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Multidrug Resistant Bacteria: A Critical Review

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Abstract

Bacteria that are multidrug resistant can withstand a wide range of antibiotics. It promotes the spread of antibiotic resistance and can be challenging to treat. A bacterium can contain numerous distinct resistance genes, each imparting resistance to a particular antibiotic. Resistance genes frequently accumulate on tiny DNA fragments known as plasmids, which can spread between bacteria in a single event. Another idea is that resistance to many antibiotics is caused by a single resistance mechanism. Pumping the antibiotic out of the cell is one way that bacteria employ resistance. These pumps can occasionally identify a wide variety of compounds, including antibiotics. In other words, the bacteria pump out several antibiotics using a single pump. Another name for this is cross-resistance. A comprehensive summary of current epidemiological patterns, prioritised resistance mechanisms, and public health consequences of multidrug-resistant (MDR) microorganisms was given in this narrative review. Multidrug-resistant (MDR) microorganisms have grown alarmingly in the last few decades, posing a major threat to human health. Since MDR bacterial infections have been linked to morbidity and mortality, addressing bacterial resistance has become an important and unfulfilled challenge. Using its creative and unconventional methods, the science of nanomedicine has the potential to design and produce effective antimicrobials for MDR microorganisms.

Keywords: Antibiotics,MDR bacteria, global health,nanomedicine

I. Introduction

The development of novel antibiotics has not kept up with the evolution of resistance mechanisms, resulting in a growing therapeutic gap that jeopardises the basis of contemporary medical procedures [1]. Microorganisms can become resistant to deadly doses of antibiotics, a condition known as multidrug resistance (MDR). Regarding the effectiveness of antibiotics against pathogenic infections, MDR has emerged as a significant concern [2]. In fact, some strains have developed resistance to almost all of the widely used medications. One well-known example is the methicillin-resistant Staphylococcus aureus (MRSA), which is resistant to aminoglycosides, macrolides, tetracycline, chloramphenicol, and lincosamides in addition to methicillin, which was created to combat penicillinase-producing S. aureus. MRSA can be a significant cause of hospital-acquired infections, and these strains are also resistant to disinfectants. Vancomycin, an outdated antibiotic, was brought back to life to treat MRSA infections. Although these strains are still uncommon, transferable resistance to vancomycin is already very frequent in Enterococcus and eventually made its way to MRSA in 2002 [3]. The indiscriminate use of antibiotics in healthcare, veterinary care, aquaculture, and agriculture is the main cause of antibiotic resistance, which has become a serious global public health concern. Antimicrobial-resistant (AMR) bacteria have proliferated as a result of this trend, making it more difficult for us to fight infectious diseases. Infections brought on by germs like Pseudomonas aeruginosa and multidrug-resistant Enterobacteriaceae have grown more resistant to

