

Microbial Threats: Global Health Governance in The Age of Superbugs

Maria NAZIR

Rohina ARIF

Jawad ASLAM

Shafeeq Ur REHMAN

Muhammad MUDASSAIR

Muhammad SAFDAR

Mehmet OZASLAN

1. Introduction

When it comes to the chronicle of man, there was no greater advancement in how man fought off diseases than the use of antibiotics. Such ‘wonder drugs,’ which were considered the tonic for diseases, changed the history of medical sciences and raised the bar of health indices (Davies, 2013). However, the narrative of triumph has taken a disquieting turn as a new threat looms large on the horizon the increasing cases of substances that are resistant to antibiotics, such as antimicrobial resistance (AMR), commonly referred to as “superbugs. Exclusion of the elements other than Superbugs and AMR Other than implying the Superbugs and AMR, the above terms refer to those bacteria that have been deemed highly resistant to antibiotics. In other words, antimicrobial resistance can also be described as the microorganisms’ ability to not be neutralized by the antimicrobial agents that are claimed to either eliminate the microorganisms or inhibit their multiplication. This is a progressive process however, the uptake and abuse of antimicrobials have triggered the occurrence of this event at an unusually fast rate (Christaki et al., 2020).

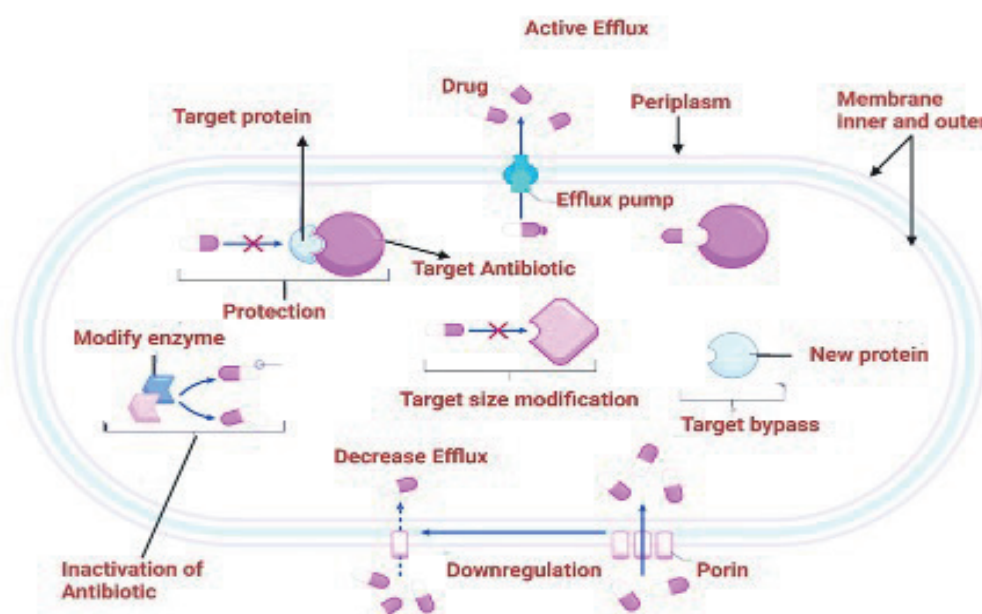


Figure 1. Mechanisms of Antimicrobial Resistance

Superbugs are the fearsome offspring of this resistance, types of microorganisms that factor in the ability to resist more than one type of antimicrobial agent, making them almost inflammable. The methicillin-resistant *Staphylococcus aureus* (MRSA), Carbapenem-resistant Enterobacterales (CRE), and vancomycin Resistant Enterococci (VRE) are among the well-known superbugs all have distinct weapons in their arsenals of resistance. These resistance mechanisms (Figure 1) include the elimination of drugs by enzymatic activity, modifications to the targets of drugs as well as through efflux pumps that eject antibiotics out of the bacterial cell (Farhat et al., 2020). This leads to the evolution of what has come to be referred to as superbugs. Since the genetic resistance can be mutated or transferred from one microorganism to another.

A Global Threat by Superbugs

The scale and reach of AMR and superbugs do not remain limited to hospitals and clinics but affect everyone. This not only turns into an issue but is categorized as a great threat to health security in the world that has rolled back the years of progress in eradicating diseases. AMR is recognized as one of the main challenges for world health. On the economic side, the picture is no different, with estimates pointing to an aggregate figure of 100 trillion USD in terms of foregone output by the same year (Dasgupta, 2021). The effect is deep-seated in that easily curable diseases turn into a nightmare, thus prolonging patients' stay in healthcare facilities, escalating the cost of treating the patients in addition to record high mortality rates. The emergence of AMR is worrisome due to its increased risk in LMICs, characterized by poor healthcare accessibility, poor sanitation, and inadequate or almost non-existent stewardship programs (Kpokiri, 2019). In these contexts, AMR drives the incidence of other communicable diseases such as TB, malaria, and HIV/AIDS, while greed widens existing socioeconomic imbalances (Michaud et al., 2024). Global health governance is an important topic that must not be neglected, especially given today's complex systems worldwide. Due to the globalization of AMR, there is a need to address the issue collaboratively and holistically (Aijaz et al., 2023). There is an urgent need to scale up international health diplomacy to prevent the rise of superbugs and protect people's health domestically and globally. This includes surveillance and monitoring, infection prevention and control, continuing antimicrobial stewardship, research and development, new antibiotics and other therapies, and social-financial-ecological actions across borders. Intensive antimicrobial usage and the emergence of superbugs have turned global health governance into a science, politics, economics, and moral issue. It entails achieving consensus with heterogeneous players, including governments, international organizations, healthcare professionals, pharmaceutical firms, and civil society (Walser, 1997). The details regarding the nature of threats posed by superbugs, the state of global health, the current system of governance of such pathogens, and the measures needed to fight this terrorizing threat shall be explored in the subsequent chapters. Utilizing past interventions' difficulties as the primary knowledge, we will reveal the challenges on the way to a sophisticated system of governance and create a blueprint of humanity's roadmap in the context of the current and future microbial threats. The path that we are about to follow can hardly be called predictable, yet the world's state today leaves no space for hesitation and calls for immediate, concerted action to safeguard the currently existing, as well as future, generations' health.

2. Understanding Superbugs

These superbugs are not strictly new species of microbes but mutated strains that can withstand almost all forms of antibiotics being used in the modern world and rank amongst the most fearsome opponents in the ongoing war against infections. This acquired resistance, perfectly normal in evolution, has been made several-fold worse due to the widespread misuse and overuse of antibiotics in humans, animals, and feedstock (Ram et al., 2020). The implications of this phenomenon give rise to dire effects, which are witnessed by the fact that superbug infections necessarily prolong an individual's sickness, raise costs drastically, and can even be fatal. To grip the threat from superbugs, it is necessary to look deeper into the strategies that the organisms use to escape the impact of the drugs. One such mechanism is enzymatic degradation, which entails using enzymes by bacteria capable of degrading the antibiotics before they exhibit their antimicrobial action.

One of the best examples can be narrowed down to the synthesis of beta-lactamases, enzymes that neutralize penicillin and other related antibiotics to the bacteria hence becoming ineffective (Fatima et al., 2021). The other is an example of target alteration; here, the bacteria change the structure of the antibiotic's target within the cell to ensure that the antibiotic cannot bind and exert its inhibitory or killing effect. An example of this mechanism is MRSA, which has had a change in its penicillin-binding protein to that which makes it resistant to methicillin and another beta-lactam category of antibiotics (Kirmusaoğlu, 2017). Efflux pumps in the cell membrane of bacteria such as *Pseudomonas aeruginosa* expel the antibiotics from their cellular structure before the antibiotic can affect the bacteria (Iman Islamieh et al., 2018). This mechanism enables bacteria to keep sub-lethal concentrations of antibiotics within the cell, thus surviving the drug exposure. Some of the strategies used by bacterial pathogens to exhibit resistance include reduced permeability involved with Gram-negative bacteria and carbapenem-resistant Enterobacteriaceae (CRE). These organisms modify their outer membranes in such a way that the penetration of antibiotics through the cell is limited and is, therefore, unable to get to the target site. This intrinsic resistance, accompanied by other resistance mechanisms, makes CRE infection rather difficult to combat. The superbug market is inhabited by a large number of resistant agents, which are characterized by specific resistance patterns and related diseases (Doron & Broom, 2019). Together, the most common is MRSA causing skin and soft tissue, and bloodstream infection. CRE is a group of bacteria that comes next to facility-acquired or healthcare-associated infections that are very difficult to manage. VRE is responsible for urinary tract, bloodstream, and wound infections; and MDRPA, which is a universal pathogen in hospitalized patients, especially immunocompromised (Fontanot et al., 2024). The appearance and dissemination of these and other resistant pathogens threaten the same audience, testifying to the importance of fighting AMR. This has a very important implication in understanding the right strategies for tackling these superbugs with resistance and in sustaining the effectiveness of the current and newly promoted antibiotics.

3. Antibiotic Resistance

The Rise of Antimicrobial Resistance

This world is not turning into a more customary place. There is conflict going on here and there, let's say even diseases, hunger, and natural disasters. Antibiotics were discovered in the early 20th century, starting with Alexander Fleming in 1928, and introduced new paradigms to medical curing (Lalchhandama, 2021). Where infectious diseases used to wipe out a significant percentage of the entire population, they were now controlled, and life expectancy rocketed. But the excitement of having antibiotics was short-lived because, within a few decades, we had faced a new challenge antibiotic resistance. Antibiotics and other antiseptic substances, together with many others, have catalyzed the escalating instances of antimicrobial resistance or AMR as it is commonly known today (Domínguez & Meza-Rodriguez, 2019).

Historical perspective on the usage of antibiotics and antibiotic resistance

Thus, the story of antibiotics and resistance is a narrative of scientific discovery, social advances, and biological evolution (Table 1). Antibiotic discovery took off in the mid-twentieth century and was characterized by the generation of diverse classes of molecules. Nevertheless, this period also witnessed the birth of the resistance issue, with information indicating that penicillin-resistant *S. aureus* was first reported in the 1940s (Basset et al., 2011).

