policy	Delhi	1
Center for Science and Environment	Delhi	1
Central Agricultural University	Mizoram	1
Central Avian Research Institute	Uttar Pradesh	1
Central Institute of Fisheries Technology Kerala	Kerala	2
Central Institute of Fisheries Technology Maharashtra	Maharashtra	1
Centre of Advanced Study	Uttar Pradesh	1
Chaudhary Charan Singh (C.C.S.) University	Gujarat	1
Chhattisgarh Kamdhenu Vishwavidyalaya	Chattisgarh	2
Cochin University of Science and Technology	Kerala	3
College of Veterinary Science	Assam	2
College of Veterinary and Animal Husbandry	Uttar Pradesh	1
College of Veterinary and Animal Sciences Kerala	Kerala	1
College of Veterinary and Animal Sciences Uttarakhand	Uttarakhand	1
DUVASU	Uttar Pradesh	1
Dr. G. R. Damodaran College of Science	Tamil Nadu	2
GADVASU	Punjab	1
Guru Angad Dev Veterinary and Animal Sciences University	Delhi	1
ICAR Research Complex for NEH Region	Meghalaya	4
ICAR-Indian Veterinary Research Institute	Uttar Pradesh	2
Indian Council of Agricultural Research	Assam	3
Indian Veterinary Research Institute	Arunachal Pradesh	1
Indian Veterinary Research Institute, Uttar Pradesh	Uttar Pradesh	2
Indian Veterinary Research Institute, West Bengal	West Bengal	2
Jawaharlal Nehru Institute of Advanced Studies	Telangana	1
Karnataka Veterinary Animal and Fisheries Sciences University	Karnataka	2
Kurukshetra University	Gujarat	1
Nagpur Veterinary College	Maharashtra	1
Nanaji Deshmukh Veterinary Science University	Madhya Pradesh	1
National Bureau of Fish Genetic Resources	Uttar Pradesh	1
National Centre for Cell Science	Maharashtra	1
National Research Centre on Yak	Arunachal Pradesh	1
Patna Women's College	Bihar	1
Post Graduate Institute of Veterinary Education and Research	Rajasthan	1
RVS College of Arts and Science	Tamil Nadu	1
Rajasthan University of Veterinary and Animal Sciences	Rajasthan	1
Sher-e-Kashmir University	Jammu and Kashmir	2

Institution	State	Total publications
UNESCO MIRCEN for Marine Biotechnology	Karnataka	1
University of Hyderabad	Telangana	1
University of North Bengal	West Bengal	1
Veterinary College and Research Institute	Tamil Nadu	1
West Bengal University of Animal and Fishery Sciences	West Bengal	4

Table A.6:

Institutions with at least one publication on AMR in the environment

Institution	State	Total publications
Alagappa University	Tamil Nadu	1
Aligarh Muslim University	Uttar Pradesh	4
Anand Agricultural University	Gujarat	2
Anna University	Tamil Nadu	1
Annamalai University	Tamil Nadu	2
Assam University	Assam	1
BIS Group of Institutions	Punjab	1
Banaras Hindu University	Uttar Pradesh	1
Bharathidasan University	Tamil Nadu	3
Biju Patnaik University of Technology	Odisha	1
CSIR-Central Food Technological Research	Karnataka	1
CSIR-Indian Institute of Toxicology Res	Uttar Pradesh	2
CSIR-National Institute of Oceanography	West Bengal	1
Central Leather Research Institute (CSIR	Tamil Nadu	1
Central Marine Fisheries Research Instit	Kerala	1
Cochin University of Science and Technol	Kerala	4
College of Veterinary and Animal Husband	Uttar Pradesh	1
Dayananda Sagar Institutions	Karnataka	2
Department of Veterinary Pharmacology an	Uttar Pradesh	1
Dr. Ram Manohar Lohia Avadh University	Uttar Pradesh	1
IIT Delhi	Delhi	6
IIT Guwahati	Assam	1
Indian Council of Medical Research	West Bengal	1
Indian Institute of Technology Kharagpur	West Bengal	1
Institute of Chemical Technology	Maharashtra	1
Institute of Minerals and Materials Tech	Odisha	1
Integral University	Uttar Pradesh	2
International Centre for Ecological Engi	West Bengal	1
Jadavpur University	West Bengal	1
Jain University	Karnataka	1
Jamal Mohamed College	Tamil Nadu	1
Jamia Millia Islamia	Delhi	2
Jawaharlal Nehru University, Delhi	Delhi	1
Jawaharlal Nehru University	Uttar Pradesh	1
Jaypee Institute of Information Technology	Himachal Pradesh	1
King Saud University	Tamil Nadu	1
Lovely Professional University	Punjab	1
Madhav Institute of Technology and Scienes	Madhya Pradesh	1
Manipal University	Karnataka	6
Mizoram University	Mizoram	1
NGO Gamana	Telangana	1
National Centre for Cell Science	Maharashtra	2
National Institute of Cholera and Enteri	West Bengal	1
National Institute of Science Education	Odisha	2
PGIMER	Chandigarh	1

