

A Survey Based Study on Antimicrobial Resistance as a Global Public Health Threat

¹Pritesh S Surana, ²Mubeen Ahmad Mohammad aarif

^{1,2} *Aditya Institute of Pharmacy Derabardi, Industrial Area, Chalisgaon, District-Jalgaon, Maharashtra, 424101*

Abstract—Antibiotics have been one of the most significant medical breakthroughs of the 20th century, saving millions of lives. However, widespread misuse and overuse have led to antimicrobial resistance (AMR), where microbes evolve to withstand these drugs. The discovery of penicillin revolutionized treatment, but today, resistant infections pose a major global health threat. This review highlights the public health impact of AMR, its key drivers (such as over prescription and misuse), and current strategies to combat it. The One Health approach integrating human, animal, and environmental health is emphasized as a crucial framework for controlling resistance. Strategies include antimicrobial stewardship, improved surveillance, and increasing public awareness. A major concern is the lack of new antibiotics being developed, which contrasts sharply with the growing demand due to resistant infections. As a result, treatment options are becoming limited, leading to higher illness rates, deaths, and financial burdens. The article also discusses alternative therapies that could reduce reliance on traditional antibiotics. Overall, it provides a comprehensive overview of AMR and outlines potential strategies and research directions to address this urgent global issue.

Index Terms—Antimicrobials resistance, Antibiotics, mechanisms, pathogens, IPC, Public awareness, vaccination.

I. INTRODUCTION

Antimicrobial resistance (AMR) occurs when microorganisms such as bacteria, viruses, fungi, and parasites evolve and develop the ability to resist drugs designed to kill them, including antibiotics. This makes standard treatments ineffective, leading to infections that are harder or sometimes impossible to treat, and increasing the risk of disease spread, severe illness, and death. Antibiotics are a major class of antimicrobials specifically used to treat bacterial infections, and antibiotic resistance is the most commonly observed form of AMR (3). Antimicrobials, in general, are medicines used to treat and prevent infections in humans, animals, and plants. Today,

AMR has emerged as a significant and growing global public health concern (1).

Antimicrobial resistance (AMR) has emerged as one of the most pressing global public health threats of the 21st century (5). It is responsible for an estimated 4.95 million deaths annually, with around 1.27 million deaths directly attributed to bacterial AMR. Driven largely by the misuse and overuse of antimicrobials in humans, animals, and agriculture, AMR makes infections increasingly difficult to treat and threatens the effectiveness of modern medical practices such as surgeries and chemotherapy (7).

Antimicrobial therapy refers to the use of antimicrobial agents for the treatment, prevention, or control of infectious diseases, including classes of drugs such as β -lactam antibiotics, macrolides, aminoglycosides like streptomycin, anti-tubercular drugs, and antiviral medications (12). Antimicrobial resistance (AMR) is primarily driven by the misuse and overuse of antimicrobials, leading to the emergence of drug-resistant pathogens. Inappropriate use of antibiotics is further compounded by factors such as poverty and inequality, with the burden being particularly high in low- and middle-income countries. Studies indicate that the greatest impact of AMR is observed in regions such as sub-Saharan Africa and South Asia (1). AMR accounts for a significant proportion of global mortality, contributing to approximately 9% of total deaths, with a substantial and continuing rise in associated cases. Despite the urgent need for robust surveillance systems to monitor and control AMR, several challenges hinder effective implementation, notably limitations in data infrastructure and financial resources (12).

Penicillin, discovered by Alexander Fleming in 1928 and widely produced by the 1940s, marked a turning point in modern medicine. However, resistance to antibiotics emerged soon after their introduction (16). Antimicrobial resistance (AMR) has since become a major global health concern, posing a serious threat to effective disease treatment (2). Antibiotics are chemical substances produced by microorganisms such as bacteria and fungi, capable of inhibiting or destroying other microbes even at low concentrations, and are primarily used to treat infectious diseases (9). The first reports of penicillin-resistant *Staphylococcus aureus* appeared as early as 1942, followed by resistance to tetracycline in 1953 (5). These antibiotics were initially highly effective against both Gram-positive and Gram-negative bacteria and became the primary treatment for many bacterial infections. In the late 1950s and early 1960s, the introduction of vancomycin and methicillin provided new advances in treating infections (9). Nevertheless, methicillin-resistant *Staphylococcus aureus* (MRSA) was identified in 1961, demonstrating the rapid ability of bacteria to develop resistance to multiple drug classes

(5). Nalidixic acid, discovered in 1962 and introduced into clinical practice in 1967, was one of the first synthetic quinolone antibiotics and showed effectiveness against a broad range of Gram-positive and Gram-negative bacteria (9).