Table 1: Evolution of Antibiotic Discovery and Rise of Antimicrobial Resistance (AMR)

Year	Milestone	Significance	References
1928	Discovery of penicillin by Fleming	Revolutionized medicine marked the beginning of the antibiotic era.	(Haider, 2023)
1940s	Widespread use of penicillin	Demonstrated the life-saving potential of antibiotics.	(Lobanovska & Pilla, 2017)
1950s-1960s	"Golden Age" of antibiotic discovery	Numerous new antibiotics were introduced, expanding the arsenal against bacterial infections.	(Fairley)
1960s-1970s	Emergence of penicillin-resistant <i>S. aureus</i>	First documented antibiotic resistance, highlighting bacterial adaptability.	(Pal et al., 2017)
1980s-1990s	Increasing reports of multi-drug-resistant bacteria (e.g., MRSA)	Raised alarm about AMR and the need for new solutions.	(ALSAAD & ZAFER, 2023)
2000s-present	Emergence of extensively drug-resistant (XDR) and pan-drug-resistant (PDR) bacteria	Signaled a critical juncture in the AMR crisis, with virtually untreatable bacteria.	(Peraman et al., 2021)
2015	declares AMR a global health emergency	Underscored the urgency of the crisis and the need for a coordinated global response.	(Aijaz et al., 2023)

This earliest form of resistance only established that bacteria are capable of developing certain changes in reaction to certain selective factors. Subsequent years and decades have shown constant oscillation of new antibiotics with the appearance of resistant strains to these drugs. It has been witnessed since the 1980s that the rate at which new resistance species evolved was far higher than the discovery of new antibiotics, suggesting that the world was heading toward a problem (Selvarajan et al., 2022). The causes for this type of crisis are also complex and based on human actions and structural problems.

Cause of the Emergence of AMR

1. Overuse and Misuse of Antibiotics: The misuse, over-prescription, and over-consumption of antibiotics, whether to humans or animals, is one of the leading causes of AMR. It involves the administration of antibiotics to patients with viral infections, starting with broader spectrum antibiotics instead of going for the more specific ones, or stopping antibiotic therapy midway in a course, which grants rise to resistant bacteria (Justham, 2014). The fact that antibiotics are bought over the counter in some countries with no prescription from a qualified medical practitioner worsens the situation.

2. Agricultural Practices: Another factor that can be attributed to AMR is the liberal use of antibiotics in animal farming, especially in growth promoter diets for livestock. Essential antibiotics that are administered or used in feeding animals have the potential to develop resistance, which could spread to humans through the food chain or direct contact (Kumar et al., 2020). This underlines the necessity to implement the "One Health" concept that deals with the connections between human health, animal health, and the environment.

3. Lack of New Antibiotics: The discovery of new antibiotics has been reported in the past decades for several reasons. New antibiotic development is expensive, antibiotics face long development cycles, antibiotics' profitability is relatively low compared to other drugs, and finally, there are regulatory barriers (Monnier et al., 2019). This has left us with scanty solutions for infections arising from resistant bacteria without adequate treatment. Antimicrobial resistance is potentially

one of the most pressing global issues of the century, and its development is intricate and diverse. It poses serious risks to overpowering advancements made in medicine and public health in the past fifty years and has strong upsetting implications for vulnerable groups in low and middle-income countries (Chilemya, 2016). Combating this crisis involves several preventive strategies, which include the appropriate use of antibiotics, infection prevention and control measures, a search for new antibiotics, and fighting social, economic, and ecological forces that lead to AMR (Figure 2). The consequences cross everyone's threshold, yet the risks cannot wait; we need a joint response that can protect ourselves and all subsequent generations.

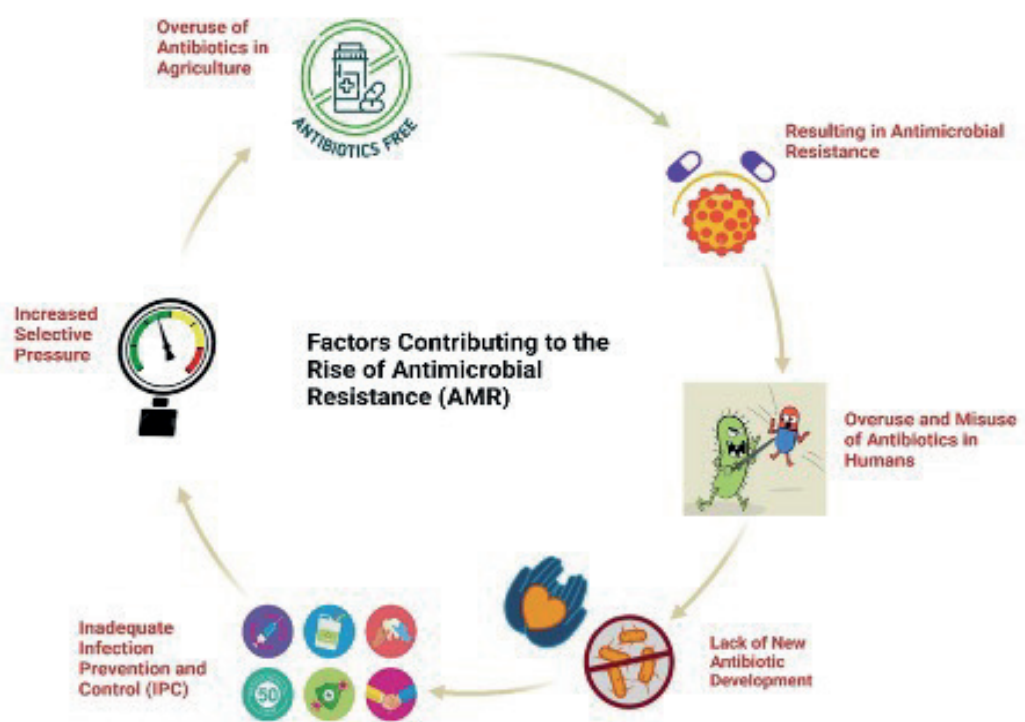


Figure 2. Factors Contributing to the Rise of Antimicrobial Resistance (AMR)

4. Impact of Superbugs on Global Health

Such trends characterize today's global healthcare environment as the growth of AMR and the emergence of superbugs. These antibiotic-resistant microbes are not only a health issue but an extended multifaceted issue that affects the global public health, economy, and healthcare system with the potentiality to act as a potential ground to roll back the several years battle against infectious diseases (Table 2).

Table 2: Impact of Superbugs on Global Health

Area Affected	Consequences	Examples	References
Public Health	Increased illness, and death, especially in vulnerable groups.	1.27 million deaths globally in 2019	(Hamrefors, 2014)
Medical Care	Disrupted surgeries, transplants, and chemotherapy.	Increased risk of infections & delays in treatment	(Mohammed et al., 2020)
Economy	Trillions of dollars are lost globally due to healthcare costs, lost work, etc.	Up to \$100 trillion loss by 2050	(Cordeiro & Wood, 2023)
Hospitals	Strained resources, longer patient stays, difficulty controlling infections.	Overcrowding, increased antibiotic use.	(Hijazi et al., 2019)

Public Health Implications: Superbugs also become a menace to the rate of Morbidity and Mortality, especially to more vulnerable groups of people, including seniors, underage children, and other candidates with compromised immunity. Those infections are often more severe, complicated, and deadly; they require longer curing and are less sensitive to standard antibiotics. Thus, superbug infection affects LMICs much more than the developed world; the reasons include poor access to healthcare, poor hygiene, and misuse of antibiotics (Greco et al., 2022). In addition, superbugs are a threat to public health since they affect people individually. These resistant infections can cause episodic outbreaks in healthcare facilities and society in general, thus posing a high risk to the health and well-being of everyone. These outbreaks can strain healthcare facilities and other services, besides leading to panicky feelings and fear within the populace (Apisarnthanarak et al., 2021).

Economic Burden: The economic ramifications of AMR and superbugs are massive and quite complex. For instance, a report on AMR sponsored by the UK government put the economic loss figure at \$100 trillion if no measures are taken to address the threat in the subsequent three and half decades (Rush & Davies, 2016). This staggering figure includes direct health care costs or the costs of prolonged hospital stays, of treatments sourced with last resort antibiotics and additional diagnostic tests, for instance, indirect costs such as lost productivity due to diseases and disability, tourism decreases, and trade restrictions, among others. The economic effect is immensely severe in LMICs that suffer from inadequate resources in healthcare facilities to combat superbugs. In such environments, AMR has the potential of putting already vulnerable communities in the category of the poor, leading to a vicious cycle where disease leads to poverty, and poverty leads to diseases (Hartwig & Segura Kliesow, 2020).

Impact on Healthcare Systems: Global healthcare systems are severely challenged by superbugs. The management of resistant infections is much more invasive and expensive, including the use of last-line antibiotics, which are generally more toxic and less potent than first-line antibiotics (Surya Prakash et al., 2023). Moreover, patients sustaining infections that are resistant to the used means stay longer in the hospital, hence exerting more pressure on the limited resources and are likely to develop other infections acquired from the hospital environment. The subsequent rise in cases of superbug infections also implies the need to incorporate the use of isolation measures as part of infection prevention and control measures, alongside increased hygiene practices (Mitra et al., 2022). These measures are useful in reducing the occurrence of patients with resistant pathogens in the healthcare facility but lead to additional resource challenges and disrupt the regular functioning of the healthcare system.

Case Studies of Outbreaks and Their Consequences: Superbug infection outbreaks have been frequent, thus making AMR a Global health challenge that has had numerous ECIs. Carbapenem-resistant *Klebsiella pneumoniae* emerged at a New Delhi hospital, killing many patients and spreading to other countries, confirming AMR as a global problem (Das, 2023). This outbreak illustrated the issues of controlling resistant pathogens in hospitals and healthcare facilities and the ability of such a pathogen to quickly spread globally. These are commonly linked to contaminated medical instruments and substandard infection control measures that, therefore, call for intensified measures in the right prevention of infections. All these case studies and many more clearly depict the need to act on the AMR crisis. It shows the possibility of superbugs and their effect on producing diseases and fatalities, affecting the health care systems and the overall economic impacts. This global issue is multi-faceted and requires interdisciplinary research, policy, practice, and education-based solutions internationally (Riekkilä & Mämmelä, 2021). In conclusion, human beings can fight the menace of superbugs if only they heed the quest of medical practitioners to work hand in hand without compromising future generations' health.

5. Global Health Governance Framework

AMR and the superbugs in the offing require intensive and organized control hence the need for a global health governance system. It entails a system of important organizations, stakeholders, and international relationships created by AMR and requires solving. The following are some of the key players in this global effort:

Key Organizations and Stakeholders

1. World Health Organization (WHO): By being the World Health Organisation, WHO continues to assume a central role in the global management of AMR. They include technical support, establishing international policies, and directing surveillance alongside offering support for policies on the right use of antibiotics and the fight against AMR. The member countries of the WHO at the moment have endorsed the Global Action Plan for AMR. In response, the organization assists countries in the process of creating their national action plans concerning AMR (Hein et al., 2022).

2. Centers for Disease Control and Prevention (CDC): AMR surveillance and research is conducted by some of the best national public health institutions, including the CDC in the USA. It monitors resistance to antimicrobial products, offers assistance to practitioners, and drives measures for the proper use of antibiotics and controlling infections. CDC of the USA has the National Action Plan for Combating Antibiotic-Resistant Bacteria that contains strategies for the control and handling of AR in the United States of America (Bristol, 2020).

