

# Growing Dangers of Antibiotic Resistance: Examining Causes and Methods of Prevention and Control Strategies

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This short review provides an overview of antibiotic resistance, its sources, consequences, and potential techniques to fight this rising global health concern. Antibiotics are a type of drug prescribed to treat a bacterial infection, working by eliminating bacteria or inhibiting their growth. This review explains how the excessive and improper utilization of antibiotics in medical and agricultural settings has accelerated the rise of antibiotic-resistant bacteria. Antibiotics are popularly used in agriculture in plants and animals, causing antibiotics to enter our bodies. Overuse or unnecessary use of antibiotics can contribute to bacteria's resistance to being eliminated. This short review suggests that the best ways to address this issue are through prevention and control practices such as public education, funding and research, enhanced infection control procedures, and decreased use of antibiotics in agriculture and meat production. These problems can be solved to maintain the effectiveness of antibiotics for upcoming generations and reduce the harm that antibiotic-resistant microorganisms cause to public health. The paper highlights the serious effects of antibiotic resistance, such as prolonged diseases, higher medical expenses, and increased risks during treatments. The study also explores alternative treatments such as phage therapy, an efficient way to eliminate antibiotic-resistant bacteria.

## Introduction

Antibiotics are a class of drugs used to treat bacterial infections by working to kill bacteria or inhibit their growth. Doctors or other medical professionals prescribe antibiotics to treat specific bacterial infections, such as Penicillins and Macrolides, to name a few examples. They are given in several forms, such as oral tablets, capsules, liquids, or injections. Ways to use antibiotics responsibly are to take the full course as prescribed, even if symptoms progress, not use antibiotics for viral infections like the common cold or flu, not share antibiotics with others, and not use leftover prescriptions. However, these rules are not always followed by patients, which can pose hazards to one's health and increase antibiotic resistance. Antibiotic resistance occurs when bacteria evolve mechanisms to resist the effects of antibiotics, which can later develop through mutations, in which the DNA sequence of a cell can change. Antibiotic resistance works through bacteria-producing enzymes that destroy the antibiotic (ex. beta-lactamases break down penicillins).

Antibiotic Resistance is a threat because infections caused by resistant bacteria are harder to treat, leading to prolonged illnesses, and higher medical costs. Resistant bacteria can easily spread to others, including vulnerable populations like the elderly and infants because their bodies are more prone to diseases since their immune systems aren't fully developed yet or their body is worn out. Six bacterial diseases that are resistant to antibiotics increased by 20% during the COVID-19 pandemic, according to a data sheet released by the CDC in July 2024. In

2022, these infections continued to be higher than pre-pandemic levels. As a result, more than 1.2 million people have died each year<sup>1</sup>.

The effects of antibiotic resistance are unnecessary expensive medical bills, impact on healthcare procedures, organ transplants, cancer therapy, and major surgeries. Such procedures become riskier with antibiotic-resistant bacteria and lead to longer hospital stays, which increase medical costs. That's why it is crucial to highlight the dangers of antibiotic-resistant bacteria and explore ways to prevent increased antibiotic resistance.

Antibiotic resistance can also make illnesses difficult or impossible to cure, increasing disease, suffering, and death. The more the population relies on antibiotics to cure illnesses, it will strengthen bacteria to evolve and adapt to antibiotic use. Increased illnesses are one of the main reasons antibiotic resistance is a dangerous threat to society. Antibiotic resistance has the potential to make curable diseases like tuberculosis and pneumonia incurable. Increased costs and longer treatments make healthcare unaffordable to many citizens, causing the disease to attack a larger group of people. If drugs remain ineffective, patients may require further testing, medical visits, and prescriptions for other medicines. Growth of side effects, multiple and more powerful medications can have major negative effects on patients. Harm to medical advances, such as organ transplants, cancer therapy, and joint replacements, depends on antibiotics. Moreover, antibiotic resistance makes certain medical procedures, such as surgery and cancer treatment, riskier since they rely on antibiotics to prevent and treat infections. In some cases,

there may be no treatment options for antimicrobial-resistant infections. Antibiotics destroy other microorganisms that the body uses for defense when they eradicate the germs that cause diseases.