Years	Development of antimicrobial agents
1928	Discovery of penicillin
1935	Discovery of sulfonamide
1940	Clinical application of penicillin
1950	Discovery of aminoglycoside, chloramphenicol, tetracycline and macrolide
1956	Discovery of vancomycin
1960	Synthesis of methicillin
1962	Synthesis of nalidixic
1967	Development of first generation cephems
	↓ Development of second generation cephems
	↓ Development of third generation cephems
1983	Development of carbapenem and monobactam
	↓ Increased use of third generation cephem, carbapenem, oral cephem and new quinolone antimicrobials
2000	(Decrease in newly developed antimicrobial agents)

Table :- Schematic diagram of year and development of antimicrobial agents.

II. IMPORTANCE OF ANTIMICROBIAL MEDICINE

- 1) Antimicrobial resistance (AMR) refers to the ability of microorganisms, including bacteria, viruses, fungi, and parasites, to survive exposure to drugs that are designed to kill or inhibit

them.

- 2) As a result, treatments become less effective or even fail, making infections harder or sometimes impossible to cure, and increasing the risk of disease transmission, severe illness, disability, and death.
- 3) Antimicrobial agents such as antibiotics, antivirals, antifungals, and antiparasitic drugs play a vital role in modern medicine.
- 4) These medicines are essential for treating infections and significantly contribute to saving lives.
- 5) Antibiotics are used to treat bacterial infections, including diseases like pneumonia and tuberculosis.
- 6) Antiviral drugs are important for managing viral infections such as HIV and influenza.
- 7) Many advanced medical procedures, including surgeries, organ transplants, and cancer chemotherapy, rely heavily on effective antimicrobial protection.
- 8) By effectively treating serious infections, these drugs help reduce both mortality (death rates) and morbidity (disease burden).
- 9) In veterinary and agricultural settings, antimicrobials are used to maintain animal health and support food safety.
- 10) They also play a key role in limiting the spread of infectious diseases within communities.

III. MECHANISM OF ANTIMICROBIAL RESISTANCE

Antimicrobial resistance can be either intrinsic (natural) or acquired. Intrinsic resistance is an inherent characteristic of certain microorganisms; for example, *Pseudomonas aeruginosa* exhibits natural resistance to many antibiotics due to its low outer membrane permeability, which limits drug entry (10). Microorganisms and antimicrobial agents often coexist within the same environment, allowing microbes to gradually develop strategies to counteract the harmful effects of these drugs. Antibiotics typically target key structures or processes within bacterial cells, including the cell wall, cell membrane, protein synthesis machinery, and nucleic acid synthesis pathways (3).

However, the rapid rise of multidrug-resistant (MDR) strains highlights the remarkable ability of bacteria, as well as viruses, fungi, and protozoa, to evade or withstand these therapeutic agents (5). The mechanisms underlying antimicrobial resistance are well established. Resistance may arise through spontaneous genetic mutations or through the acquisition of resistance genes from other organisms via horizontal gene transfer. This transfer is often mediated by mobile genetic elements such as plasmids (6). At the species level, resistance is frequently associated with genetic changes, although microorganisms can employ multiple mechanisms to survive antimicrobial exposure.