3. Global Antibiotic Research and Development Partnership (GARDP): Double, GARDP is an international non-profit making organization that only focuses on new antibiotics or the next best thing. It is geared towards responding to diseases of high demand that affect all populations with those with chronic illnesses and neglected populations. GARDP's work involves engaging with academic institutions, pharma players, and other partners to make new antibiotics for patients in need and foster the innovation of new ones (Segers, 2017). Combating superbugs can only be done in a coordinated manner. Together with the stakeholders and NGO partners, it is possible to design and promote meaningful approaches for countering the threats that come with AMR and maintaining the health of the population (Mudenda et al., 2023).

International Agreements and Policies: A Whole Effort to Address AMR

It is also appropriate to note that many organizations and nations have signed and developed various treaties and policies due to the AMR crisis's overarching and international nature (Figure 3). These agreements are a sort of plan that would facilitate collective movement so that there is a symphony across countries and sectors regarding preventing the emergence of superbugs. Among these strategies, two main strategies include the WHO Global Action Plan on Antimicrobial Resistance (GAP-AMR) and the One Health strategy. This plan is well known by the full name of the Global Action Plan on Antimicrobial Resistance or GAP-AMR.

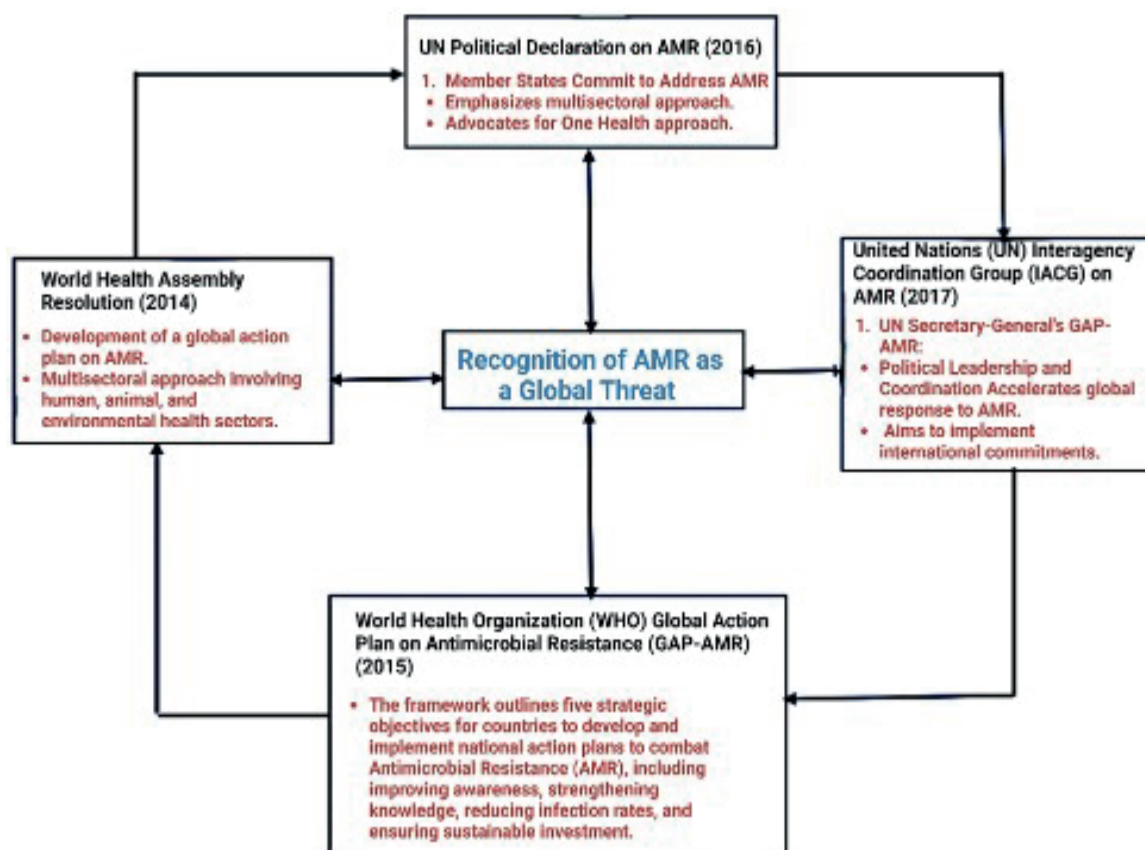


Figure 3. International Agreements and Policies for Combating Antimicrobial Resistance

1. Improve awareness and understanding of AMR: This includes investing in the general public's education, human resources in health care facilities, and the effectiveness or inefficiency of laboratories. Other institutions are involved in research on the emergence of new and spread-resistant pathogens by extending knowledge to the public on how the general population can take antibiotics through public awareness and healthcare education (Arafa, 2019).

2. Strengthen knowledge through surveillance and research: This includes funding research to understand various factors that make bacteria resistant, and improved methods for early identification of such resistant bacteria. New drugs forms of treatment for resistant bacteria, and preliminary assessment of control measures for AMR are used (Sekyere & Asante, 2018).

3. Reduce the incidence of infection: This pertains to strengthening the measures relating to Infection prevention and control in healthcare facilities wards and communities (Alhumaid et al., 2021). Hence, it underlines the need to observe hand washing, vaccinations, safe water and sanitation practices, and proper waste handling to reduce the likelihood of acquiring an infection and the ability of pathogens to develop resistance.

4. Optimize the use of antimicrobial medicines: This involves support of the APR programs that will ensure that antibiotics are not administered carelessly but where necessary. It entails developing a set of protocols for the use of antibiotics, reporting on the use of the drugs, and giving feedback to the concerned practitioners to enable them to enhance their practices (Hulscher & Prins, 2017).

5. Ensure sustainable investment in countering AMR: This entails investment in research and development of new antibiotics and other effective treatments. This enhancement of healthcare facilities to increase infection prevention and control, and increased cross-country cooperation

to address the existing social, economic, and ecological factors that favor AMR (Shrestha et al., 2022). The GAP-AMR works as a blueprint for countries to devise and execute national action plans that will help combat AMR (Moloney-Omar, 2022). It promotes cooperation at the cross-sector level, being aware of the fact that AMR is not and cannot be viewed solely in the categories of health but rather as a social, economic, and even environmental problem. The GAP-AMR has been adopted by many countries and international organizations, proving that the problem has received international-level attention.

One Health Approach

The one health concept is among the core tenets of global AMR management. That is why it appreciates the One Health concept that asserts that human, animal, and environmental health must be treated together with close cooperation among the sectors as a way of combating multifaceted issues like AMR (Humboldt-Dachroeden & Mantovani, 2021). This is why the One Health concept recognizes that the misuse of antibiotics in any of the three sectors can breed resistant bacteria and that solutions have to be as well. It focuses on the implementation of one health approach, which entails the use of multiple strategies based on the interaction of human health, veterinary medicine, agriculture, and the environment (Binot et al., 2015). This entails raising awareness on the rational administration of antibiotics in humans and animals, enhancing infection control measures in hospitals and industries rearing animals, and checking for traces of antibiotic residues in food, water, and soil, among other aspects that may lead to the spread of resistant bacteria. One Health is not just a theoretical model because it has been applied to fight AMR in distinct zones. For example, in Denmark, the One Health program, for one year, has drastically cut the rate of antibiotics employed across people's and animal health sectors without compromising animals' well-being or food security (Aarestrup, 2015). There are Global Action Plans and policies, namely GAP-AMR and One Health, that are vital in combating AMR. These are a basis for coordinated operations, give directions to national and regional actions, and advocate for combined approaches to address this issue. However, the effectiveness of these programs lies in political will, sufficient funding, and proper coordination of various structures.

6. Strategies for Combating Superbugs

The growing threat of AMR and superbugs requires society to employ reactive and preventive strategies that can shoulder the increasing responsibility of protecting and delivering healthcare. This section delves into two crucial strategies: surveillance and monitoring and antimicrobial stewardship programs. Further, the discovery of the best ways of infection control measures, researching the development of new antibiotics, and other treatment therapies and innovations in the medical field.

Surveillance and Monitoring Systems: Good surveillance and monitoring systems act as the regulators and detectors of the world in combating AMR. They give basic information regarding the distribution and trends of antibiotic resistance in various regions and pathogens, thus notifying quick identification of any novel threats and subsequent responsive measures. Such systems are usually accompanied by documenting antibiotic prescribing practices, resistance patterns of bacteria to the drugs, and the emergence of antibiotic-resistant infections in humans and animals. These data are instrumental in defining the prevalence and complexity of the AMR issue, outlining the populations and facilities at higher risk, and assessing the efficiency of mitigations (Mudenda et al., 2023).

Global Antimicrobial Resistance Surveillance System (GLASS): GLASS is a coordinated system of the WHO for the collection, analysis, comparison, and sharing of national-level AMR. They concentrate on priority pathogens causing frequent human diseases and report on the tendencies in antimicrobial resistance and antibiotic intakes (Endale et al., 2023). The information from GLASS is useful for showing the increasing threat of AMR worldwide and was used to direct the necessary actions on the national and international levels. The work published by GLASS recently exhibited

that there had been a high rise in the level of resistance of the *E. coli* and *Klebsiella pneumoniae* isolates from the bloodstream infection to third-generation cephalosporins and fluoroquinolones (Saeed et al., 2021).

National Surveillance Systems: In this regard, most countries today have developed local surveillance systems to monitor AMR nationally. Most of the above systems encompass partnerships between public health organizations, laboratories or facilities, and physicians. On one hand, they gather information on antibiotic resistance rates in bacteria obtained from clinical samples, and on the other information on antibiotic consumption in healthcare facilities and the population. In the United States, NHSN has been established for surveillance for HAI, including the one caused by antibiotic-resistant bacteria, for infection prevention and control (Ananda et al., 2022).

Integrated Surveillance Systems: One Health concept will also refer to the surveillance systems that mobilize information concerning antibiotic resistance across the three interfaces. It provides the chance to get the systemic picture of the redeployment of resistant bacteria and the steps that eliminate the root cause of AMR in all the sectors if done in the following way. For instance, this is seen in the case of antibiotics administered to animals for evaluation of the effect of the production of agricultural products on AMR (Törneke et al., 2015).

Antimicrobial Stewardship Programs: Thus, ASP has been defined as one of the serious strategies for dealing with the increasing trends of AMR. Stewardship interventions seek to enhance the proper prescription of antibiotic medication, decrease unnecessary prescriptions, and ensure that clients receive the correct antibiotic at the correct dose for the appropriate duration (Bankar et al., 2022). ASPs are mainly integrated into the healthcare context; however, they can also be employed in the community and veterinary medicine.