## Methodology

Relevant literature for this study was found by using other research papers that discussed antibiotic use and its dangers to the population. Infographics representing the growing dangers of antibiotic resistance from research papers were used to gather more information about different ways antibiotics can enter the ecosystem, such as through agriculture and animals. When researching how to combat antibiotic resistance, research papers about phage therapies and drugs that inhibit microorganisms were used for this review.

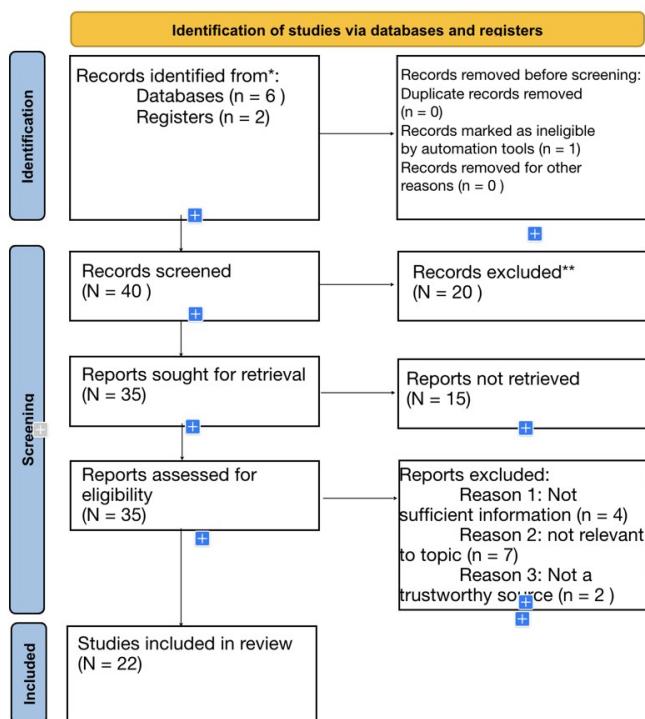


Fig. 1 Quantification of Cell Death Using Ethidium Dimer III Dye

## Results and Discussion

### Prevention Practices

Implementing good infection prevention practices: This includes hand hygiene, screening for infection with multidrug-resistant bacteria, and isolating infected patients. The importance of these practices is to ensure that bacteria and germs don't spread easily amongst other people. Ensuring patients take the right

antibiotics for their specific illness is crucial since taking the wrong antibiotics can keep bacteria in the body. Research shows that when a toilet is flushed, the waste discarded in the toilet has particles that flow into the air. This will contaminate the air and the accessories you have in your bathroom. It's essential to close the toilet seat before flushing because toothbrushes, tongue cleaners, soap bars, towels, and many more utilities will be contaminated with germs from the waste in the toilet. This will ensure that none of the bacteria will go on the appliances in your bathroom. Cleaning your toilet is also crucial since it prevents the spread of bacteria entering your body. This will cause bacterial infections leading doctors to prescribe antibiotics to treat illnesses. This causes bacteria to be immune to antibiotics. Over time this strengthens bacterial strains to be more resistant to drugs, making them harder to eliminate.

Respiratory and cough hygiene like covering your cough and sneezes plays a tremendous role in maintaining the spread of bacteria. Such hygiene prevention practices reduce the need for antibiotic use since the spread of bacteria will be minimized.

### Spread of bacteria from meat and vegetables:

Cross-contamination is a popular way for bacteria to spread from meat to vegetables, infecting the food we eat. All customers need to be taught to inspect and wash their produce to prevent microbes from entering from food to the body. Microbes can be carried from one food to another by using the same knife, cutting board, or other utensil without washing the surface or utensil in between uses. People also don't wash their food before cooking it, leading them to catch a bacterial infection or disease. Food and kitchen tools and surfaces may become contaminated from raw food products (like meat and poultry). Salmonella is a bacterial infection that commonly occurs when meat and vegetables with bacteria are consumed. Fluoroquinolones, antibacterial agents, such as ciprofloxacin and levofloxacin are common antibiotics prescribed to treat Salmonella. Since these drugs are used frequently, the bacteria has developed high rates of resistance to ciprofloxacin and levofloxacin.