Institution	State	Total publications
Periyar University	Tamil Nadu	1
Pramukh Swami Science and H. D. Patel Ar	Gujarat	1
Pune University	Maharashtra	1
RD Gardi Medical College	Madhya Pradesh	4
Sher-e-Kashmir University	Jammu and Kashmir	2
Sri Ramachandra Medical College and Rese	Tamil Nadu	1
St John's Medical College and Hospital	Karnataka	1
University of Delhi	Delhi	2
University of North Bengal	West Bengal	1
Vallabhbhai Patel Chest Institute	Delhi	1
Veer Bahadur Singh Purvanchal University	Uttar Pradesh	1
Veer Narmad South Gujarat University	Gujarat	2
Vinayaka Missions University	Tamil Nadu	1

Table A.7:

Institutions with at least one publication on AMR in the novel agents category

Institution	State	Total publications
AIIMS Delhi	Delhi	1
Adichunchanagiri Biotechnology and Cancer	Karnataka	3
Alagappa University	Tamil Nadu	14
Aligarh Muslim University	Uttar Pradesh	12
Amity University	Uttar Pradesh	2
Anna University	Tamil Nadu	5
Arts, Commerce and Science College	Maharashtra	1
Assam University	Assam	2
Aurigene Discovery Technologies Ltd	Karnataka	1
B.J.B. Autonomous College	Odisha	1
Baba Farid University of Health Sciences	Punjab	1
Banaras Hindu University	Uttar Pradesh	4
BarodaMedical College	Gujarat	1
Bhabha Atomic Research Centre	Maharashtra	1
Bharathiar University	Tamil Nadu	2
Bharathidasan University	Tamil Nadu	1
Birla Institute of Technology	Jharkhand	1
Birla Institute of Technology & Science	Telangana	1
Birla Institute of Technology and Science Pilani	Goa	1
Bombay College of Pharmacy	Maharashtra	2
Bose Institute	West Bengal	2
C.B.S.H., G. B. Pant University of Agriculture and Technology	Uttarakhand	1
CSIR - National Environmental Engineering	Maharashtra	1
CSIR Institute of Genomics and Integrating	Delhi	1
CSIR-Central Drug Research Institute	Uttar Pradesh	1
CSIR-Central Food Technological Research	Karnataka	1
CSIR-Central Institute of Medicinal and	Uttar Pradesh	5
CSIR-Indian Institute of Integrative Medicine	Jammu and Kashmir	4
CSIR-Institute of Genomics and Integrative Biology	Delhi	1
CSIR-Institute of Microbial Technology	Chandigarh	4
CSIR-National Botanical Research Institute	Uttar Pradesh	1
CSIR-National Chemical Laboratory	Maharashtra	1
CSIR-National Environmental Engineering	Maharashtra	1
Calcutta School of Tropical Medicine	West Bengal	2
Central Institute of Freshwater Aquacul	Odisha	1
Central Institute of Medicinal and Aroma	Uttar Pradesh	3
Central Leather Research Institute (CSIR)	Tamil Nadu	1
Central Tuber Crops Research Institute	Kerala	2
Central University of Rajastan Ajmer	Rajasthan	2
Chhattisgarh Dental College and Research	Chattisgarh	1
Christian Medical College, Tamil Nadu	Tamil Nadu	3
Cochin University of Science and Technology	Kerala	1
Coorg Institute of Dental Sciences	Karnataka	1
Council of Scientific and Industrial Research (CSIR)	Kerala	1