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current antibiotics despite efforts to create novel medicinal treatments. Antibiotic resistance is one of the top ten hazards to world health, according to the World Health Organization [4]. It is widely acknowledged that one of the most significant issues facing public health today is multidrug resistant (MDR) microorganisms. In the US, there are around 2.8 million antibiotic-resistant infections annually, which result in 35,000 fatalities. Growing rates of antibiotic resistance affect every facet of contemporary medicine and jeopardise the outcomes of surgery, transplantation, and cancer treatment. Antibiotic resistance also has significant financial effects, although being challenging to quantify. Longer hospital stays, more outpatient follow-up, and the increased expense of new medications required to treat MDR bacteria could all contribute to this [5]. Microorganisms create substances called antibiotics that can stop bacteria from growing. These days, any substance that can be used to combat a bacterial infection is referred to as an antibiotic. Antibiotic resistance is rising, though, and it is predicted that by 2050, antibiotic-resistant microbes would be responsible for more than 10 million deaths globally each year. This is mostly due to how slowly new antibiotics are being developed. The World Health Organization (WHO) and a number of other stakeholders have taken notice of the issue of antibiotic resistance. Several nations, including India, developed national health action plans for controlling drug-resistant bacteria in response to the WHO's 2011 announcement that antibiotic resistance is an important research priority [6]. A major worldwide health concern of our day is antimicrobial resistance (AMR), which significantly reduces the efficacy of antibiotics, which are essential to contemporary medicine. According to analyses, bacterial AMR was linked to over 4.95 million fatalities in 2019, of which about 1.27 million were directly caused by resistant infections. These numbers highlight the fact that in many areas, AMR already outpaces the death tolls of HIV/AIDS, malaria, and tuberculosis. By 2050, the number of annual deaths could reach 10 million if prompt action is not taken [7]. The discovery of antibiotics has transformed medicine over the past century, allowing us to quickly treat illnesses that were previously frightening and typically fatal. However, overuse and abuse of these life-saving medications over the past few decades has resulted in bacterial resistance to antibiotics, which has generated a serious public health problem that is developing and spreading at an alarming rate [8]. Bacteria that show resistance to three or more kinds of antimicrobial medications currently used in clinical settings are known as multidrug-resistant organisms (MDROs). Methicillin-resistant Staphylococcus aureus (MRSA), Vancomycin-resistant Enterococci (VRE), and some gram-negative bacilli (GNB) are examples of these extremely resistant bacteria. MDROs have become important pathogens in hospital-acquired infections in recent years, restricting treatment options and raising hospital stays, death rates, and healthcare expenses [9]. The ability of a bacterium to withstand the effects of various antimicrobials is known as antimicrobial resistance. This kind of resistance allows bacteria to withstand drugs that were previously effective against them. Multidrug resistance (MDR) is the term used to describe this resistance to several medications. microorganisms exhibit a variety of resistance mechanisms, such as acquired resistance from other species, genetic mutation, or natural resistance in some microorganisms against a specific antimicrobial [10]. Smart Nanosystems for Antibiotics Delivery, Multidrug Resistance Caused by Altered Physiological States, Nanobiotics, Determination of antibiotic resistance pattern, Epidemiology and Mechanisms of Resistance, Targeting Novel Bacterial Pathwaysare the main topic of this review paper.

II. Methodology

Gram-Positive Pathogens [11-13]

With changing resistance patterns and virulence characteristics, methicillin-resistant MRSA continues to pose a serious danger to world health. MRSA epidemiology has changed, according to recent surveillance data, with community-associated strains increasingly producing infections linked to healthcare. Vancomycin-resistant enterococci (VRE) are becoming more common in oncology and transplant departments, making them significant nosocomial pathogens.

Gram-Negative Pathogens [14, 15, 16]

With mortality rates in some patient populations over 50%, CRE (Cabapenem Resistant Enterobacterales) is one of the most serious dangers. With notable increases in community-onset illnesses, ESBL (Extended Spectrum Beta Lactamase)-producing pathogens, especially Escherichia coli and Klebsiellapneumoniae, are still spreading around the world. Acinetobacterbaumannii with Pseudomonas aeruginosa have become highly resistant to drugs; certain strains, like the pan-resistant Acinetobacterbaumannii, showing resistance to

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every antibiotic on the market, including cefiderocol and other last-line treatments

Smart Nanosystems for Antibiotics Delivery [2]