### Invest in Research and Development:

Funding for alternative therapies for bacterial illnesses should be increased. Using phages to treat bacterial illnesses is known as phage treatment. Phages, also known as bacteriophages, are viruses that infect and reproduce in bacterial cells. Phages kill and selectively target bacteria<sup>7</sup>. Phage therapy is a biological treatment that uses bacteriophages to heal bacterial infections. To infect and lyse bacteria at the infection site, lytic phages, bioengineered phages, and isolated lytic proteins of phages are utilized. Mainly, it kills the bacteria host efficiently causing it to be a smart and effective treatment<sup>7</sup>. Phage therapies are criticized and not recommended by doctors because there are a few issues with how the therapy was regulated and created. However recently, studies have shown that the success rate of phage therapy is 87%.

The benefit of phage therapy is that it can act like a bacteria-

Author Name	Year of Publication	Method	Findings
Hibstu, Z., Belew, H., Akelew, Y., Mengist, HM. (2022) <sup>2</sup> .	2022	Highlighted the comparison of antibiotics and lytic phage therapy, the pros and cons of phage therapy, factors influencing human phage therapy trials, specifications for the safety and quality of phages, phage handling and storage, and present phage therapy issues.	Phage therapy is a good approach to fight bacterial infections, including multidrug-resistant bacteria. It can be used either as an alternative or as a supplement to antibiotics. However, many questions remain regarding the therapeutic use of phages, and phage therapies for humans have not been approved yet.
Lin, J., Du, F., Long, M., Li, P. (2022) <sup>3</sup> .	2022	This review article outlined the present uses and constraints of PT and provided an overview of the available remedies for these constraints. Clinicians, professionals in the agricultural and industrial sectors, and fundamental researchers will find this information helpful.	Phage therapy poses some limitations, such as a narrow host range, lack of relevant policies, and lack of pharmacokinetic data. However, it can still develop effective, rapid, and stable bacteriological drugs that can prevent antibiotic resistance.
Loc-Carrillo, C., & Abedon, S. T. (2011) <sup>4</sup> .	2011	Discussed features of phage therapy that may enhance its affordability, safety, or convenience, but in ways that may not be as critical to the phage's ability to fight bacteria.	The pros of phage therapy are: low toxicity, minimal disruption to bodily flora, low environmental impact, smaller dosage required, and low cost. The cons: narrow host range, and not all phages allow proper treatment. Since the pros outweigh the cons, phage therapy should be endorsed as an effective treatment for bacterial diseases.
Pires, D. (2020) <sup>5</sup> .	2020	Reviewed case studies and clinical trial results related to human phage therapy, and discussed the main obstacles to phage use in clinical settings.	Phage therapy programs have clinical success; however, phage therapy creates additional challenges. These include the need to increase phage collections of reference phage banks, the development of efficient phage screening methods, and the establishment of efficient phage therapy strategies.
Suh, Gina A, Ferry, T., Abdel, M. (2023) <sup>6</sup> .	2023	Examined the safety and efficacy of phage therapy by conducting a survey. A nonrandomized, cohort of patients with prosthetic joint infections (PJIs) was treated with a combination of phage therapy and antibiotics and compared with a control group of patients treated with antibiotics without phages.	29 (87%) achieved microbiological or clinical success, 2 (5.9%) relapsed with the same organisms, and 2 (5.9%) with a different organism.