Institution	State	Total publications
Dayananda Sagar Institutions	Karnataka	2
Defence Institute of Physiology and Allied Sciences	Delhi	1
Dibrugarh University	Assam	1
Doctors Diagnostic Centre	Tamil Nadu	1
Dr. B.R. Ambedkar University	Uttar Pradesh	1
Dr. H.S. Gour Central University	Madhya Pradesh	2
East-West College of Science	Karnataka	1
Entomology Research Institute	Tamil Nadu	1
GITAM University	Andhra Pradesh	1
Gangagen Biotechnologies Pvt. Ltd	Karnataka	2
Garhwal University	Uttarakhand	1
Gujarat University	Gujarat	1
Gulbarga University	Karnataka	1
Guru Gobind Singh Indraprastha University	Delhi	1
Guru Jambheshwer University of Science and Technology	Haryana	3
Guru Nanak Dev University	Punjab	2
Gurukul Kangri University	Uttarakhand	1
Haldia Institute of Technology	West Bengal	2
Hamdard University	Delhi	1
Herbicure Healthcare Bio-Herbal Foundation	Not Applicable	1
IFTM University	Uttar Pradesh	1
IIT Guwahati	Assam	4
IIT Hyderabad	Telangana	1
IIT Kharagpur	West Bengal	10
IIT Roorkee	Uttarakhand	4
IMS & Sum Hospital Medical College, S 'O	Odisha	7
IPGME&R and SSKM Hospital	West Bengal	1
India and M M College of Pharmacy	Haryana	1
Indian Agricultural Research Institute	Delhi	1
Indian Association for the Cultivation of Science	West Bengal	1
Indian Council of Medical Research, Karnataka	Karnataka	1
Indian Institute of Chemical Technology	Telangana	1
Indian Institute of Science	Karnataka	1
Indian Institute of Science Education and Research, MP	Maharashtra	1
Indian Institute of Technology Bombay	Maharashtra	1
Indian Veterinary Research Institute, Uttar Pradesh	Uttar Pradesh	1
Indian Veterinary Research Institute, West Bengal	West Bengal	1
Institute of Advanced Study in Science and Technology (IASST)	Assam	1
Institute of Bioresources and Sustainabl	Manipur	1
Institute of Nuclear Medicine and Allied	Delhi	8
Integral University	Uttar Pradesh	3
J N Medical College	Uttar Pradesh	1
JSS University	Karnataka	2
Jadavpur University	West Bengal	7
Jain University	Karnataka	1
Jamia Millia Islamia	Delhi	2
Jawaharlal Nehru Centre for Advanced Scientific Research	Karnataka	18
Jawaharlal Nehru University, Delhi	Delhi	3
Jawaharlal Nehru University, Uttar Prade	Uttar Pradesh	3