Due to the extraordinary advancements in nanotechnology over the past few decades, smart DDSs with stimuli-responsive features have replaced traditional DDSs. These clever nanocarriers can enhance the effectiveness of therapeutic targeting and reduce drug toxicities or adverse effects by utilising the benefits of the response to particular internal or external stimuli. The release of pharmaceuticals from smart nanocarriers is triggered by specific exogenous or endogenous stimuli, such as changes in electric or light pulses, ultrasonic intensity, magnetic field, temperature, or endogenic stimuli, such as changes in redox gradients, enzyme concentration, or pH. The pH shift has been widely used to change how medications are delivered to particular organs (such the gastrointestinal system or the vagina) and intracellular spaces (like lysosomes or endosomes). When minute changes in the environment are associated with pathological conditions like cancer or infection, these nanocarriers can release medications. The development of polymeric systems with acid-labile bonds, whose cleavage or alteration permits the release of payloads anchored to the polymer backbone, and the use of polymers (polybases or polyacids) with ionisable groups that undergo solubility and/or conformational changes in response to environmental pH variation are the two main methods to achieve this stimuli-responsive release. In many different sectors, including cancer, temperature has also been thoroughly investigated as a stimulus for DDSs. These DDSs are mostly made of polymers with thermo-responsive blocks, which undergo a dramatic change in their characteristics in aqueous solution. Thus, disrupt the structure of the nano-system and allow the payload to be released in a regulated manner. The lower critical solution temperature (LCST), below which the polymer retains water molecules by forming hydrogen bonds, is the temperature at which some polymers become partially soluble. Polymer hydrophobicity and precipitation come from the disruption of the hydrogen bonds between the polymer chains and water over LCST. It is an intriguing characteristic caused by radiation forces or cavitation events. Physical forces related to cavitation have been demonstrated to cause drug release, nanocarrier destabilisation, and a brief increase in vascular permeability, which results in the uptake of therapeutic compounds by cells. The non-invasiveness, lack of ionising radiation, and ease of controlling tissue penetration depth by adjusting frequency, duty cycles, and exposure duration make ultrasound waves an exceptional tool.

Multidrug Resistance Caused by Altered Physiological States [17-21]

Bacterial cells' physiological conditions influence their susceptibility to antibiotics. The appearance of "persister" cells is one significant effect of this process. As a result, it was found early on that even high antibiotic concentrations do not completely eradicate the bacterial population, leaving behind a persister population that shares the same genetic makeup as the susceptible cells. Initially, the discovery that biofilms were more resistant to the majority of antibiotics was explained by a more restricted drug diffusion via the biofilm structure. Nevertheless, significant increases in resistance cannot be produced by this method. Despite intriguing evidence linking drug resistance in P. aeruginosa biofilms to periplasmic β-(1-3)-glucans and an efflux system, it is currently challenging to explain the widespread antibiotic resistance of biofilms based on changes to every cell in the population. Therefore, it is appealing to attribute this resistance to the biofilm population's high persister cell count. Persisters are now believed to be an example of how bacteria spontaneously produce combinations of phenotypically distinct populations so that one of them can be beneficial to a shifting environmental demand. We point out that a recent single-cell study found an antibiotic-susceptible stage in the life cycle of normal persister cells, which limits the effectiveness of antibiotic therapy.

Nanobiotics [4]

Because of their special qualities and adaptability, nanoparticles (NPs) have become a promising platform for the regulated administration of antibiotics and other therapeutic drugs. NPs have a number of benefits, such as the capacity to target certain bodily locations or cells, improve solubility and bioavailability, and encapsulate and shield medications from deterioration. Furthermore, some NPs have innate antibacterial qualities, which makes them useful weapons against bacterial infections. Because they have a number of benefits over traditional antibiotics, nanobiotics present a viable strategy to fight antimicrobial resistance (AMR).

NPs fall into four basic categories: carbon-based (carbon nanotubes, graphene NPs, and fullerenes), inorganic (metallic, silica, and

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mesoporous silica NPs), organic (polymeric NPs, liposomes, and dendrimers), and composite (metal, polymer, and ceramic). These NPs' size, shape, surface chemistry, drug loading capacity, release kinetics, and targeting specificity all affect how effective they are in drug delivery and antibacterial applications. Furthermore, some NPs, like copper and silver, have intrinsic antibacterial qualities that can be used to increase their therapeutic effectiveness against bacterial infections. By increasing the drugs' bioavailability in the targeted tissue, nanobiotics stop drug deterioration and lessen the negative effects on patients.