**Table 1** Summary of Research on Phage Therapy

killing agent because bacteria infected by these specific phages cannot survive or recover<sup>5</sup>. In contrast, some antibiotics—like tetracycline—are bacteriostatic, which means that they can help the evolution of bacterial resistance more easily. With certain restrictions, such as a reliance on relatively large bacterial densities, phages can only reproduce in the vicinity of their hosts during the bacterial-killing process; this works like auto “dosing”, which is when phages establish phage dose by themselves. Lastly, phages are not toxic to the body and, therefore, safe to use<sup>2</sup>. The disadvantage of phage therapy is that further research is necessary to determine the effectiveness of this therapy<sup>6</sup>. It’s

unknown if phages could cause harm to humans or animals in ways other than direct toxicity. Furthermore, it’s unclear if phage therapy could make bacteria more resistant to bacteriophages, leading to phage resistance<sup>4</sup>. Lastly, it’s not known how long phage therapy may take to work. The limit of phage therapy is resistance; bacteria can develop resistance to phages, which can prevent phage adsorption and DNA entry, or degrade phage DNA.

Investing in drug therapies can also decrease antibiotic resistance. Certain drugs prevent bacterial DNA from replicating. Drugs like nalidixic acid selectively inhibit the activity of bacte-

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rial DNA gyrase, blocking DNA replication. DNA gyrase is an enzyme that opens the origins of DNA replication and eliminates positive supercoils that build up in front of transcription complexes and replication forks. Levofloxacin is a fluoroquinolone that targets gyrase too, leading to the prevention of bacterial DNA replication. Researching ways to develop these drugs effectively can minimize the effect of antibiotic resistance.

## Control Practices

### Reduce Antibiotic Use in Agriculture:

To reduce the amount of antibiotic resistant bacteria that go up the food chain, more laws governing the use of antibiotics in food animal production should be implemented. Streptomycin and oxytetracycline are two antibiotics that are popularly used in agriculture in both plants and animals. Antibiotics given to humans and animals are expelled through urine and feces. Animal feces, such as manure, are high in nutrients and frequently applied as fertilizer to agricultural fields, directly contaminating the environment with germs resistant to antibiotics and antibiotic residues. Certain antibiotics are injected into the trunks of palm and elm trees<sup>8</sup>. They are used to control and treat certain bacterial infections. This is how antibiotics are applied to crops and our food. Such control practices of reducing antibiotic use would help to understand antibiotic resistance to decrease it.

Antibiotics are mostly used in agriculture to treat infections, promote growth, and prevent disease in livestock. Common antibiotics include sulfonamides, which are frequently coupled with other antibiotics for an additional effect, macrolides, which are typically used for respiratory infections, and penicillins, which are effective against a variety of bacterial illnesses. Penicillins are usually dosed at 5-10 mg/kg body weight and are metabolized in the liver, with excretion occurring via urine. Macrolides are administered at dosages ranging from 10-20 mg/kg, are metabolized in the liver, and are excreted in both bile and urine. Sulfonamides are given at a dosage of 15-30 mg/kg, metabolized in the liver, and primarily excreted through urine<sup>8</sup>.

These antibiotics can be given to animals in a variety of ways. For example, they can be injected to treat individual animal infections, applied directly to the skin or mucous membranes to treat confined infections, or added to animal feed or water to prevent disease and promote growth. Antibiotics undergo metabolic processes in the liver and other tissues. Metabolism can change the chemical structure of antibiotics, making them more or less active. After they metabolize, antibiotics are excreted from the body, primarily through urine or feces. The rate of excretion can influence how long antibiotics remain in the animal's system and how quickly they are discarded.

The widespread use of antibiotics in agriculture and livestock is a significant factor in the development of antibiotic-resistant bacteria, which can be transferred to humans through the consumption of animal or plant products, direct contact with ani-

mals, or through the environment, such as soil and water. Such a critical issue needs careful management and mitigation.