Core Elements of ASPs

1. Leadership Commitment: Judging from the analysis, there is a general agreement that LSC is critical to the effectiveness of ASPs. These comprise the formation of a multidisciplinary steering committee to manage the program, resource provision, and sustained support for ASP activities (Divecha et al.).

2. Accountability: There should be clear reporting authorities, and the accountability of that particular ASP should be clear, with the roles and responsibilities of the distinct individuals. This assists in checking whether the program is being achieved as planned and whether there is regular progress (O'Shea, 2005).

3. Drug Expertise: ASPs need access to drug knowledge to make decisions about the choice of an antibiotic, its dosage, and regimen duration. This may include pharmacists, specialists in infectious diseases, and other practitioners who have a professional interest in the practice of antimicrobial therapy (Ernst et al., 2009).

4. Actionable Recommendations: The ASPs are supposed to offer implementation advice to healthcare providers involving state-of-the-art research findings and local resistance profiles. These guidelines may encompass the type of antibiotics that should be used, the frequency of administering them, and the length of treatment (Elliott et al., 2004).

5. Education and Feedback: Training and education are also components of ASPs. Educational interventions need to be implemented focusing on healthcare practitioners regarding antimicrobial stewardship principles, current guidelines, and local resistance patterns. Prescribing reviews for staff members should be conducted frequently to reveal potential problem areas in the practice (Carter et al., 2021).

6. Tracking and Reporting: ASPs should periodically evaluate and report on the use of antibiotics and resistance data to assess the outcomes of measures and define further directions for

enhancing practice. This data can also help inform intervention and policy in the field of public health (Pezzani et al., 2020).

Infection Prevention and Control Measures

Infection prevention and control (IPC) is acknowledged as one of the key approaches to stopping the emergence of superbugs and lessening their effects. These plans are aimed at termination of further transmission of infection, decreasing HAI contraction, and protecting the exposed people (Percival et al., 2014). IPC strategies encompass a wide range of interventions, including IPC can be described with the help of several approaches and measures that can be grouped as follows:

1. Hand Hygiene: IPC begins with hand washing, which is among the most effective and costless techniques for combating contaminants. Every worker in healthcare, clients, and visitors should wash their hands with water and soap or use alcohol-based hand rub, before and after contact with a patient, object device, or equipment (Swan & McDonald, 2020). Having substantiated it the adherence to hand washing protocols can be of considerable assistance in the fight against HAIs and the promotion of non-resistance to antibiotics.

2. Personal Protective Equipment (PPE): Gloves and gowns, masks, and the protection of eyes are essential since they are barriers to pathogenic organisms to both, workers and patients. Depending on the pathogen or the probability of the pathogen circulating in the community or from the patient to the caregiver, a typical form of PPE involves (Harland, 2020). The measures involving personal protective equipment include proper wearing or putting on and removing or taking off. Governments, international organizations, and private foundations are funding activities that aim at directing resources to identify and develop new antibiotics, especially with the evolving multidrug-resistant pathogens. Such steps include offering crumbs for research grants, providing tax credits for working on antibiotic production, and increasing the ease of regulatory processes (van Hamelen).

Alternative Therapies and Innovations

Other approaches that are currently under active investigation, include the identification of new sources of antibiotics and other therapies for the superbugs. These include:

1. Phage Therapy: Almost all of the phages are bacteria that can kill bacteria that have affected a human being. The process that entails the application of phages to eliminate particular bacterial diseases is known as phage therapy. It has been used to some extent in treating infections caused by multidrug-resistant bacteria, though more research is required to standardize the approach and its outcomes (Nørgaard et al., 2019). Clinical trials have already been carried out to assess the prospect of phage therapy against different infections such as *Pseudomonas aeruginosa* and *Staphylococcus aureus*.

2. Monoclonal Antibodies: These are small manufactured proteins for inhibitory uses in bacterial cell physiology: either immobilizing the bacteria or occupying its destruction by the immune system. These therapies are under consideration for use in infections by drug-resistant bacteria (MacNair et al., 2024). For instance, a monoclonal antibody against the PcrV protein of *Pseudomonas aeruginosa* is another promising candidate observed only in preclinical essays and now in clinical practice.

3. Vaccines: Vaccination is a strategy that assists in controlling the spread of communicable diseases. The discovery of immunizations against bacterial agents could help decrease the reliance on antibiotic-dependent diseases. Several vaccines developed against bacterial pathogens are in the pipeline, including vaccines against *S. aureus* and *Klebsiella pneumonia* (Mba et al., 2023). Thus, the development of vaccines for bacterial pathogens is difficult; however, if achieved, that would decrease antibiotic consumption and slow down the development of resistance.

7. Challenges in Global Health Governance

The strategy for world and ex-communication of antimicrobial resistance and superbugs has complex and intertwining threats and obstacles, which make governance difficult and slow progress toward long-lasting cures. All these challenges are systematic and complex; hence, their solutions demand multi-sectoral and multi-disciplinary efforts.

Coordinating International Efforts: The Fragmented Landscape describes the attempts at creating such a space by progressive, ambitious, and creative individuals from around the Western world. Therefore, the threat of AMR is global, which means that solutions must be sought at the international level. It is a very complex system where the interaction between many players, namely governments, international organizations such as WHO, FAO, OIE, NGOs, projects, and a profit-driven sector, are involved with different interests and goals (Kiriti Nganga & Mugo, 2018). It results in overlapping of activities, the objectives and goals of the different agencies may collide, and there are no concerted efforts, as observed in the handling of COVID-19 by different countries and international organizations (Lee, 2021). Also, specific legislation, priorities, and available assets can differ from one country to another, thus raising obstacles to cooperation. For instance, differences in the rules regarding the use of antibiotics, infection monitoring and reporting systems, and infection control measures complicate the ability to draw comparisons and share data on the global AMR problem and progress in addressing it (Kirchhelle et al., 2020).

Funding and Resource Allocation: Growing the combating of AMR thus needs capital-intensive investment in research and development of new antibiotics and other treatments, the implementation of surveillance and monitoring networks, the strengthening of IPC programs, and public health education. However, there is a huge disappointment concerning the available and necessary resources (Gill & Prowse, 2012). The funding shortage is even more challenging given that the development of antibiotics is not as profitable as other forms of pharmaceutical research, cutting off private funding. Low- and middle-income countries (LMICs) are in greatest need of resources to address AMR since the latter is most prevalent in these regions, however, the resource availability is significantly limited (Sartelli et al., 2020). Such a situation forms a negative feedback system because confusion in LMICs to combat AMR due to resource constraints merely fuels the propagation of resistant pathogens and more global strain. The World Bank, in their study, pointed out that the impact of the AMR could be a cut of up to 5% of the GDP in LMICs by the year 2050 (Dolamulla, 2021). Due to the insufficiency of resources to invest in health care in LMIC, they cannot support surveillance systems, infection control measures, and public health education hence, they are cages more by AMR.

Political and Economic Barriers: Several challenges affect the process of global health governance due to political and economic factors. Governments may not act in the best interest of people's health, preferencing immediate economic benefits, so policies could encourage the misuse of antibiotics in meat production or hamper the creation of new antibiotics. For example, feeding livestock with antibiotics as growth enhancers is still rampant in some countries although it is agreed to be compounding the issue of AMR (Ahmed et al., 2024). This is due to economic factors that compel farmers to produce food with high yields for the market, and the ramifications that befall consumers' health in the long run are infinitesimal. In addition, profits instead of saving people's lives can become the focus of large pharmaceutical corporations, which may affect agendas and strategies, including delays in bringing new antibiotics to the market due to the desire to gain more profits. This is apparent in the few acutely needed new antibiotics due to the rising risk of AMR (Chandra et al., 2021). New antibiotics are not being created effectively due to the current economic structure because it is unprofitable to develop a drug.

Cultural and Behavioral Factors: The New Perspectives

This chapter also shows that principles and behavior are major factors of AMR. Many of

the principles used antibiotics for illnesses as simple as headaches, or colds, which has introduced the wrong prescription and wrong use of the antibiotics. This, in combination with the growing practice of antibiotics without a prescription, further worsens the situation (Dyar et al., 2016). Across most nations, the consumption of antibiotics without proper prescription from professional health care practitioners has become the new tradition in others due to reasons such as; inaccessible health care, poverty, and lack of understanding of the right use of antibiotics. In other situations, the patients may not even finish their antibiotics as prescribed; this may be attributed to ignorance or inability to afford the drugs, thus adding to the development of resistance (Sachdev et al., 2022). This is especially detrimental in LMICs, in which the patients may not be able to seek the services of a healthcare professional to follow up on the patient's treatment progress or may be financially unable to complete the course of antibiotics. To alter such a strong-rooted culture, it is essential to launch long-term and specific health promotional activities that help inform the public about the threats of AMR and the irrational use of antibiotics. It also requires solving fundamental social issues such as poverty, lack of health care access, and sanitation, which in turn are the precursors of the resistant pathogen agents. Research evidence indicates that efforts directed towards changing the doctor's and public knowledge can lead to a considerable decrease in the use of antibiotics (Awad & Aboud, 2015). But, as you're probably aware, converting culture and modifying behavioral patterns isn't a quick and easy task and would still need the exertion of lots of time, money, and resources. Altogether, it is clear that the obstacles to global health governance are huge but by no means insurmountable. Thus, by recognizing these threats and efforts to overcome them, combining financial resources, improving coordination, and overcoming political and sociocultural factors, the fight against AMR and the health of future generations might be strengthened.

8. Opportunities for strengthening the structure of global health governance

Thus, despite the comprehensible obstacles in the global health governance settings that have emerged in response to AMR, the issues are far from irreversible. There are quite a few scenarios that depict how these frameworks can be enforced and improved to pave the way for enhanced global cooperation that would help to avert the emergence of superbugs altogether.

Enhancing Surveillance and Reporting Systems: Among these interfaces, the one considered the most significant point of intervention in efforts to improve the framework of global health governance is the systems of surveillance and reporting. The surveillance systems must be strong and all-encompassing to detect antibiotic-resistant bacteria, trends of antibiotic usage, and the efficacy of the implemented strategies (Rajput, 2023). The effectiveness of extensions in the coverage and the range of such programs, such as Global Surveillance of Antimicrobial Resistance (GLASS), would inspire accurate measurement of the actual burden. Science and specimen increase of whole-genome sequencing and other molecular tools can improve the timeliness and precision in categorizing pathogens and their resistance profiles (Trotter et al., 2019). In addition, possible threats and the international dissemination of pathogens with increased resistance must be elucidated based on global cooperation in the sharing and analysis of data. Successful multifaceted systems for collecting and improving international cooperation include the Global Antimicrobial Resistance Surveillance System (GLASS), founded by the WHO, and the European Antimicrobial Resistance Surveillance Network (EARS-Net) (Malania et al., 2021).