Institution	State	Total publications
Jaypee Institute of Information Technology, UP	Himachal Pradesh	5
K.S.R. College of Arts and Science	Tamil Nadu	1
KIIT University	Odisha	3
KLE University	Karnataka	1
KLE VK Institute of Dental Sciences, Belgaum	Karnataka	2
Kakatiya Government Degree & P.G College	Telangana	1
Karnatak University	Karnataka	1
Kovai Medical Center and Hospital	Tamil Nadu	1
LBS College of Pharmacy	Rajasthan	1
Lovely Professional University	Punjab	1
Loyola College (Autonomous)	Tamil Nadu	1
M. D. University	Haryana	1
Madhav Institute of Technology and Science	Madhya Pradesh	1
Madurai Kamaraj University	Tamil Nadu	2
Maharshi Dayanand University	Haryana	1
Mahatma Gandhi Medical College	Rajasthan	1
Mahatma Gandhi Medical College and Research Institute	Puducherry	1
Mahatma Gandhi University	Kerala	2
Malankara Catholic College	Tamil Nadu	1
Manipal University	Karnataka	2
Manonmaniam Sundaranar University	Tamil Nadu	2
Medical College	Gujarat	1
Medicinal Chemistry Department	Uttar Pradesh	1
Modern College of Arts	Maharashtra	1
Motilal Nehru National Institute of Technology	Uttar Pradesh	1
NMIMS university	Maharashtra	1
NRI college of pharmacy	Andhra Pradesh	1
Nandha College of Pharmacy and Research	Tamil Nadu	1
National Centre for Cell Science	Maharashtra	1
National Centre for Compositional Characterisation of Materials (NCCCM)	Telangana	1
National Chemical Laboratory	Maharashtra	3
National Dairy Research Institute	Haryana	2
National Institute for Interdisciplinary	Kerala	1
National Institute for Research in Repro	Maharashtra	1
National Institute of Cholera and Enteric Diseases	West Bengal	3
National Institute of Pharmaceutical Education	Punjab	1
National Institute of Science Education	Odisha	2
National Institute of Technology Gujarat	Gujarat	1
National Institute of Technology Odisha	Odisha	1
National Institute of Unani Medicine	Karnataka	1
Natubhai V. Patel College of Pure and Applied Sciences	Gujarat	1
Nirma University	Gujarat	1
North Maharashtra University	Maharashtra	1
North Orissa University	Odisha	4
PDM College of Pharmacy	Haryana	1
PRIST University	Tamil Nadu	1
Padmashree Institute of Management and Sciences	Karnataka	1
Panjab University	Chandigarh	13
Periyar Maniammai University	Tamil Nadu	1

Institution	State	Total publications
Piramal Enterprises Ltd	Maharashtra	1
Pondicherry University	Puducherry	2
Pune University	Maharashtra	1
Ranbaxy Research Laboratories	Haryana	3
S L Raheja Hospital	Maharashtra	1
S. S. Institute of Medical Sciences & Research Centre	Karnataka	1
SASTRA University	Tamil Nadu	3
SGB Amravati University	Maharashtra	3
SGT University	Haryana	1
SHIATS	Uttar Pradesh	2
SRM University	Tamil Nadu	1
SRNMN College of Applied Sciences	Karnataka	1
SSN College of Engineering	Tamil Nadu	1
Sanjay Gandhi Post Graduate Institute of Medical Sciences	Uttar Pradesh	2
Sant Gadge Baba Amravati University	Maharashtra	1
Savitribai Phule Pune University	Maharashtra	1
Sheth M.N.Science College	Gujarat	1
Siksha 'O' Anusandhan University	Odisha	1
Sree Vidhyanikethan College of Pharmacy	Andhra Pradesh	1
Sri Krishnadevaraya University	Andhra Pradesh	1
Sri Ramachandra Medical College and Research Institute	Tamil Nadu	4
St. Gregorios Dental College	Kerala	1
St. Xavier's College Goa	Goa	1
St. Xavier's College Tamil Nadu	Tamil Nadu	1
Tezpur University	Assam	1
Thapar University	Punjab	1
Thiagarajar College	Tamil Nadu	1
Tripura University	Tripura	2
University of Calcutta	West Bengal	4
University of Delhi	Delhi	4
University of Hyderabad	Telangana	1
University of Kalyani	West Bengal	3
University of Lucknow	Uttar Pradesh	1
University of Madras	Tamil Nadu	2
University of Mysore	Karnataka	3
University of Pune	Maharashtra	3
Unknown	Punjab	3
VHNSN College	Tamil Nadu	1
VIT University	Tamil Nadu	7
Venus Remedies	Haryana	1
Vidyasagar University	West Bengal	4
Vijaya Institute of Pharmaceutical Sciences for women	Andhra Pradesh	1
Visva-Bharati University	West Bengal	1
Visvesvaraya Technological University	Karnataka	1
Vivekananda College	Tamil Nadu	1
Yashvantrao Chavan Institute of Science	Maharashtra	1
Yenepoya University	Karnataka	1