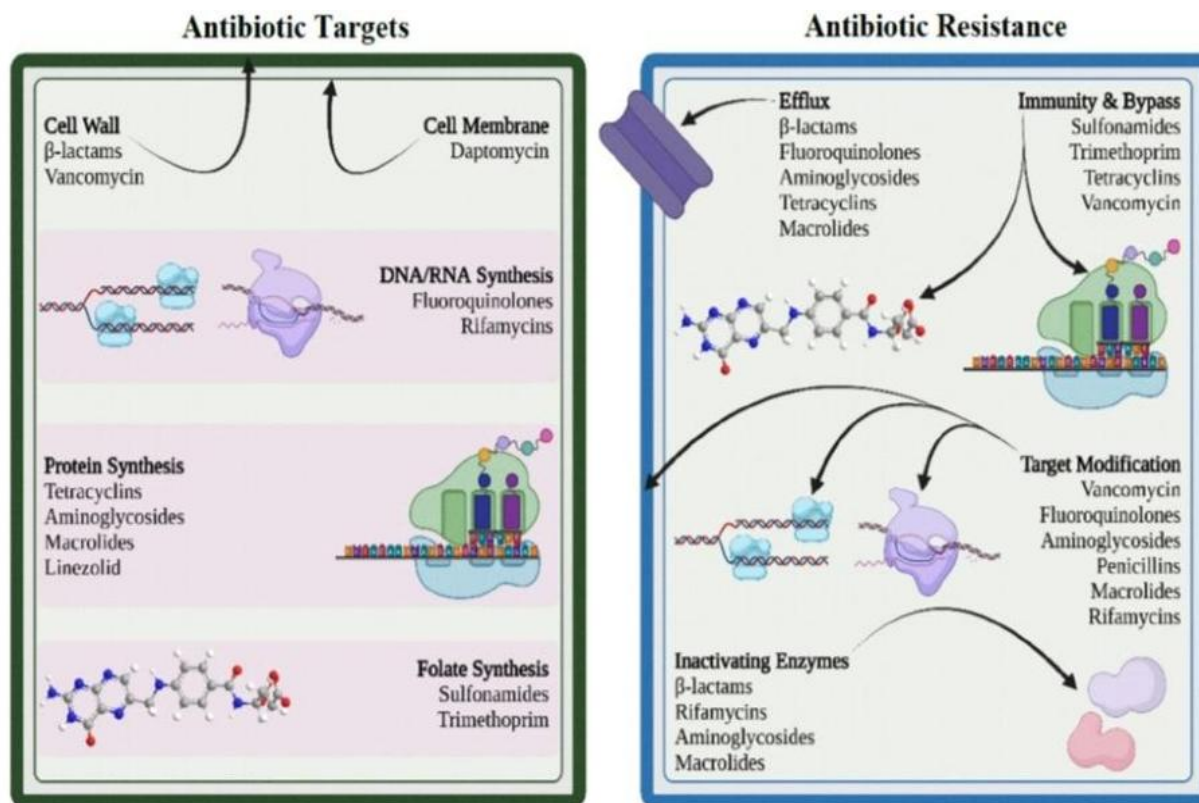


Fig . Mechanisms of Antimicrobial Resistance

In acquired resistance, bacteria commonly employ mechanisms such as alteration of the drug target, enzymatic inactivation of the drug, and active efflux of the antimicrobial agent. In contrast, intrinsic resistance is typically associated with reduced drug uptake, natural drug inactivation, and the presence of efflux systems (3). Among these, efflux pumps are one of the most prevalent resistance mechanisms observed in pathogenic microorganisms (11). Structural differences between Gram-positive and Gram-negative bacteria play a significant role in determining their resistance strategies. Gram-positive bacteria generally rely less on limiting drug uptake because they lack an outer membrane containing lipopolysaccharides (LPS). Additionally, their ability to use efflux-based resistance may be limited for certain classes of antibiotics (29). On the other hand, Gram-negative bacteria possess an outer membrane that acts as a barrier to many antimicrobial agents, contributing to reduced permeability. They also frequently utilize efflux mechanisms to expel antibiotics, such as tetracyclines, thereby reducing intracellular drug concentrations and diminishing their effectiveness (17).

1) Limiting Drug Uptake:

In Gram-negative bacteria, the outer membrane acts as an effective barrier against many antimicrobial agents. A key component of this membrane is lipopolysaccharide (LPS), a highly acylated glycolipid that reduces the permeability of various substances, including antibiotics. This structural feature contributes to the intrinsic resistance observed in Gram-negative organisms by limiting the entry of specific drugs into the cell (3). Microorganisms have a strong

ability to develop resistance to antimicrobial agents over time. This resistance may arise through spontaneous genetic mutations or by acquiring resistance genes from external sources. Such changes can alter bacterial metabolic pathways, enabling the organism to survive despite the presence of antibiotics (17).