Promoting Global Cooperation and Collaboration: It upholds that the AMR crisis involves more than a nation's issue and, therefore, requires multilateral effort to tackle the issues involved. International organizations, such as WHO, FAO, and OIE, are critical in directing global relations and standards setting, besides offering advisory on issues affecting countries (Kouba). However, for them to be effective, members of the international community must be willing participants in the facing initiatives. Strengthening global cooperation involves several key strategies:

1. Political Commitment: This requires political commitment from senior political leaders in governments to enable them to mobilize resources and policies and implement effective interventions.

This includes pushing for global frameworks such as the Global Action Plan on AMR and for AMR to be incorporated in-country health and development blueprints (Bhatia, 2021).

2. Capacity Building: OTA capacities in LMICs must be enhanced, especially in surveillance, infection prevention, and antimicrobial stewardship. Hence, an approach to this is through sensitization, administrative support, and financing from the World Bank, the United Nations, and other developed countries (Fox & Brown, 1998).

3. Public-Private Partnerships: It risks polarizing multi-sectoral implementation of strategies on how the public-private partnership through the former party shall address AMR. It can be done by the pharmaceutical companies sharing their work and knowledge in the development of new antibiotics, while on the other hand, governments and international organizations can promote the funding and support the regulation of new antibiotics (Årdal et al., 2016).

4. Civil Society Engagement: Partnering with civil society organizations, such as patient associations, professional associations, and CBOs, is essential for the intended program since it fosters awareness of AMR and develops policies for the right use of antibiotics (September). Through enhancing international collaboration and partnership, there is a need to share knowledge, information, and expertise in combating AMR since it threatens mankind. Thus, the necessary approach is multifaceted and integrated, where a thousand points of light amplify each other's efforts to counter the burden of AMR for the benefit of all.

Genomic Surveillance: Next-generation sequencing of bacterial genomes is transforming AMR surveillance globally, with WGS being the most utilized method. WGS facilitates quick identification of pathogens and their resistance genes that can help in tracking the flow and spread of outbreaks, new developing resistance mechanisms, and, in turn, making recommendations as far as public health is concerned (Organization, 2018). Over the world, programs such as the Global Microbial Identifier (GMI) are using WGS to generate the Global Microbial Genome Catalogue, which enables exposure of information and coordination on new diseases among researchers and health experts (Trees et al., 2015).

Rapid Diagnostics: Rapid diagnostic tests (RDTs) that distinguish the causative organism and its level of sensitivity to antibiotics are needed to avoid irrational antibiotic utilization. Innovations in molecular diagnostics include PCR and various isothermal amplification formats, which have paved the way to highly sensitive and specific RDTs for various pathogens, including MDR organisms (Kaprou et al., 2021).

Artificial Intelligence (AI): Information gathered on AMR surveillance can be used by AI and machine learning to handle big data through pattern recognition and the ability to foresee the creation of new resistance mechanisms (Ali et al., 2023). AI can also be used to promote healthcare providers' decision-making to identify needs and choose the best antibiotics that can be administered in the right combination.

Vaccine Development: Modern vaccines, like mRNA vaccines and recombinant protein vaccines, present different prospects for controlling contagious diseases that antibiotic-resistant bacteria may cause. Although it is difficult to develop a vaccine against bacterial pathogens, successful vaccines could dramatically decrease antibiotic use and thus curb resistance (Khalid & Poh, 2023).

Community Engagement and Public Education: 'Empowering' people and 'communities'

Awareness about AMR, a positive attitude toward responsible antibiotic use, and a desire to change one's behavior requires communication strategies and community engagement. Public health-promoting messages enhance individual knowledge on matters related to health, remind people to consult a medical practitioner in cases of an ailment and reduce the rate of antibiotic overuse (Anjuli, 2019). Many methods of communication can be used for targeted stakeholders; these are mass

media, social media, learning institutions, and NGOs. It is essential to provide messages that are adapted to cultural and social settings (Waters & Lo, 2012). Community engagement methodologies are stakeholders' collaboration with LMIC leaders, health professionals, and CBOs for information sharing concerning AMR. Participatory workshops and or peer education, for instance, are efficient in behavior change and capacity development of communities to handle AMR proactively (Lambraki et al., 2021). Applying technologically advanced solutions and working with communities, it is possible to advance the concept of global health governance and create better conditions for global health preparedness to fight the dangers of the AMR threat. These interventions, along with timely identification through necessary surveillance systems, proper antimicrobial stewardship program, and strong infection prevention and control measures give a holistic approach to combat superbugs, to protect the current and future generations' health.

9. Effective Governing: Case Studies

However, the global fight against AMR is not entirely devoid of success. The following national and regional programs have also shown effective ways towards good governance and have been inspirational in inspiring newer ideas to counter this problem. The causes of rum have also demonstrated that national and regional programs can underpin efficient governance.

Denmark: AMR has been alarming globally in the last decades, and Denmark has been at the forefront of fighting this menace (Majumder et al., 2020). One Health approach of working at the human-animal interface, high standards of animal welfare and food safety have been achieved in the country without compromising the diminished rate of antibiotic usage in both the human and animal health sectors. This has been done via appropriate legislation and measures on the management of antibiotics, surveillance, monitoring, and education targeting diverse groups and members of the population (Wall, 2019).

Netherlands: The Netherlands has also achieved major shifts in decreasing the use of antibiotics, which involve antimicrobial stewardship in hospitals and primary care, limitations on giving antibiotics to agriculture, and public campaigns (Allerberger et al., 2009). As a consequence of these measures, the consumption of antibiotics and the growth of resistance have been reduced not only for people but also for animals.

Kerala, India: AMR surveillance and control interventions in Kerala state of India is one of the best practice models of CBIs as seen in previous literature. As part of the program, CLWAs have to first engage the community in raising awareness of AMR, the appropriate use of antibiotics for treating infections, and prescribing and reporting of AMR-related infections (Diskin, 2021). It has built onto the awareness created about AMR apart from advocating for community participation in the prevention and control of AMR.

Innovations in Policy and Practice: Feasible New Directions for Change

Innovations of policies and practices that are recognized today to curb AMR have started to trickle in in the recent past. These include:

1. Antibiotic Incentives: Governments and international organizations are assessing an innovative financing option correctly termed pull incentives for developing new antibiotics. These incentives involve providing financial incentives in terms of the revenues controlled by pharmaceutical corporations to value the creation and commercialization of new antibiotics (Dutescu & Hillier, 2021).

2. Diagnostics and Decision Support: New diagnostic tools, point-of-care tests, and Whole-Genome Sequencing are under development to facilitate quicker and correct identification of pathogens that are resistant to a particular antibiotic and, thus, the right decisions regarding treating the disease. Machine learning strategies are also proposed to recommend the best antibiotic

regimens for therapy (Wang et al., 2024).

3. Alternative Therapies: Studies are being conducted for the development of non-antibiotics as these are defined as phage therapy, monoclonal antibodies, and vaccines (Ozma et al., 2023). These therapies encompass potential solutions for infections caused by multidrug-resistant bacteria and may well be an important element in lowering the dependence on antibiotics.

10. Future Directions and Recommendations: Toward a World After Antibiotics

As AMR emerges as the world's greatest problem, it is crucial to envision a future free from superbugs and start preparing right now. These include risk identification and assessment and the formation of sustainable and fairly strong health systems, the delivery of a package of measures and interventions.

Emerging Trends and Future Threats

Some of the emerging trends include more frequent identification of resistance mechanisms and pathogens periodically. The future threats include AMR is an evolving discipline as the world changes continuously in different ways. Some of the emerging trends and future threats include: The future threats and emerging trends includes the following;

1. The Rise of Pan-Resistant Bacteria: This development entails the production of bacteria that are resistant to all existing types of antibiotics. These pathogens are a nuisance to human health since they cause untreatable infections characterized by high mortality rates (Khabbaz et al., 2015).

2. The Spread of AMR in LMICs: Currently, the impact of AMR is most acutely felt in developing nations, or LMICs, mainly because of the inclination toward substandard healthcare infrastructures, poor sanitation, and the utilization of antibiotics for some treatment sessions. AMR is a critical threat to the health of people living in LMICs, and if left unchecked, it will eventually spread to affect the world's population (Otaigbe & Elikwu, 2023).

3. The Impact of Climate Change on AMR: Climate change could aggravate the AMR scenario because it alters the distribution and methods of transmission of pathogens, increases the vulnerability to infections, and provides appropriate environmental factors in the development of antibiotic-resistant bacteria (Allel, 2021).

Importance of Sustainable and Resilient Health Systems

Access to strong and efficient health systems is, therefore, a critical aspect when planning to confront the AMR problem. This encompasses improving health facilities, providing measures to prevent and control infections, increasing the capacity to monitor and report infectious diseases and diseases of public health importance, and providing health to all. Thus, it has been stated that well-functioning health systems can identify and manage episodes of ARIs, treat patients properly, and conduct preventive efforts to control the development of AMR (Costa et al., 2021).

Implementation Strategies for Policies by Global Health Leaders

To address the complex challenges posed by AMR, global health leaders must prioritize the following policy recommendations: So, to overcome the numerous challenges presented by AMR, the international health officers have the following policies to adopt:

1. Invest in Research and Development: There is also the need to foster research where they shall develop new antibiotics, other therapies, and better diagnostics tests. This involves backing both the need to extend edging knowledge on the tactics of resistance as well as efforts to improve its practical application (Hale, 2008).

2. Strengthen Surveillance and Monitoring Systems: Improving detections and assessments at local, regional, and global levels is critical for mapping more resistant pathogens, recognizing vulnerable groups and spaces, and appraising prevention measures (Palaniyandi et al., 2017).

3. Promote Antimicrobial Stewardship: Commissioning and enhancing the ASP in all healthcare facilities is important for the effective use of antibiotics and the avoidance of unnecessary prescriptions, with exemplary measures to counter resistance (Emberger et al., 2018).

4. Improve Infection Prevention and Control: To combat the issue, policies to improve IPC and practices to eliminate the spread of resistant pathogens within HCWs, facilities, and communities should be implemented. These measures cover awareness creation of practices such as hand washing, vaccination, safe water and sanitation handling, and proper waste disposal (Nahimana et al., 2017).

5. Foster Global Collaboration: AMR affects all countries worldwide, so strategies must be used to reach people worldwide. Enhancing regional interoperation and cooperation is valuable for information exchange, resources, policies, and programs, as well as for learning from other countries experiences and how they tackled the problem (Boekholt & Thuriaux, 1999). With these policy recommendations in place, global health leaders can map out a course toward a future where AMR poses no more risks to the two kinds of security. Nevertheless, despite being quite a difficult task, it is crucial for the benefit of current and future generations.