Table A.8:

Institutions with at least one publication on AMR in the miscellaneous category

Institution	State	Total publications
AIIMS Delhi	Delhi	4
Alagappa University	Tamil Nadu	3
Aligarh Muslim University	Uttar Pradesh	5
Amrita Vishwa Vidyapeetham University	Kerala	1
Anand Agricultural University	Gujarat	2
Animal Sciences University	Punjab	1
Apollo Institute of Medical Sciences and Research	Telangana	1
Aravind Eye Care Madurai	Tamil Nadu	1
Assam University	Assam	5
Banaras Hindu University	Uttar Pradesh	7
Bhabha Atomic Research Centre	Maharashtra	2
Bharathidasan University	Tamil Nadu	2
Birla Institute of Technology	Jharkhand	1
Birla Institute of Technology & Science	Telangana	1
Bose Institute	West Bengal	2
Burdwan University	West Bengal	1
CSIR - National Environmental Engineering Research Institute	Maharashtra	1
CSIR Institute of Genomics and Integrative Biology	Delhi	1
CSIR-Central Drug Research Institute	Uttar Pradesh	1
CSIR-Central Food Technological Research Institute	Karnataka	4
CSIR-Indian Institute of Chemical Technology	Telangana	1
CSIR-Indian Institute of Integrative Medicine	Jammu and Kashmir	2
CSIR-Institute of Genomics and Integrative Biology	Delhi	1
CSIR-Institute of Microbial Technology	Chandigarh	11
Central Institute of Fisheries Education (CIFE)	Maharashtra	1
Central University of Rajastan Ajmer	Rajasthan	1
Centre for Cellular and Molecular Biology (CSIR)	Telangana	1
Centre for DNA Fingerprinting and Diagnostics	Telangana	2
Centre for Materials for Electronics Technology	Maharashtra	1
Chettinad Hospital and Research Institute	Tamil Nadu	1
Christ College	Gujarat	1
Christian Medical College, Tamil Nadu	Tamil Nadu	4
Cochin University of Science and Technology	Kerala	1
Dayananda Sagar Institutions	Karnataka	1
Deemed University Tamil Nadu	Tamil Nadu	1
Deemed University Uttar Pradesh	Uttar Pradesh	1
Department of Science & Technology	Gujarat	1
Division of Avian Genetics and Breeding	West Bengal	1
Dr. Baba Saheb Ambedkar Hospital	Delhi	1
Eminent Biosciences	Madhya Pradesh	1
GITAM University	Andhra Pradesh	2
Gangagen Biotechnologies Pvt. Ltd	Karnataka	1
Gauhati University	Assam	1
Goa University	Goa	1