Alterations in outer membrane proteins, particularly porins, play a significant role in acquired resistance. Porins function as channels that allow the passage of hydrophilic antibiotics such as β -lactams, fluoroquinolones, tetracyclines, and chloramphenicol into the bacterial cell (18). Variations in the number, structure, or expression of these porin proteins can reduce drug entry, thereby decreasing bacterial susceptibility to these antibiotics (16). Additionally, the formation of biofilms further enhances resistance.

Biofilms are structured communities of microorganisms enclosed within a self-produced extracellular polymeric matrix and attached to surfaces. This matrix can hinder antibiotic penetration and create a protective environment, allowing bacteria within the biofilm to tolerate higher concentrations of antimicrobial agents (3).

2) Modification of Targets for Drug :-

Bacteria can develop resistance by altering the molecular targets that antibiotics are designed to bind (3). These changes reduce the ability of the drug to attach effectively, or in some cases prevent binding altogether (16). Such modifications typically arise from spontaneous mutations in genes encoding the target proteins (19). One well-known example involves mutations in the quinolone-resistance determining region (QRDR) of enzymes such as DNA gyrase (topoisomerase II) and topoisomerase IV. These mutations decrease the binding affinity of fluoroquinolones, leading to resistance in both Gram-positive and Gram-negative bacteria (3). Target modification can also occur through enzymatic processes such as methylation. For instance, Erm methyltransferases alter ribosomal targets, thereby reducing the effectiveness of macrolides, lincosamides, and streptogramin B antibiotics. This mechanism has been observed in various bacterial species, including *Proteus vulgaris*, *Staphylococcus* spp., *Enterococcus* spp., *Bacillus* spp., and *Escherichia coli* (16). *Staphylococcus* spp.

Exhibits a significant reduction in its affinity to β -lactam antibiotics due to an alternative penicillin-binding protein encoded by *Meca* and *Mecca* genes (3).

3) Inactivation of Drugs

Antibiotic resistance can occur when bacteria inactivate drugs through enzymatic degradation or chemical modification of the antibiotic molecule. In one mechanism, the antibiotic is broken down entirely; in another, a chemical group is added to alter its structure and function (3). A well-known example is the production of β -lactamase enzymes by members of the Enterobacteriaceae family, which effectively deactivate β -lactam antibiotics (16). These enzymes, formerly referred to as penicillinases and cephalosporinases, hydrolyse the β -lactam ring at a specific site. This structural disruption prevents the antibiotic from binding to its target, the penicillin-binding proteins (PBPs), thereby rendering it ineffective (3). Some bacteria also develop resistance by modifying metabolic pathways. For instance, sulphonamide-resistant strains may lose their dependence on para-aminobenzoic acid (PABA), which is normally

required for folic acid synthesis. Instead, they utilize preformed folic acid, similar to mammalian cells, allowing them to bypass the inhibitory action of sulphonamides (20). Several Gram-negative and Gram-positive organisms, including *Staphylococcus aureus*, *Enterococcus faecalis*, and *Enterococcus faecium*, can acquire β -lactamase genes through horizontal gene transfer, enhancing their resistance capabilities (16). In addition, certain bacteria produce enzymes that can inactivate other antibiotics, such as tetracycline, through gene-encoded enzymatic modification. Drug resistance may also arise from alterations in target sites; for example, in methicillin-resistant *Staphylococcus aureus* (MRSA), changes in penicillin-binding proteins reduce the binding affinity of β -lactam antibiotics like penicillin resistant bacteria (20).

4) Efflux of Drug

Bacteria can control the concentration of antibacterial agents such as antibiotics within their cells through energy-dependent efflux pumps located in the cytoplasmic membrane. These transport systems help maintain cellular homeostasis by expelling toxic compounds, including antibiotics, metabolic by-products, and quorum sensing molecules (16). Most efflux systems are capable of transporting multiple drugs and are typically encoded on the bacterial chromosome, contributing to intrinsic resistance in bacteria(3). In addition to antibiotics, these pumps may also export heavy metals, environmental pollutants, plant-derived compounds, signalling molecules, bacterial metabolites, and even neurotransmitters (21).