11. Conclusion

Training germs that are resistant to medicines, the concept of AMR, and the existence of superbugs are undoubtedly a headache of the future for the whole world of every health sector. Very often, dynamic and coordinated changes in biological, social, economic, and political aspects create a multilayered context of human rights issues that cannot afford to wait long-term, not to mention individual action. The consequences of doing nothing are severe, possibly eradicating up to a hundred years of achievements in the medical field and widening the inequality gap in the healthcare system. In this extremely comprehensive collection of microbial threats, which are now greatly worsened by the new generation of superbugs, the solutions to the AMR issue have been described in this work. We have mentioned how exactly these sticky bacteria and other microorganisms are in a position to counteract or, at the very least, withstand the effects of antibiotics, what may be the reason for the incapability of those small enemies to be influenced, and how devastating superbugs can be to everyone around the world's health care system, economy, and people. The institutions, the agreements, the policies of the G7, and the other additional layers of the international regulation of health governance offer order to action. However, it is being practiced with some difficulties, such as Inadequate and fragmented coordination, poor funding for programs and services, conflicting interests, and cultural differences, among others. However, at the same time, the potential for future developments and strengthening of the governance of global health is still very vast. Thus, surveillance and reporting events should be enhanced, countries' cooperation should be better performed, technology growth should be introduced, and community engagement should be advanced to strengthen the world for the future. Therefore, Danish, Dutch, and the experience of the Indian state of Kerala illustrate what is possible at the national and regional levels, based on which further steps should be taken. It proves that by employing a series of practices in various sectors, such as proper antibiotic usage, infection prevention and control, and raising and creating awareness, one could fight AMR. Hence, the positive or negative outcome of all such attempts to predict and influence the global health of future hits and misses depends on the appropriate resolution of the AMR issue. The current situation of AMR involves the effects of climate change and the development of pan-resistant bacteria, to mention but a few. Thus, it is high time for the top priority to concerted and take rapid action to strengthen and expand health-system research and development financing. Lastly, it can be affirmed that the fight against superbugs is all about time. This war engulfs them on international, multidisciplinary, and multisectoral levels.

The stakes are high, but the potential rewards are even greater: future, where people are no longer dying from communicable diseases or where modern medicine is still a perfect way of eradicating diseases, diseases, and illnesses, are effectively tackled without any impact on people's earnings and where every individual in the world can get good and effective health care services. This is a future that the world's population will cheer for if it is being sought and carried out at the present.

References

Aarestrup, F. M. (2015). The livestock reservoir for antimicrobial resistance: a personal view on changing patterns of risks, effects of interventions and the way forward. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 370(1670), 20140085.

Ahmed, S. K., Hussein, S., Qurbani, K., Ibrahim, R. H., Fareeq, A., Mahmood, K. A., & Mohamed, M. G. (2024). Antimicrobial resistance: impacts, challenges, and future prospects. *Journal of Medicine, Surgery, and Public Health*, 2, 100081.

Aijaz, M., Ahmad, M., Ansari, M. A., & Ahmad, S. (2023). Antimicrobial Resistance in a Globalized World: Current Challenges and Future Perspectives. *International Journal of Pharmaceutical Drug Design*, 1(1), 7-22.

Alhumaid, S., Al Mutair, A., Al Alawi, Z., Alsuliman, M., Ahmed, G. Y., Rabaan, A. A., Al-Tawfiq, J. A., & Al-Omari, A. (2021). Knowledge of infection prevention and control among healthcare workers and factors influencing compliance: a systematic review. *Antimicrobial Resistance & Infection Control*, 10(1), 86.

Ali, T., Ahmed, S., & Aslam, M. (2023). Artificial intelligence for antimicrobial resistance prediction: challenges and opportunities towards practical implementation. *Antibiotics*, 12(3), 523.

Allel, K. (2021). Exploring the Relationship between Climate Change and Antimicrobial-resistant Bacteria: To What Extent Does This Present a Current and Long-term Threat to Population Health? *International Journal of Climate Change: Impacts & Responses*, 13(1).

Allerberger, F., Gareis, R., Jindrák, V., & Struelens, M. J. (2009). Antibiotic stewardship implementation in the EU: the way forward. *Expert Review of Anti-infective Therapy*, 7(10), 1175-1183.

ALSAAD, M. M., & ZAFER, M. (2023). Antibiotic Resistance in Microorganisms–Current Status. *Quorum Quenching: A Chemical Biological Approach for Microbial Biofilm Mitigation and Drug Development*(22), 175.

Ananda, T., Modi, A., Chakraborty, I., Managuli, V., Mukhopadhyay, C., & Mazumder, N. (2022). Nosocomial infections and role of nanotechnology. *Bioengineering*, 9(2), 51.

Anjuli, B. (2019). Communicating Antibiotic Resistance to the Public: How effective was Public Health England's 2018 'Keep Antibiotics Working' campaign TV advertisement at increasing public understanding of antibiotic resistance and motivating a change in antibiotic seeking behaviours? In: *Malmö universitet/Kultur och samhälle*.

Apisarnthanarak, A., Siripraparat, C., Apisarnthanarak, P., Ullman, M., Saengaram, P., Leeprechanon, N., & Weber, D. J. (2021). Patients' anxiety, fear, and panic related to coronavirus disease 2019 (COVID-19) and confidence in hospital infection control policy in outpatient departments: A survey from four Thai hospitals. *infection control & hospital epidemiology*, 42(10), 1288-1290.

Arafa, M. (2019). Factors influencing emergence and spread of antibiotic resistance in Egypt using a one health approach.

Årdal, C., Outterson, K., Hoffman, S. J., Ghafur, A., Sharland, M., Ranganathan, N., Smith, R., Zorzet, A., Cohn, J., & Pittet, D. (2016). International cooperation to improve access to and sustain effectiveness of antimicrobials. *The lancet*, 387(10015), 296-307.

Awad, A. I., & Aboud, E. A. (2015). Knowledge, attitude and practice towards antibiotic use among the public in Kuwait. *PloS one*, 10(2), e0117910.

Bankar, N. J., Ugemuge, S., Ambad, R. S., Hawale, D. V., & Timilsina, D. R. (2022). Implementation of antimicrobial stewardship in the healthcare setting. *Cureus*, 14(7).

Basset, P., Feil, E. J., Zanetti, G., & Blanc, D. S. (2011). The evolution and dynamics of methicillin-resistant *Staphylococcus aureus*. In *Genetics and Evolution of Infectious Disease* (pp. 669-688). Elsevier.

Bhatia, R. (2021). National Framework for One Health. Food & Agriculture Org.

Binot, A., Duboz, R., Promburom, P., Phimpraphai, W., Cappelle, J., Lajaunie, C., Goutard, F. L., Pinyopummintr, T., Figuié, M., & Roger, F. L. (2015). A framework to promote collective action within the One Health community of practice: using participatory modelling to enable interdisciplinary, cross-sectoral and multi-level integration. *One Health*, 1, 44-48.

Boekholt, P., & Thuriaux, B. (1999). Public policies to facilitate clusters: background, rationale and policy practices in international perspective. *Boosting innovation: the cluster approach*, 381-412.

Bristol, N. (2020). The US Government and Antimicrobial Resistance. JSTOR.

Carter, M., Chapman, S., & Watson, M. C. (2021). Multiplicity and complexity: a qualitative exploration of influences on prescribing in UK general practice. *BMJ open*, 11(1), e041460.

Chandra, P., Mk, U., Ke, V., Mukhopadhyay, C., U, D. A., & V, R. (2021). Antimicrobial resistance and the post antibiotic era: better late than never effort. *Expert opinion on drug safety*, 20(11), 1375-1390.

Chilemya, M. S. (2016). Mental health services in Zambia; past, present and future.

Christaki, E., Marcou, M., & Tofarides, A. (2020). Antimicrobial resistance in bacteria: mechanisms, evolution, and persistence. *Journal of molecular evolution*, 88(1), 26-40.

Cordeiro, J., & Wood, D. (2023). How Much Does It Cost? In *The Death of Death: The Scientific Possibility of Physical Immortality and its Moral Defense* (pp. 97-127). Springer.

Costa, A. L., Privitera, G. P., Tulli, G., & Toccafondi, G. (2021). Infection prevention and control. *Textbook of patient safety and clinical risk management*, 99-116.

Das, S. (2023). The crisis of carbapenemase-mediated carbapenem resistance across the human–animal–environmental interface in India. *Infectious Diseases Now*, 53(1), 104628.

Dasgupta, S. P. (2021). The economics of biodiversity the Dasgupta review abridged version.

Davies, J. (2013). *Cracked: Why psychiatry is doing more harm than good*. Icon Books Ltd.

Diskin, M. G. (2021). ONE HEALTH: Awareness to Action Antimicrobial and Anthelmintic Resistance Conference.

Divecha, C., Tullu, M., & Karande, S. Challenges in implementing an Antimicrobial Stewardship Program (ASP) in developing countries. In (pp. 10.4103): Medknow.

Dolamulla, S. S. (2021). Reconsidering middle-Income country approaches to a global antimicrobial resistance (AMR) problem: A case study of Sri Lanka University of York].

Domínguez, D. C., & Meza-Rodriguez, S. M. (2019). Development of antimicrobial resistance: Future challenges. In *Pharmaceuticals and Personal Care Products: Waste Management and Treatment Technology* (pp. 383-408). Elsevier.

Doron, A., & Broom, A. (2019). The spectre of superbugs: waste, structural violence and antimicrobial resistance in India. *Worldwide Waste*, 2(1), 7-7.

Dutescu, I. A., & Hillier, S. A. (2021). Encouraging the development of new antibiotics: are financial incentives the right way forward? A systematic review and case study. *Infection and Drug Resistance*, 415-434.

Dyar, O. J., Obua, C., Chandy, S., Xiao, Y., Stålsby Lundborg, C., & Pulcini, C. (2016). Using antibiotics responsibly: are we there yet? *Future microbiology*, 11(8), 1057-1071.

Elliott, T., Foweraker, J., Gould, F., Perry, J., & Sandoe, J. (2004). Guidelines for the antibiotic treatment of endocarditis in adults: report of the Working Party of the British Society for Antimicrobial Chemotherapy. *Journal of Antimicrobial Chemotherapy*, 54(6), 971-981.

Emberger, J., Tassone, D., Stevens, M. P., & Markley, J. D. (2018). The current state of antimicrobial stewardship: challenges, successes, and future directions. *Current infectious disease reports*, 20, 1-12.

