CHAPTER 5
ANTIBACTERIAL APPLICATION OF NANOMATERIALS

Wong Kher Thi, Wong Sru Thi,
Mohd Hayrie Mohd Hatta, and Nik Ahmad Nizam Nik Malek

5.1 INTRODUCTION

The rapid emergence of antimicrobial resistance poses a worldwide threat to the effectiveness of currently available antibiotics. This problem has led to multi-drug resistance (MDR) bacteria issues. In general, MDR bacteria are resistant to numerous antibiotics, making them more difficult to treat effectively. The resistance occurs due to various factors, such as the inappropriate use or excessive use of antibiotics, incomplete treatment regimens, and the natural ability of bacteria to evolve and adapt. A bacterium classified as MDR demonstrates resistance to various antibiotics commonly used in antibacterial treatment. This poses significant public health concerns as it reduces the range of available treatment options, making treating infections more difficult and potentially resulting in higher morbidity and mortality rates (Van Duin & Paterson, 2016).

Two types of antibiotics can be grouped according to their origin, which are natural and synthetic. Natural antibiotics, such as turmeric, honey, garlic, and ginger, have been widely used as alternative medicine for their numerous benefits. Meanwhile, synthetic antibiotics like linezolid, meropenem, and cephalosporin C are manufactured through

chemical processes in the laboratory. Synthetic antibiotics are known for their rapid action and are regarded to have high toxicity on pathogens compared to natural antibiotics (Upmanyu & Malviya, 2020). However, the improper use or excessive use of antibiotics has contributed to antibiotic resistance, signifying that the antibiotic has lost its effectiveness in combating the bacteria (Parmanik et al., 2022). Antibiotic resistance can manifest through four mechanisms, as illustrated in Figure 5.1. These mechanisms involve deactivating the drug, hindering drug uptake, altering the drug target, and involving drug efflux.

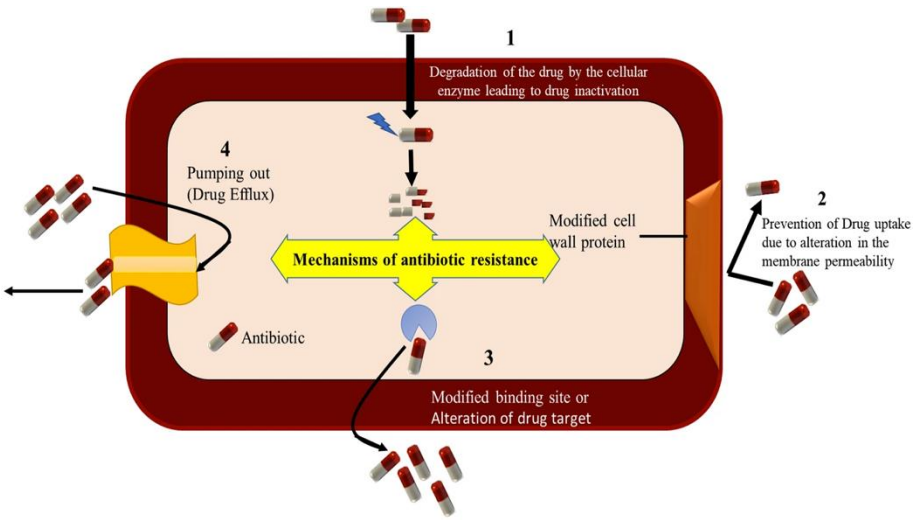

Figure 5.1 Schematic diagram of the four primary antibiotic resistance mechanisms (Source: Parmanik et al., 2022)

According to Parmanik et al. (2022), the increase in antibacterial resistance patterns can differ depending on the particular class of antibiotics and the associated level of risk. The World Health Organisation [WHO] (2017) listed a group of MDR bacteria, which has been categorised into three groups (see Table 5.1) based on the urgency of the research and development of new antibiotics. These bacteria are associated with prevalent diseases like gonorrhoea and food poisoning from salmonella contamination (WHO, 2017). It has been said that the

treatment caused by MDR bacteria often requires more extensive and expensive healthcare interventions. Therefore, a highly recommended solution is to explore effective alternatives.

Table 5.1 Examples of multi-drug resistance bacteria listed by WHO (2017)

Priority Classification	Bacteria
Critical	*Acinetobacter baumannii, Pseudomonas aeruginosa* and *Enterobacteriaceae*
High	*Enterococcus faecium, Staphylococcus aureus, Helicobacter pylori, Campylobacter spp, Salmonellae,* and *Neisseria gonorrhoeae*
Medium	*Streptococcus pneumoniae, Haemophilus influenzae,* and *Shigella spp*

Addressing the issue of antibiotic resistance involves developing new antibiotics, which, despite being an effective solution, often requires significant time and resources. Moreover, the effectiveness of new antibiotics tends to be limited as resistance reemerges after a relatively short period. For the past few decades, nanomaterials have attracted significant worldwide interest due to their excellent physical and chemical properties at the nanometre scale. The unique physicochemical properties of nanomaterials, such as their high surface area-to-volume ratio that led to high antibacterial performance, enable them to exhibit significant antibacterial effects even at relatively low concentrations. Metallic and metal oxide nanoparticles (NPs), such as gold (Au), silver (Ag), iron oxide (Fe_2O_3), zinc oxide (ZnO), copper oxide (CuO), and titanium dioxide (TiO_2), are commonly utilised in antibacterial applications against various types of bacteria, particularly MDR bacteria (Table 5.2) (Slavin et al., 2017). Thus, the advancement of nanotechnology presents a prospect for addressing the problems associated with MDR bacteria (Parmanik et al., 2022).