The first plasmid-mediated efflux pump was identified in *Escherichia coli* in 1980, where it was found to actively expel tetracycline from the bacterial cell (3). Some antibiotics can also stimulate or regulate the expression of efflux pump genes. When a bacterial species expresses multiple efflux systems, it can develop broad-spectrum resistance because many of these pumps share overlapping substrate specificities. As a result, a single efflux pump system may provide resistance to several different antimicrobial agents (21). Efflux pumps are membrane transport systems that actively expel antimicrobial agents from bacterial cells, thereby lowering their intracellular concentration. When these pumps are sufficiently active, they enable bacteria to survive and grow even in the presence of antibiotics (22). Most efflux systems function as multidrug transporters and are usually encoded on the bacterial chromosome, contributing to intrinsic resistance. However, genes encoding more substrate-specific efflux pumps (e.g. chloramphenicol, tetracyclines, or macrolides) are located on mobile genetic elements like plasmids, which facilitates their spread among bacteria (16). In Gram-positive bacteria, the most common efflux systems belong to the ABC and MFS families and may be encoded either chromosomally or on plasmids. In contrast, Gram-negative bacteria predominantly rely on the RND family, which is clinically most important. RND efflux pumps typically operate as multiprotein complexes consisting of an inner membrane transporter, a periplasmic protein, and a cytoplasmic membrane pump (3).

IV. ANTIMICROBIAL RESISTANCE OF PATHOGENS

Antimicrobial resistance (AMR) refers to the ability of microorganisms including bacteria,

viruses, fungi, and parasites to develop mechanisms that allow them to survive exposure to drugs designed to eliminate them, such as antibiotics and antifungal agents. These resistant organisms are often called “superbugs” because they make standard treatments less effective or even ineffective. As a result, infections become more difficult to treat, leading to longer hospital stays, higher healthcare costs, and increased risk of mortality. Environments such as water, soil, and other ecological niches contain a vast and diverse pool of genetic material. These habitats provide conditions that support extensive microbial diversity, often exceeding that found in human and domestic animal microbiota, and therefore serve as important reservoirs for resistance genes (4). Pathogens acquire resistance mainly through genetic mutations and the exchange of genetic material. This process has been intensified by the extensive and sometimes inappropriate use of antimicrobial drugs in healthcare, including self-medication and the use of incorrect or sub-therapeutic doses (11).

Although antimicrobial resistance is a natural evolutionary phenomenon that occurs over time, its development and spread are significantly accelerated by human activities. The misuse and overuse of antimicrobial agents in human medicine, veterinary practice, and agriculture contribute substantially to the rapid emergence and global dissemination of resistant organisms (12).

V. ROLE OF WHO IN COMBAT ANTIMICROBIAL RESISTANCE (AMR)

The World Health Organization (World Health Organization) plays a central role in addressing antimicrobial resistance (AMR), which is a growing global threat to health and development. WHO supports countries in designing and implementing Antimicrobial Stewardship Programmes (ASPs), which are considered among the most cost-effective strategies to ensure the rational use of antimicrobial medicines (13). These programmes help improve patient outcomes, reduce the spread of AMR, and lower healthcare-associated infections. AMR requires a coordinated response across multiple sectors and levels of the health system (15). To address this, WHO works closely with national governments to prioritize actions, estimate costs, and scale up interventions that enhance awareness and strengthen training on AMR (14). It also promotes the development of multisectoral national action plans and encourages collaboration between human health, animal health, and environmental sectors (13). Key strategies supported by WHO include improving infection prevention and control measures in healthcare facilities, such as better water, sanitation, hygiene, and stronger immunization coverage. In addition, WHO emphasizes strengthening antimicrobial stewardship policies and practices to ensure evidence-based prescribing and appropriate use of antibiotics and other antimicrobial agents (14). Further important actions include improving the quality, safety, and availability of antimicrobial medicines, strengthening supply chain systems, and ensuring financial protection for patients facing the high cost of treating drug-resistant infections (13). WHO also promotes awareness campaigns, behavioural change initiatives, and advocacy efforts to improve public and professional understanding of AMR (15).