Endale, H., Mathewos, M., & Abdeta, D. (2023). Potential causes of spread of antimicrobial resistance and preventive measures in one health perspective-a review. *Infection and Drug Resistance*, 7515-7545.

Ernst, E. J., Klepser, M. E., Bosso, J. A., Rybak, M. J., Hermesen, E. D., Segarra-Newnham, M., & Drew, R. H. (2009). Recommendations for Training and Certification for Pharmacists Practicing, Mentoring, and Educating in Infectious Diseases Pharmacotherapy: Joint Opinion of the Society of Infectious Diseases Pharmacists and the Infectious Diseases Practice and Research Network of the American College of Clinical Pharmacy. *Pharmacotherapy: The Journal of Human Pharmacology and Drug Therapy*, 29(4), 482-488.

Fairley, C. CAE. ethics, 6, 1Z2.

Farhat, N., Ali, A., Bonomo, R. A., & Khan, A. U. (2020). Efflux pumps as interventions to control infection caused by drug-resistance bacteria. *Drug Discovery Today*, 25(12), 2307-2316.

Fatima, H., Goel, N., Sinha, R., & Khare, S. K. (2021). Recent strategies for inhibiting multidrug-resistant and β -lactamase producing bacteria: A review. *Colloids and Surfaces B: Biointerfaces*, 205, 111901.

Fontanot, A., Ellinger, I., Unger, W. W., & Hays, J. P. (2024). A Comprehensive Review of Recent Research into the Effects of Antimicrobial Peptides on Biofilms—January 2020 to September 2023. *Antibiotics*, 13(4), 343.

Fox, J. A., & Brown, L. D. (1998). *The struggle for accountability: The World Bank, NGOs, and grassroots movements*. MIT press.

Gill, D., & Prowse, V. (2012). A structural analysis of disappointment aversion in a real effort competition. *American Economic Review*, 102(1), 469-503.

Greco, S., Putans, R., & Springe, L. (2022). Antimicrobial and antibiotic resistance in developing countries: Health economics, global governance, and sustainable development goals. In *Antimicrobial Resistance* (pp. 113-140). CRC Press.

Haider, R. (2023). Penicillin and the Antibiotics Revolution Global History. *Asian Journal of Pharmaceutical Research*, 13(1), 55-62.

- Hale, C. R. (2008). *Engaging contradictions: Theory, politics, and methods of activist scholarship*. Univ of California Press.
- Hamrefors, V. (2014). Cardiovascular Risk Genes in Prevention and Treatment Response.
- Harland, D. (2020). *INFECTION CONTROL: UNDERSTANDING DISEASES, EPIDEMIOLOGY, AND PATHOGEN TRANSMISSION*.
- Hartwig, R., & Segura Kliesow, P. (2020). Antimicrobial Resistance between Lack of Access and Excess.
- Hein, W., Aglanu, L. M., Mensah-Sekyere, M., Harant, A., Brinkel, J., Lamshöft, M., Lorenz, E., Eibach, D., & Amuasi, J. (2022). Fighting antimicrobial resistance: development and implementation of the Ghanaian national action plan (2017–2021). *Antibiotics*, 11(5), 613.
- Hijazi, K., Joshi, C., & Gould, I. M. (2019). Challenges and opportunities for antimicrobial stewardship in resource-rich and resource-limited countries. *Expert Review of Anti-infective Therapy*, 17(8), 621-634.
- Hulscher, M., & Prins, J. (2017). Antibiotic stewardship: does it work in hospital practice? A review of the evidence base. *Clinical microbiology and infection*, 23(11), 799-805.
- Humboldt-Dachroeden, S., & Mantovani, A. (2021). Assessing environmental factors within the one health approach. *Medicina*, 57(3), 240.
- Iman Islamieh, D., Afshar, D., Yousefi, M., & Esmaeili, D. (2018). Efflux pump inhibitors derived from natural sources as novel antibacterial agents against *Pseudomonas aeruginosa*: a review. *International Journal of Medical Reviews*, 5(3), 94-105.
- Justham, D. (2014). *A study of nursing practices used in the management of infection in hospitals, 1929-1948*. The University of Manchester (United Kingdom).
- Kaprou, G. D., Bergšpica, I., Alexa, E. A., Alvarez-Ordóñez, A., & Prieto, M. (2021). Rapid methods for antimicrobial resistance diagnostics. *Antibiotics*, 10(2), 209.
- Khabbaz, R., Bell, B. P., Schuchat, A., Ostroff, S. M., Moseley, R., Levitt, A., & Hughes, J. M. (2015). Emerging and reemerging infectious disease threats. *Mandell, Douglas, and Bennett's principles and practice of infectious diseases*, 158.
- Khalid, K., & Poh, C. L. (2023). The promising potential of reverse vaccinology-based next-generation vaccine development over conventional vaccines against antibiotic-resistant bacteria. *Vaccines*, 11(7), 1264.
- Kirchhelle, C., Atkinson, P., Broom, A., Chuengsatiansup, K., Ferreira, J. P., Fortané, N., Frost, I., Gradmann, C., Hinchliffe, S., & Hoffman, S. J. (2020). Setting the standard: multidisciplinary hallmarks for structural, equitable and tracked antibiotic policy. *BMJ Global Health*, 5(9), e003091.
- Kiriti Nganga, T., & Mugo, M. G. (2018). Impact of economic regimes on food systems in Kenya.
- Kırmusaoğlu, S. (2017). MRSA and MSSA: The mechanism of methicillin resistance and the influence of methicillin resistance on biofilm phenotype of *Staphylococcus aureus*. *The Rise of Virulence and Antibiotic Resistance in Staphylococcus aureus*; Enany, S., Ed, 25-41.
- Kouba, V. Critical analysis of the OIE Code for international trade facilitating irreparable globalization of animal infections.
- Kpokiri, E. E. (2019). *Optimizing antibiotic prescribing in Nigerian hospitals UCL (University College London)*].

- Kumar, S. B., Arnipalli, S. R., & Ziouzenkova, O. (2020). Antibiotics in food chain: The consequences for antibiotic resistance. *Antibiotics*, 9(10), 688.
- Lalchhandama, K. (2021). History of penicillin. *WikiJournal of Medicine*, 8(1), 1-16.
- Lambraki, I. A., Majowicz, S. E., Parmley, E. J., Wernli, D., Léger, A., Graells, T., Cousins, M., Harbarth, S., Carson, C., & Henriksson, P. (2021). Building social-ecological system resilience to tackle antimicrobial resistance across the one health spectrum: protocol for a mixed methods study. *JMIR Research Protocols*, 10(6), e24378.
- Lee, J. (2021). Fragmented before a Global Menace: WHO, COVID-19 and the Fragmentation of International Law. *Hong Kong LJ*, 51, 169.
- Lobanovska, M., & Pilla, G. (2017). Focus: drug development: Penicillin's discovery and antibiotic resistance: lessons for the future? *The Yale journal of biology and medicine*, 90(1), 135.
- MacNair, C. R., Rutherford, S. T., & Tan, M.-W. (2024). Alternative therapeutic strategies to treat antibiotic-resistant pathogens. *Nature Reviews Microbiology*, 22(5), 262-275.
- Majumder, M. A. A., Rahman, S., Cohall, D., Bharatha, A., Singh, K., Haque, M., & Gittens-St Hilaire, M. (2020). Antimicrobial stewardship: fighting antimicrobial resistance and protecting global public health. *Infection and Drug Resistance*, 4713-4738.
- Malania, L., Wagenaar, I., Karatuna, O., Andrasevic, A. T., Tsereteli, D., Baidauri, M., Imnadze, P., Nahrgang, S., & Ruesen, C. (2021). Setting up laboratory-based antimicrobial resistance surveillance in low-and middle-income countries: lessons learned from Georgia. *Clinical microbiology and infection*, 27(10), 1409-1413.
- Mba, I. E., Sharndama, H. C., Anyaegbunam, Z. K. G., Anekpo, C. C., Amadi, B. C., Morumda, D., Doowuese, Y., Ihezuo, U. J., Chukwukelu, J. U., & Okeke, O. P. (2023). Vaccine development for bacterial pathogens: Advances, challenges and prospects. *Tropical Medicine & International Health*, 28(4), 275-299.
- Michaud, A., Stawicki, S. P., Izurieta, R., & Iyer-Raniga, U. (2024). *Global Health Security: Contemporary Considerations and Developments*. BoD–Books on Demand.
- Mitra, S., Sultana, S. A., Prova, S. R., Uddin, T. M., Islam, F., Das, R., Nainu, F., Sartini, S., Chidambaram, K., & Alhumaydhi, F. A. (2022). Investigating forthcoming strategies to tackle deadly superbugs: current status and future vision. *Expert Review of Anti-infective Therapy*, 20(10), 1309-1332.
- Mohammed, A. H., Blebil, A., Dujaili, J., & Rasool-Hassan, B. A. (2020). The risk and impact of COVID-19 pandemic on immunosuppressed patients: cancer, HIV, and solid organ transplant recipients. *AIDS reviews*, 22(3), 151-157.
- Moloney-Omar, K. (2022). Analysis of the progress of antimicrobial resistance management in the pacific island countries and territories through the development and implementation of national action plans.
- Monnier, A. A., Schouten, J., Tebano, G., Zanichelli, V., Huttner, B. D., Pulcini, C., Årdal, C., Harbarth, S., Hulscher, M. E., & Gyssens, I. C. (2019). Ensuring antibiotic development, equitable availability, and responsible use of effective antibiotics: recommendations for multisectoral action. *Clinical Infectious Diseases*, 68(11), 1952-1959.
- Mudenda, S., Chabalenge, B., Daka, V., Mfuno, R. L., Salachi, K. I., Mohamed, S., Mufwambi, W., Kasanga, M., & Matafwali, S. K. (2023). Global strategies to combat antimicrobial resistance: a one health perspective. *Pharmacology & Pharmacy*, 14(8), 271-328.

Nahimana, M.-R., Ngoc, C. T., Olu, O., Nyamusore, J., Isiaka, A., Ndahindwa, V., Dassanayake, L., & Rusanganwa, A. (2017). Knowledge, attitude and practice of hygiene and sanitation in a Burundian refugee camp: implications for control of a *Salmonella typhi* outbreak. *Pan African Medical Journal*, 28(1).

Nørgaard, S. M., Jensen, C. S., Aalestrup, J., Vandenbroucke-Grauls, C. M., De Boer, M. G., & Pedersen, A. B. (2019). Choice of therapeutic interventions and outcomes for the treatment of infections caused by multidrug-resistant gram-negative pathogens: a systematic review. *Antimicrobial Resistance & Infection Control*, 8, 1-13.

O'Shea, M. R. (2005). *From standards to success: A guide for school leaders*. ASCD.