Numerous studies have shown that putting antibiotics into nanocarriers can boost their antibacterial efficacy. "Nanobiotics" refers to the employment of purposefully produced pure antibiotics with a size range of ≤100 nm or antibiotic molecules encased in artificial nanoparticles (NPs) for delivering novel antibacterial modalities to bacteria. These methods offer unique opportunities to combat infections brought on by planktonic and multidrug-resistant biofilms. Even while antibiotic-loaded nanocarriers may reduce the dosage required to eradicate bacterial resistance, their chemical makeup may raise questions regarding immunological action, cytotoxicity, biocompatibility, and biodegradability.

Antimicrobial nanoparticles (NPs) provide many remarkable advantages over traditional antibiotics in terms of conquering resistance and cutting costs. Numerous nanosized drug carriers are already available to enhance the pharmacokinetic properties of antibiotics and lessen their side effects. Antibacterial nanoscale materials have a great deal of promise for treating serious infections. These compounds are purposefully designed to improve biofilm penetration and successfully interfere with bacterial processes.

The use of metals at the nanoscale is preferred for the safe treatment of superficial infections and infectious diseases; metal oxides, organic nanoparticles, and nanocomposites all have strong antibacterial qualities. These antibacterial nanomaterials, also known as nanobiotics, provide a variety of tactics for fighting specific bacteria due to their varied chemical compositions and intrinsic qualities. "Antibiotic nanocarriers" based on liposomal, solid/lipid, terpenoid, polymeric, dendrimeric, and inorganic materials have shown promising results in increasing the overall efficacy of antibiotics as compared to employing antibiotics in bulk.

NPs can target disease regions in an active or passive manner. On-target accumulation outcomes are enhanced because infected areas have more nanocarrier permeability than uninfected tissue. Additionally, ligands (like antibodies) that attach to diseased tissues or microorganisms as receptors (like antigens) can be functionalised on the surfaces of nanocarriers. The latter approach is known as active targeting or ligand-mediated targeting.

Furthermore, by increasing cell absorption, ligand-conjugated nanocarriers may improve the therapy of intracellular infections. In recent years, targeted drug delivery systems have made significant strides, mainly in the treatment of cancer and Mycobacterium TB-caused tuberculosis. Compared to the antibiotic in its free form, the conjugation proved more potent. Most significantly, intracellular bacteria that the antibiotic would have overlooked and left "hidden" appear to be affected by the focused therapy, functioning as a latent cause of recurrent illness.

Inorganic NPs differ in size, form, solubility, and stability because they are made up of the inorganic oxides of Ag, Mn, Al, Ti, Se, Au, Si, or Cu. Aggregation behaviour, pH, temperature, reduction time, and reducing agent concentration all affect their antibacterial activity. AgNPs, for example, stick to cell membranes, interact with membrane proteins, increase membrane porosity, and enter and stimulate ROS generation in order to hinder respiration, including bacterial cell lysis and generating inflammatory reactions.

Silver has shown great potential as an antiseptic and antibacterial agent since antiquity. There may be a unique method to reduce the emergence of antibiotic resistance by using fewer medications overall due to the antibacterial activity of bacterial AgNPs. AgNPs serve as a delivery vehicle for ampicillin (amp), an antibiotic that is spherical, 4 nm in size, and coated with citrate. They can load 1.06 × 10−6 amp to target the cell walls and β-lactamase species of Pseudomonas aeruginosa, Escherichia coli, and Vibrio cholerae.

Gold nanoparticles (AuNPs) are known to have bactericidal effects due to strong electrostatic forces that result in intracellular loss and cell death. AuNPs have bactericidal properties and build up on cell surfaces. Bacterial membrane destruction, cellular enzyme activity suppression, and energy metabolism are among the facet-dependent antibacterial characteristics of Au nanocrystals. Vancomycin (Van) antibiotic delivery is exemplified by AuNPs that are spherical in shape and have a size of 4–5 nm. Van's phenyl group binds

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to AuNP through the Au-S bond, and each AuNP joins with about 31 Van on its surface to target the cell membranes of Vancomycin-resistant Enterococci and Escherichia coli.