VI. INFECTION PREVENTION AND CONTROL (IPC)

Infection Prevention and Control (IPC) is a vital, evidence-based approach aimed at protecting patients, healthcare workers, and communities from preventable infections, including those caused by drug-resistant microorganisms (3). IPC strategies focus on reducing the transmission of pathogens, including antimicrobial-resistant strains, within healthcare facilities and beyond, thereby playing a key role in limiting the spread of antimicrobial resistance (AMR) (23). IPC is one of the most important interventions for reducing AMR in healthcare settings. Effective implementation relies on the active participation of all healthcare professionals. Physicians, nurses, pharmacists, and other healthcare workers each have an essential role in ensuring adherence to infection control practices. Physicians involved in patient care contribute significantly by following hospital infection control protocols, adhering to antibiotic stewardship guidelines, and promptly reporting cases of resistant infections to infection control teams (3). These actions help in early detection and containment of AMR. Nurses and other healthcare staff also play a critical role by maintaining strict aseptic techniques and being well-trained in infection prevention practices, which reduces the risk of cross-infection among patients (23). Pharmacists, as key members of the IPC and antimicrobial stewardship teams, support rational antibiotic use by educating patients on proper medication adherence and ensuring appropriate antimicrobial dispensing. This contributes significantly to reducing misuse and resistance development (3).

Recommended measures to prevent and control infection in a health-care facility :

- Establishing an infection prevention and control committee (IPC).
- Good hand hygiene practices.
- Effective diagnosis and treatment of infection.
- Rational antimicrobial use.
- Surveillance of antibiotic resistance and antibiotic use.
- Improving the antimicrobial quality and supply chain.
- Good Microbiology Practices (23).

VII. RATIONAL USE OF ANTIBIOTICS

The World Health Organization (WHO) defines the rational use of medicines as the appropriate selection and use of drugs, including antibiotics, that are suitable for a patient's clinical condition, given in doses tailored to individual needs, administered for an adequate duration, and provided at the lowest possible cost (3). Rational antibiotic use is therefore not arbitrary; it requires careful clinical judgment and adherence to established principles. Key factors influencing antibiotic selection include accurate diagnosis, the patient's overall condition, the site of infection, severity of illness, likely causative organisms, and their sensitivity patterns. In addition, the pharmacokinetic and pharmacodynamic properties of the drug, along with its potential side effects and cost, must be considered before prescribing (24). Optimal management

of infections is achieved when antibiotic selection minimizes toxicity, limits the emergence of resistance, and ensures effective pathogen eradication. To support these goals, Antibiotic Stewardship Programs (ASPs) have been implemented in healthcare systems, with the primary objective of promoting the rational and responsible use of antibiotics (3).

VIII. PUBLIC AWARENESS

Antimicrobial resistance (AMR) develops when microorganisms such as bacteria, viruses, fungi, and parasites undergo changes that make medicines, including antibiotics, less effective or ineffective, leading to infections that are increasingly difficult to treat. Better treatment outcomes are achieved when antibiotic use is rational, minimizing unnecessary exposure, toxicity, and the development of resistance. In this context, Antibiotic Stewardship Programs (ASPs) play an important role in healthcare systems by ensuring the appropriate and responsible use of antibiotics (11). Public health campaigns aim to educate people about using antibiotics only when prescribed by a qualified healthcare professional, maintaining good hygiene to prevent infections, and understanding that not all infections require antibiotics, as many are viral in origin. Improving awareness is strongly associated with more responsible antibiotic use and helps reduce the widespread issue of self-medication, particularly in developing countries. Therefore, healthcare providers at primary, secondary, and tertiary levels have a key responsibility to educate patients and communities about AMR and its risks

(11). Awareness initiatives often focus on community participation, including educating groups such as new mothers and conducting local health discussions. Along with this, healthcare professionals must ensure antibiotics are prescribed rationally, with the correct drug, dose, duration, and route of administration.