Organization, W. H. (2018). Whole genome sequencing for foodborne disease surveillance: landscape paper.

Otaigbe, I. I., & Elikwu, C. J. (2023). Drivers of inappropriate antibiotic use in low-and middle-income countries. *JAC-Antimicrobial Resistance*, 5(3), dlad062.

Ozma, M. A., Moaddab, S. R., Hosseini, H., Khodadadi, E., Ghotaslou, R., Asgharzadeh, M., Abbasi, A., Kamounah, F. S., Aghebati Maleki, L., & Ganbarov, K. (2023). A critical review of novel antibiotic resistance prevention approaches with a focus on postbiotics. *Critical reviews in food science and nutrition*, 1-19.

Pal, C., Asiani, K., Arya, S., Rensing, C., Stekel, D. J., Larsson, D. J., & Hobman, J. L. (2017). Metal resistance and its association with antibiotic resistance. *Advances in microbial physiology*, 70, 261-313.

Palaniyandi, M., Anand, P., & Pavendar, T. (2017). Environmental risk factors in relation to occurrence of vector borne disease epidemics: Remote sensing and GIS for rapid assessment, picturesque, and monitoring towards sustainable health. *International Journal of Mosquito Research*, 4(3), 09-20.

Peraman, R., Sure, S. K., Dusthacker, V. A., Chilamakuru, N. B., Yiragamreddy, P. R., Pokuri, C., Kutagulla, V. K., & Chinni, S. (2021). Insights on recent approaches in drug discovery strategies and untapped drug targets against drug resistance. *Future Journal of Pharmaceutical Sciences*, 7, 1-25.

Percival, S. L., Williams, D., Cooper, T., & Randle, J. (2014). *Biofilms in infection prevention and control: a healthcare handbook*. Academic Press.

Pezzani, M. D., Mazzaferri, F., Compri, M., Galia, L., Mutters, N. T., Kahlmeter, G., Zaoutis, T. E., Schwaber, M. J., Rodríguez-Baño, J., & Harbarth, S. (2020). Linking antimicrobial resistance surveillance to antibiotic policy in healthcare settings: the COMBACTE-Magnet EPI-Net COACH project. *Journal of Antimicrobial Chemotherapy*, 75(Supplement_2), ii2-ii19.

Rajput, A. (2023). Examining the Implementation and Effectiveness of Antibiotic Stewardship Programs in Healthcare Settings to Prevent Antibiotic Resistance and Promote Prudent Antibiotic Use. *Knowledgeable Research: A Multidisciplinary Journal*, 1(11), 11-24.

Ram, S., Panidepu, H., Cheernam, V., & Tyagi, R. (2020). Pharmaceutical metabolites and their by-products in hospital wastewater. In *Current Developments in Biotechnology and Bioengineering* (pp. 43-78). Elsevier.

Riekkki, J., & Mämmelä, A. (2021). Research and education towards smart and sustainable world. *Ieee Access*, 9, 53156-53177.

Rush, M., & Davies, S. C. (2016). *Combating antimicrobial resistance: building consensus*

for global action. *Pathways to global health: case studies in global health diplomacy*, 2, 89-118.

Sachdev, C., Anjankar, A., & Agrawal, J. (2022). Self-medication with antibiotics: an element increasing resistance. *Cureus*, 14(10).

Saeed, D. K., Farooqi, J., Shakoor, S., & Hasan, R. (2021). Antimicrobial resistance among GLASS priority pathogens from Pakistan: 2006–2018. *BMC infectious diseases*, 21, 1-16.

Sartelli, M., C. Hardcastle, T., Catena, F., Chichom-Mefire, A., Coccolini, F., Dhingra, S., Haque, M., Hodonou, A., Iskandar, K., & Labricciosa, F. M. (2020). Antibiotic use in low and middle-income countries and the challenges of antimicrobial resistance in surgery. *Antibiotics*, 9(8), 497.

Segers, J.-P. (2017). The interplay of regional systems of innovation, strategic alliances and open innovation.

Sekyere, J. O., & Asante, J. (2018). Emerging mechanisms of antimicrobial resistance in bacteria and fungi: advances in the era of genomics. *Future microbiology*, 13(2), 241-262.

Selvarajan, R., Obize, C., Sibanda, T., Abia, A. L. K., & Long, H. (2022). Evolution and emergence of antibiotic resistance in given ecosystems: possible strategies for addressing the challenge of antibiotic resistance. *Antibiotics*, 12(1), 28.

September, H. The AMR Challenge.

Shrestha, P., He, S., & Legido-Quigley, H. (2022). Antimicrobial resistance research collaborations in Asia: challenges and opportunities to equitable partnerships. *Antibiotics*, 11(6), 755.

Surya Prakash, D., Gupta, I., Singhal, S., Pal, D., & Munawar, T. M. (2023). Antibiotic Resistance in Pathogens—a Global Concern.

Swan, J., & McDonald, M. (2020). Infection Control Training for New York State Healthcare Professionals.

Törneke, K., Torren-Edo, J., Grave, K., & Mackay, D. (2015). The management of risk arising from the use of antimicrobial agents in veterinary medicine in EU/EEA countries—a review. *Journal of Veterinary Pharmacology and Therapeutics*, 38(6), 519-528.

Trees, E., Rota, P. A., MacCannell, D., & Gerner-Smidt, P. (2015). Molecular epidemiology. *Manual of clinical microbiology*, 131-160.

Trotter, A. J., Aydin, A., Strinden, M. J., & O'grady, J. (2019). Recent and emerging technologies for the rapid diagnosis of infection and antimicrobial resistance. *Current opinion in microbiology*, 51, 39-45.

van Hamelen, E. Pharma Food.

Wall, S. (2019). Prevention of antibiotic resistance—an epidemiological scoping review to identify research categories and knowledge gaps. *Global Health Action*, 12(sup1), 1756191.

Walser, B. L. (1997). Shared Technical Decisionmaking and the Disaggregation of Sovereignty: International Regulatory Policy, Expert Communities, and the Multinational Pharmaceutical Industry. *Tul. L. Rev.*, 72, 1597.

Wang, Y., Liu, A., Yang, J., Wang, L., Xiong, N., Cheng, Y., & Wu, Q. (2024). Clinical knowledge-guided deep reinforcement learning for sepsis antibiotic dosing recommendations. *Artificial Intelligence in Medicine*, 150, 102811.

Waters, R. D., & Lo, K. D. (2012). Exploring the impact of culture in the social media

sphere: A content analysis of nonprofit organizations' use of Facebook. *Journal of intercultural communication research*, 41(3), 297-319.

About The Authors

Maria Nazir is an MPhil Scholar of Microbiology at the Cholistan University of Veterinary and Animal Sciences (CUVAS) in Bahawalpur, Pakistan. She is involved in a National Research Program for Universities (NRPU) Project, with research interests in Molecular Characterization. She has submitted abstracts to various conferences and authored and coauthored of several book chapters. Her research focuses on the isolation and Molecular characterization of *Corynebacterium pseudotuberculosis* and their applications in promoting animal health. Her interested research criteria are based on genetics, molecular biology, and bioinformatics.

Email: nazirmaria545@gmail.com

ORCID 0009-0004-6714-6212

Rohina Arif is a dedicated educator and researcher with a strong academic background in biotechnology. She completed her MPhil in Biotechnology from Quaid-i-Azam University, Islamabad, Pakistan, and is currently pursuing a Master's in Research (MRes) in Molecular Microbiology at Nottingham Trent University, UK. Rohina has served as a Visiting Lecturer at Fatima Jinnah Women's University, Rawalpindi, Pakistan, her teaching and research experience span various domains, including molecular biology, and biotechnology.

Email: rohinaarif11@gmail.com

ORCID Id 0009-0001-5623-8080

Jawad Aslam, doing PhD in Microbiology from Kohat University of Science and Technology Kohat. His research interests include Antibiotic resistance, nanoparticles, and biocontrol. He published one research paper in an HEC-recognized journal and one in a non-HEC-recognised journal.

Email: jawadaslam744@gmail.com
8691

ORCID ID: 0009-0003-3775-

Shafeeq Ur Rehman earned his Bachelor in Applied microbiology from Cholistan University of Veterinary and Animal Sciences (CUVAS) Bahawalpur Pakistan. Currently he is pursuing M. phil in Microbiology from Cholistan University of Veterinary and Animal Sciences (CUVAS) Bahawalpur Pakistan. He is also working as research assistant in a project titled as “Robust Molecular Detection of Silent Circulation of FMD and PPR Viruses in Cholistan as a Model for Disease-Free Zone”. His research interest is in FMD and PPR Viruses, Mucosal Immunity, Virology, Molecular cell biology, Cell culture, Microbial genetics and CRISPR case tools for combating viral diseases. He has published 7 articles and many book chapters in national and international journals.

Email: shafeequrrehmanbhutta@gmail.com

ORCID: 0000-0003-3571-8226

Muhammad Mudussair Khan received his bachelor in 2023 from Cholistan university of veterinary and animal science bhawalpur , Pakistan. He is MPhil microbiology scholar at the Islamia University of Bahawalpur, Pakistan. His research interests include predictive breeding models, Genetic selection, Genomics, reproductive biotechnology and selection and judging of animals for beauty attributes. . He also has written book chapters.

Email: muhammadmudussairkhan@gmail.com

ORCID:0009-0005-9491-2442

Dr. Muhammad SAFDAR earned his PhD in Molecular Biology and Genetics from Gaziantep University, Turkey. He is Lecturer in the Breeding and Genetics department at Cholistan University of Veterinary and Animal Sciences (CUVAS), Bahawalpur, Pakistan. His research interests are molecular genetics and genomics, nutrigenomics, nano-genomics, bioinformatics, biotechnology, and their applications. He has published more than 70 research articles in national and international journals. He has also written many book chapters as well as an edited book. He is an associate editor for international journals.

E-mail: msafdar@cuvas.edu.pk

ORCID: 0000 0002 3720 2090

Prof. Dr. Mehmet ÖZASLAN received his PhD in 1995 Institute of Natural Sciences at Cukurova University, Turkiye. He is a Professor in Molecular Biology and Genetics. His research interests are included Cancer Genetics, Molecular Virology, Molecular Genetics, Microbiology, and Genetic mutations etc. He has published more than 200 research articles in national and international well reputed journals. He also has written many book chapters as well as edited books. He is an editor and editor-in-chief of many well-reputed national and international journals.

E-mail: ozaslanmd@gantep.edu.tr,

ORCID: 0000 0001 9380 4902

To Cite This Chapter

NAZIR M et al., (2024). Microbial threats: global health governance in the age of superbugs In Current Studies in Health and Life Sciences 2024 (pp.48-72). ISRES Publishing.