Institution	State	Total publications
Grant Medical College	Maharashtra	1
Gulbarga University	Karnataka	2
Holy Cross College	Tamil Nadu	1
ICAR Research Complex for NEH Region	Nagaland	1
IIT Guwahati	Assam	1
IIT Hyderabad	Telangana	1
IIT Kanpur	Uttar Pradesh	2
IIT Kharagpur	West Bengal	6
IIT Roorkee	Uttarakhand	3
IT University	Tamil Nadu	1
India Dr G R Damodaran College of Science	Tamil Nadu	1
Indian Council of Medical Research	Delhi	1
Indian Council of Medical Research, Andaman	Andaman & Nicobar Islands	1
Indian Institute of Advanced Research	Gujarat	1
Indian Institute of Science	Karnataka	4
Indian Institute of Science Education and Research, MP	Madhya Pradesh	2
Indian Institute of Science Education and Research, Maharashtra	Maharashtra	1
Indian Institute of Technology Bombay	Maharashtra	6
Indian Institute of Soil Science	Madhya Pradesh	1
Indira Gandhi Krishi Vishwavidyalaya	Chattisgarh	1
Institute of Life Sciences	Odisha	2
Institute of Nuclear Medicine and Allied	Delhi	1
Integral University	Uttar Pradesh	2
International Crops Research Institute for the Semi-Arid Tropics (ICRISAT)	Telangana	1
JIPMER	Puducherry	1
JSS Dental College and Hospital	Karnataka	1
Jawaharlal Nehru Centre for Advanced Sci	Karnataka	1
Jawaharlal Nehru University, Delhi	Delhi	1
Jaypee Institute of Information Technology	Himachal Pradesh	7
Jaypee Institute of Information Technology, UP	Uttar Pradesh	2
Jubilant Chemsys Ltd	Uttar Pradesh	1
KIIT University	Odisha	1
Kerala Veterinary and Animal Sciences University	Kerala	1
Lady Doak College	Tamil Nadu	1
Lovely Professional University	Punjab	1
MES Ponnani College	Kerala	1
Madhav Institute of Technology and Science	Madhya Pradesh	1
Madurai Kamaraj University	Tamil Nadu	3
Maharshi Dayanand University	Haryana	1
Manipal College of Pharmaceutical Sciences	Karnataka	1
Manipal University	Karnataka	1
Meenakshi Ammal Dental College	Tamil Nadu	1
Motilal Nehru Medical College	Uttar Pradesh	1
Motilal Nehru National Institute of Technology	Uttar Pradesh	2
National Bureau of Fish Genetic Resource	Uttar Pradesh	1
National Centre for Cell Science	Maharashtra	1
National Centre for Veterinary Type Culture Collection	Haryana	1

Institution	State	Total publications
National Dairy Research Institute	Haryana	5
National Environmental Engineering Research Institute	Telangana	1
National Institute of Cholera and Enteric Diseases	West Bengal	1
National Institute of Immunohaemotology	Maharashtra	1
National Institute of Plant Genome Resea	Delhi	1
National Institute of Technology Karnata	Karnataka	1
National Institute of Technology Odisha	Odisha	1
Netaji Subhas Institute of Technology	Delhi	2
North Maharashtra University	Maharashtra	1
North-Eastern Hill University	Meghalaya	1
P. M. N. M. Dental College and Hospital	Karnataka	1
PGIMER	Chandigarh	3
PSG College of Arts and Science	Tamil Nadu	1
Pandit Bhagwat Dayal Sharma Post Graduate Institute of Medical Sciences	Delhi	1
Panjab University	Chandigarh	11
Piramal Enterprises Ltd	Maharashtra	1
Pondicherry University	Puducherry	1
Prathima Institute of Medical Sciences	Telangana	1
Presidency University	West Bengal	1
Rajendra Memorial Research Institute of Medical Sciences	Bihar	1
Ramananda College	West Bengal	1
SASTRA University	Tamil Nadu	3
SHIATS	Uttar Pradesh	1
Saurashtra University	Gujarat	1
Sawai Man Singh Medical College	Rajasthan	1
Sri Sathya Sai Institute of Higher Learn	Andhra Pradesh	1
Swami Ramanand Teerth Marathwada University	Maharashtra	1
Tata Institute of Fundamental Research	Karnataka	2
Tezpur University	Assam	1
The Maharaja Sayajirao University of Baroda	Gujarat	1
Tripura University	Tripura	1
University of Allahabad	Uttar Pradesh	1
University of Calcutta	West Bengal	2
University of Delhi	Delhi	7
University of Hyderabad	Telangana	2
University of Madras	Tamil Nadu	3
University of Mysore	Karnataka	2
Unknown	Madhya Pradesh	1
VIT University	Tamil Nadu	15
Veer Surendra Sai University of Technology	Odisha	1
Velammal Medical College Hospital and Research Institute	Tamil Nadu	1
Vidyasagar University	West Bengal	2
Visvesvaraya Technological University	Karnataka	1
Yenepoya University	Karnataka	2