IX. VACCINATION

Vaccination is an important preventive strategy for controlling antimicrobial resistance (AMR) by reducing the need for excessive use of antimicrobial drugs. By preventing infections in the first place, vaccines help lower the occurrence of secondary bacterial infections that often follow viral illnesses, thereby decreasing antibiotic consumption. Certain vaccines, such as the pneumococcal conjugate vaccine (PCV9), have shown effectiveness in reducing infections caused by drug-resistant organisms, including penicillin-resistant strains of *Streptococcus pneumoniae* (11). In this way, vaccines contribute directly to limiting resistant pathogens and reducing their spread within the community. Modern scientific approaches, such as reverse vaccinology and the development of combination strategies involving vaccines and antibiotics, are being explored to target resistant microbial strains more effectively. Vaccination not only reduces the incidence of infections caused by resistant organisms but also indirectly limits the transmission of resistance among microbial populations (2). Overall, vaccines serve as a key preventive tool in infectious disease control and play a significant role in reducing dependence

on antibiotics, thereby contributing to the fight against AMR (3). They stimulate the immune system to produce memory cells that can rapidly recognize and respond to pathogens upon future exposure. Vaccination programs have historically proven highly effective in controlling infectious diseases. For example, diseases such as smallpox have been eradicated, and polio has been eliminated from many regions due to widespread immunization efforts. These successes highlight the critical role of vaccines in reducing disease burden and supporting global health efforts against antimicrobial resistance (2).

X. CONCLUSION

The rise of antimicrobial resistance (AMR) represents a complex and pressing global health challenge. This review emphasizes the emergence of multiple resistant pathogen strains and the varied mechanisms they employ to overcome the effectiveness of antimicrobial agents. Over the past two decades, the gradual increase in AMR has posed a serious threat to global public health and is now considered one of the most significant health concerns of the 21st century, greatly restricting available treatment options. AMR continues to expand worldwide, with particularly severe impacts in regions such as sub-Saharan Africa and South Asia. Its consequences are extensive, including higher rates of illness and death from infectious diseases, escalating healthcare expenses, and broader economic burdens that can contribute to poverty. The primary causes of AMR include the inappropriate use and overuse of antibiotics in both medical and agricultural settings. Additionally, poor waste management practices contribute to the persistence and spread of resistant organisms in the environment. Individuals involved in agriculture, horticulture, apiculture, and animal husbandry should adopt strategies that minimize or avoid the use of antimicrobials. Preventive approaches such as maintaining proper hygiene, improving sanitation, and reducing stress in farm environments can significantly lower the need for such drugs. Veterinarians should prescribe antimicrobials judiciously, ensuring responsible usage. Likewise, promoting hygiene and sanitation at the community level is essential in reducing the spread of resistant infections among humans. Healthcare professionals play a vital role in educating the public about AMR and encouraging responsible antimicrobial use through stewardship programs. At the policy level, governments must implement strong regulatory frameworks, enhance surveillance systems, and utilize bioinformatics tools to monitor resistance trends. These efforts should be supported by continuous data collection and analysis of local resistance patterns to ensure effective and targeted interventions.

Combating antimicrobial resistance (AMR) demands a strengthened and well-coordinated global response involving both international governmental and non-governmental organizations, supported by firm political commitment. Effective action relies on collaboration among policymakers, researchers, public health professionals, pharmaceutical industries, healthcare administrators, agricultural stakeholders, and the general public. The shared objective of these collective efforts is to slow the progression of AMR and reduce its associated health and economic impacts. Implementing antimicrobial stewardship programs and ensuring strict

adherence to antibiotic policies in healthcare settings are critical strategies in addressing resistance. In addition, strengthening microbiological practices, enhancing surveillance and monitoring systems, limiting over-the-counter access to antibiotics, and reducing their use in food-producing animals are essential measures. Expanding access to safe, effective, and affordable medicines, vaccines, and diagnostic tools, along with enforcing appropriate regulations, is equally important in mitigating this challenge.

Prevention remains the most effective approach to limiting the emergence and spread of resistant infections worldwide. While optimizing the use of existing antibiotics is necessary to preserve their effectiveness, there is also an urgent need to invest in the development of new antimicrobial agents and alternative therapies. Advances in diagnostic technologies and vaccine development are also crucial components of this effort. If current trends continue unchecked, antimicrobial resistance could significantly undermine modern medical practices including complex surgeries, organ transplantation, neonatal care, and cancer treatment leading to serious consequences across healthcare, social systems, and global economies. Immediate and coordinated global action is therefore essential to prevent such outcomes.