For example, significant electrostatic forces, cytoplasmic leakage, cell death, and gold nanoparticles boost the bacterial 16S ribosomal RNA gene capture when iron oxide nanoparticles (FeONPs) and DNA hybridisation are coupled. CaF2 NPs have been shown to kill Streptococcus mutans because they adhere to tooth surfaces and continually release fluoride ions. This suppresses pathogenic S. mutans and encourages remineralisation. The majority of organic NPs, such as liposomes, polymeric materials, and micelles, are biocompatible and quickly opsonise due to their hydrophilic/hydrophobic individualities.

Phospholipid bilayers in the shape of spherical vesicles make up liposomes and lipid nanoparticles. When bacteria fuse with the microbial membrane, the drug may be delivered into the bacteria. They have been converted into a drug delivery system that uses antimicrobial medications to treat diseases brought on by biofilms. Their unique characteristics—such as target specificity, low toxicity, and the ability to fuse biofilm matrix/cell membrane—improve the efficacy of antibiotics by lowering recurrent infections.

Polymeric nanoparticles (NPs), including nanospheres and nanocapsules, are drug transporters. They are both chemically and physically stable and enhance targeted efficacy. Lipid-based surface-functionalized PLGA is one such drug delivery technique that can bind to biofilm components and protect antibiotics against degradation.

Photoexcited quantum dots (QDs) have a metallic appearance but a semiconductor core composed of zinc or cadmium. QDs have an antibacterial effect because of their ability to degrade bacterial cell walls or membranes, generate free radicals, bind with genetic material, and stop energy generation. When coupled with zinc and rifampicin, the antibacterial activity of transferrin-modified silver QDs is much greater than that of the zinc and rifampicin complexes. It has been discovered that the growth of multiple-drug-resistant (MDR) clinical isolates (S. typhimurium, methicillin-resistant Staphylococcus aureus, Klebsiellapneumoniae, and carbapenem-resistant Escherichia coli) is suppressed by the redox potential of photogenerated charge carriers that interact with the bacterial environment via photoexcited QDs.

The need for innovative approaches to managing microbial infections is highlighted by a number of factors, including the poor targeting of antibiotics to infection sites, increased dosing frequencies and side effects, the spread of resistance to currently used antibiotic medicines, the slow development rate of newer antibacterials, and the potential for resistance to future new antimicrobial drugs.

Prevention [5]

One of the most pressing issues facing public health is stopping the spread of MDR bacteria in the community. Unfortunately, there is sometimes a lack of national or even regional data on antibiotic susceptibilities. Furthermore, the supporting epidemiologic metadata is typically too limited to identify which isolates are actually community-associated when these data are accessible in any manner. Additionally, clinical infections are typically just the tip of the iceberg, and subclinical spread has already taken place once a signal strong enough to get policymakers' attention.

A multifaceted approach including all stakeholders is necessary for any successful preventative plan. Antibiotics must be eliminated from the food chain in addition to human clinical antimicrobial management. Additionally, we must restrict the quantity of xenobiotics that enter the environment, such as quaternary ammonium compounds. Treating contaminated wastewater, such as that produced by pharmaceutical companies and hospitals, is another difficult step in reducing bacterial exposure to antibiotics. For example, a study examined samples taken from a wastewater treatment plant in India that received water from ninety regional bulk drug manufacturers. Among other things, the samples contained higher concentrations of ciprofloxacin than are typically found in the blood of patients receiving this medication.

39 antibiotics were tested on the bacteria that were found in this water. About 20% of bacteria were resistant to 33–36 antibiotics, while about 30% of bacteria were resistant to 29–32 drugs. The significance of preventing this contamination is demonstrated by the size of this effect and the understanding that soil-dwelling bacteria will transfer resistance genes to more clinically relevant bacteria. As a hospital speciality, antimicrobial stewardship is growing quickly. In order to assess the suitability of the selection and duration of antibiotic regimens, stewardship teams frequently

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combine the expertise of chemists and infectious disease specialists. Nonetheless, the majority of antibiotics are provided in ambulatory care, and further focus in this area is required to significantly reduce antibiotic exposure in the community as a whole85.This will necessitate both a cultural shift in the public's perception of the advantages and disadvantages of antibiotics as well as a paradigm shift in the behaviour of prescribers. It will be crucial to identify MDR bacteria more promptly by rapid diagnostic tests in order to reduce the empirical use of overly broad antibiotics. Rapid testing is also crucial for identifying other, non-bacterial aetiologies. Whether any therapies can address the problem of persistent colonisation with MDR bacteria is a crucial question. Decolonising these patients would obviously reduce the transmission danger.