### Control overdose on antibiotics (drug abuse):

Overuse or unnecessary use of antibiotics can contribute to bacteria's resistance to dying. Every year, around 2.8 million antibiotic-resistant illnesses happen in the United States. These include Methicillin-resistant *Staphylococcus aureus* (MRSA), *Streptococcus pneumoniae*, and Carbapenem-resistant Enterobacteriaceae (CRE). The number of treatment options available is limited for these illnesses, thus increasing mortality rates. As a result, about 35,000 people die every year<sup>1</sup>. Drug resistance makes antimicrobial medications, including antibiotics, ineffective and makes treating infections challenging or impossible. This raises the risk of infection spread, serious illness, disability, and death. AMR, antimicrobial resistance, is a natural process caused by pathogen mutations over time. An antimicrobial medication is a medicine that kills microorganisms or stops them from multiplying.

There are many steps involved in preventing antibiotic overdose. This includes following prescriptions, proper measurement, educating oneself on antibiotic safety, storing them safely, and adhering to the rules. Following prescriptions is crucial since taking more than recommended can be dangerous. Always follow the dosage and time labels prescribed by a doctor. Proper measurement is just as vital because you need to follow the required amount your body needs. Educating oneself and others about the significance of not exceeding prescribed doses and the possible risks. Store antibiotics in a safe place and prevent children from using or taking them. Adhere to the prescribed schedule provided by a doctor on when to take the recommended dosage of antibiotics.

By adhering to these practices, you can significantly reduce the risk of antibiotic overdose. Regulating the amount of prescriptions given out also allows patients to control the amount of drugs they are consuming so they don't get illnesses or diseases because of antibiotic resistant bacteria.

### Bacteria develop resistance to antibiotics through self-mechanisms:

Antibiotics kill or prevent bacteria from multiplying by attacking the cell wall or coating surrounding bacteria and blocking protein production in bacteria. Bacteria can develop methods to withstand antibiotics. Certain bacteria have developed biochemical "pumps" that can remove antibiotics before they reach their target, while other bacteria have evolved to produce enzymes that make antibiotics ineffective. Biochemical pumps are a process where bacterial cells pump molecules from inside the bacteria to outside. Biochemical pumps can confer antibiotic resistance by pumping antibiotics out of bacterial cells, reducing the concentration of the antibiotic inside the cell. This mechanism allows bacteria to survive in the presence of antibiotics that would otherwise kill them. These pumps are often referred to as efflux pumps and are a common mechanism through which

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bacteria develop resistance to antibiotics. Certain enzymes can confer antibiotic resistance in bacteria<sup>9</sup>. For example, beta-lactamase enzymes, which are enzymes produced by bacteria that break down the beta-lactam ring of antibiotics, can break down beta-lactam antibiotics like penicillin, making them ineffective. Another example is acetyltransferases, which modify antibiotics, reducing their ability to treat illnesses. These enzymes are a few examples of how bacteria can develop resistance to antibiotics through enzymatic mechanisms. Tackling these ways of self-mechanisms in bacteria can reduce their ability to resist antibiotics and make them weaker.

## Conclusion

If the patient doesn't take all the prescribed antibiotics, the bacteria will become resistant. The bacteria may develop resistance to the antibiotic if the patient doesn't take every dose of treatment. This is because early treatment ending may allow some bacteria to multiply and develop mutations, making them immune to antibiotics. It can be more difficult to recover from an illness and resistant bacteria can be more dangerous. Antibiotic-resistant diseases have the potential to cause serious illness or even death in certain situations.

Antibiotics play a crucial role in treating bacterial infections, but their effectiveness is increasingly threatened by antibiotic resistance. This resistance arises due to factors such as incomplete antibiotic courses, their misuse in treating viral infections, and the use of antibiotics in food animal production and agriculture. The repercussions of antibiotic resistance are extreme, leading to longer illnesses, increased healthcare costs, and heightened risks during medical procedures. Urgent measures are needed to combat this global health challenge. Implementing strict infection prevention protocols, reducing antibiotic use in agriculture, investing in new therapies, and educating the public on responsible antibiotic usage are essential steps forward. By addressing these issues collectively, we can preserve the effectiveness of antibiotics for future generations and mitigate the impact of antibiotic-resistant bacteria on public health.

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