REFERENCE

- [1] Susan Ekuri, Antimicrobial Resistance: Implementing an Effective Response for a Growing Global Health Threat, Published on 14 December 2024, Premier Journal Of Public Health.
- [2] Jutima Baruah, Laishram Shantikumar Singh, Antimicrobial resistance a continued global threat to public health – A perspective and mitigation strategies Published on 2024-12-30, Journal Of Laboratory Physicians.
- [3] Md. Abdu's Salam , Md. Yusuf Al-Amin , Antimicrobial Resistance: A Growing Serious Threat for Global Public Health, Published on 5 July 2023 , Recruiting Editorial Board Members for Healthcare.
- [4] Habtamu Endale, Mesfin Mathewos, Potential Causes of Spread of Antimicrobial Resistance and Preventive Measures in One Health Perspective-A Review, Published on 8 Dec 2023, National Library Of Medicine .
- [5] Sirwan Khalid Ahmed, Safin Hussein, Antimicrobial resistance: Impacts, challenges, and future prospects, Published on April 2024, Journal Of Medicine, Surgery, And Public Health.
- [6] Amer Research Taqa, Global Trends in Antibiotic Resistance: Challenges for Public Health, Published on 07-02-2025, Research Journal Article.
- [7] Antimicrobial Resistance Global Report On Surveillance, Published on 2014, World Health Organization.
- [8] Antimicrobial Resistance in the Environment and the Food Supply: Causes and How It Spreads, Published on 1 November 2024, Journal Of Antimicrobial Resistance.
- [9] Nabin Rayamajhi, Seung Bin Cha, Antibiotics Resistances: Past, Present and Future-Review paper, Published on Jun 2025, Journal Of Biomedical Research.

- [10] Ernesto Mahizhchi, Diveyaa Sivakumar, Antimicrobial Resistance Technique To Fight AMR In Bacteria- A Review Published on 03 March 2024, Journal of Pure and Applied Microbiology.
- [11] Monalisa Patra, Atul Kumar Gupta, Antimicrobial Resistance: A Rising Global Threat to Public Health, Published on 23 Oct 2025, National Library Of Medicine .
- [12] Antimicrobial Resistance, Published on 21 November 2023, World Health Organization.
- [13] Promoting antimicrobial stewardship to tackle antimicrobial resistance, Published On 12 April 2021, World Health Organization.
- [14] Our Work Antimicrobial Resistance, Published on 24 November, World Health Organization.
- [15] Tackling antimicrobial Resistance in a western Pacific Region: A Review Of Surveillance And Public Health, Published On 27 November 2017.
- [16] Nikaido. H, Multidrug resistance in bacteria, Published On 2009, Annual Review of Biochemistry, 78, 119–146.
- [17] Tanvir Mahtab Uddin, Ameer Khusro, Antibiotic resistance in microbes: History, mechanisms, therapeutic strategies and future prospects, Published On December 2021, Journal Of Infection And Public Health.
- [18] Mehrose Ahmad, Sai Varun Aduru, The role of bacterial metabolism in antimicrobial resistance, Published On 20 Feb 2025, National Library Of Medicine .
- [19] Manisha Kasbe, Ajay Bhagwat, Antimicrobial Resistance: An Increasingly Grave Threat To Global Public Health, Published On October 2025, World Journal of Pharmaceutical Science and Research.
- [20] Fusheng Zhang, Wei chang, The Mechanism of Bacterial Resistance and Potential Bacteriostatic Strategies, Published On 8 Sep 2022, National Library Of Medicine .
- [21] Efflux Pump Revision History, Published On 29 May 2024, Wikipedia [https:// en.](https://en.wikipedia.org)
- [22] Wikipedia. Org.
- [23] Silvia Vareschi, Rosalind J Allen, Antimicrobial efflux and biofilms: an interplay leading to emergent resistance evolution, Published On September 2025,
- [24] [https://doi.org/10.1016/j.tim.2025.](https://doi.org/10.1016/j.tim.2025)
- [25] M. P. Zeegers, G. M. Varghese, India’s National Action Plan on Antimicrobial Resistance: a critical perspective, Published On December 2021, Journal Of Global Antimicrobial.
- [26] Kourkouta L, Kotsifopoulos Ch, The Rational Use Of Antibiotics Medicine, Published On 2017, Journal Of Healthcare Communication.