Additionally, one should not undervalue the hardship that this ailment places on each particular sufferer. Patients with MRSA or CRE are "labelled" as carriers for life in many healthcare systems, necessitating the implementation of isolation measures each time they are admitted to the hospital. This has several negative consequences and lowers patient satisfaction (86). Decolonisation is a conceptually appealing alternative because of these factors. Antibiotics are used in the majority of decolonising tactics, nevertheless. The majority of MRSA decolonisation techniques combine topical chlorhexidine with intranasal mupirocin. It has been demonstrated that this strategy reduces surgical site infections.However, the impact is typically transient, and colonisation tends to reoccur. There are presently no effective treatments for intestinal bacteria. Although several procedures for selective gut decontamination have been described, none have proven to be very promising. Furthermore, it would seem illogical to administer even more antibiotics given the increasing understanding of the gut microbiome's role in the defence against MDR bacteria. Decolonising patients by altering the gut microbiome by probiotics or faecal microbiota transplantation is a promising but yet experimental approach.

Determination of antibiotic resistance pattern [6]

Multiple antibiotic resistant bacteria (MAR) were defined as bacteria that exhibited resistance to three or more antibiotics. The MAR index value for each sample was calculated using the following formula. M/n is the MAR index. where n is the total number of antibiotics used in the calculated test and M is the number of drugs to which the isolate shown resistance. A MAR index value greater than 0.2 often denotes multiple antibiotic resistance in the isolate. ARI [Antibacterial resistance index] was calculated using the formula given by, which is mathematically written as ARI = y/nx, in order to identify the prevalence of antibiotic resistance according to the sample collection sites.If x is the total number of antibiotics tested in the sensitivity test, y is the actual number of resistance microorganisms in the sample, and n is the number of isolates examined. According to sample collection sites, the ARI index is typically directly correlated with the occurrence of antibiotic resistance.

Epidemiology and Mechanisms of Resistance [7]

A startling number of bacterial infection-related deaths occur each year due to the alarming increase in antibiotic resistance rates, the growing danger of infections in immunocompromised people, and the extensive use of invasive diagnostic and therapeutic techniques worldwide. 33 bacterial pathogens were responsible for 7.7 million of the 13.7 million infection-related deaths that occurred in 2019. These were responsible for 56.2% of sepsis-related deaths and 13.6% of all deaths worldwide.The most significant bacterial pathogens linked to mortality were Escherichia coli, Klebsiellapneumoniae, and Pseudomonas aeruginosa (all three Gram-negative bacilli were responsible for more than 500,000 deaths in 2019); Streptococcus pneumoniae, which was most commonly linked to deaths in the paediatric population under 5 years; and Salmonella entericaserovarTyphi, which was linked to deaths in 135 countries.

Targeting Novel Bacterial Pathways [8]

Another modern tactic to tackle antibiotic resistance in bacteria is to target emerging bacterial pathways in drug development. Attempts are being made to uncover pathways required for the germs' virulence (i.e., ability to cause a disease or damage) and pathogenesis (how the infection develops into a disease) rather of focusing on suppression or regulation of the traditional targets of antibiotics. Interfering with quorum sensing (QS), the bacterial communication mechanism used for coordinated actions like biofilm formation or virulence improvement, is one such strategy.

Outcomes [9]

The acquisition, infection, and colonisation of MDROs were the main outcome measures

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evaluated. A positive result from a screening swab or clinical specimen culture without any clinical indications or symptoms of MDRO-induced infection was referred to as colonisation. The isolation of MDROs from a patient's clinical material and the emergence of suitable clinical signs and symptoms were considered indicators of infection. Regardless of the existence of clinical signs of MDRO infection, acquisition was defined as a patient who tested negative on specimens taken within 48 hours of admission and had clinical cultures that were positive either 48 hours after admission or at the time of discharge.All-cause mortality and bacteremia linked to MDROs were secondary outcomes. Regardless of the underlying cause of death, all-cause mortality is the total number of deaths from all causes within a given population over a specified time period. Multidrug-resistant bacteria that enter the bloodstream and cause a systemic illness are referred to as MDROs-associated bacteremia. Fever, chills, and low blood pressure are among the common signs of this illness.

Nanoparticles [10]

One possible strategy for fighting MDR bacteria is nanotechnology. Increasing drug affinity toward the bacterial cell membrane by using NPs' protective properties against bacterial enzymes, improving tissular transport, increasing the surface to volume ratio, and having a high drug loading capacity are some of the therapy approaches. The conjugation of antibiotics with NPs in the recommended size range may improve the effectiveness of drug binding at the target site.

III. Conclusion:

AMR continues to pose a serious danger to both global health and the economy. Alarming increases in resistance rates among priority pathogens, expanding geographic gradients of surveillance and stewardship capabilities, significant delays in the pace of new antimicrobials reaching the clinical market, rising costs to health systems and productivity, and the pressing need for coordinated, stakeholder-led, evidence-based policy responses are just a few of the areas of significant concern in the evolving AMR landscape that this review has identified. The emergence of multidrug resistant (MDR) bacteria has proven to be a serious menace to human health and has become a challenging global issue.Monitoring and treating infections brought on by MDR bacteria would be made easier if we understood how resistance functions. biofilm growth, efflux pump overexpression, molecular genetic modification, and long-term consequences. Furthermore, in order to create nanomaterials with advantageous physicochemical properties that will make them more responsive to various biological environments for therapeutic benefits without any negative effects, a comprehensive and detailed understanding of how nanocarriers interact with biological systems is necessary.A coordinated, multidisciplinary effort is required to address this situation. To create novel solutions, raise awareness, and put sustainable policies into action, cooperation between healthcare professionals, researchers, legislators, and the general public is crucial. We can secure the development of new therapies, preserve the effectiveness of current antibiotics, and defend public health for present and future generations by developing these strategies.In a patient receiving antibiotic treatment, harmful bacteria may persist because they may develop a physiologically resistant condition without undergoing genetic alterations. It is evident that bacterial infections that are usually thought of as community-acquired are becoming more resistant to antibiotics. Common nosocomial MDR pathogens are also spreading throughout the community. Numerous factors, such as the bacteria's natural habitats and the competition in those niches, are probably secondary to these diseases' success in the population. Furthermore, some bacterial strains seem to be far more capable of spreading across the population and maintaining their MDR phenotype.The relative fitness cost of the expression of genes linked to antibacterial resistance is probably compensated for by extra genetic content. The emergence of MDR bacteria in the community poses a serious threat to public health and needs to be addressed quickly and proactively. To prevent the spread of bacterial multiple antibiotic resistance, comprehensive guidelines for the prudent use of antibiotics and the direct discharge of hospital effluent into water bodies must be prepared. Therefore, there is an opportunity to adapt to the constant evolution and resistance of bacteria when scientific discovery, industrial innovation, regulatory control, and the healthcare system can work together.To maximise accuracy and resource efficiency, healthcare organisations can choose the right therapies based on their individual resistance profiles. Antimicrobial medications must be used prudently when necessary in order to reduce bacterial MDR. To counteract this kind of drug resistance, medical professionals can also raise awareness of drug safety. Narrow-spectrum antibiotics must be chosen over broad-spectrum ones. Patients must also maintain good cleanliness

and apply disinfectants, as well as utilise antibiotics sensibly.

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