Chapter 9

Developments in Antibacterial Disinfection Techniques:
Applications of Nanotechnology

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ABSTRACT

One of the most daunting challenges facing nations today is controlling the spread of increasingly lethal bacteria. Today, a handful of bacteria can no longer be treated with traditional antibiotics and show antibacterial resistance. In this regard, nanotechnology possesses tremendous potential for the development of novel tools which help prevent and combat the spread of unwanted microorganisms. These tools can provide unique solutions for the challenges of the traditional disinfection methods, such as increased antibacterial activity, cost reduction, biocompatibility and personalized treatment. Despite its great potential, nanotechnology remains in its infancy and continued research efforts are required to achieve its full potential. In this chapter, traditional methods and their associated limitations are reviewed for their efficacy against microbial spread, and potential solutions in nanotechnology are described. A review of the state of the art disinfection techniques using nanotechnology is presented, and promising new areas in the field are discussed.

INTRODUCTION AND BACKGROUND

Colonization of surfaces by infectious microbes is a serious threat to public health (Beyth, Houri-Haddad, Domb, Khan, & Hazan, 2015; Guo, Yuan, Lu, & Li, 2013). The family of microbes consists of bacteria, fungi, and other protozoans. Individuals coming into contact with a surface hosting these microorgan-

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isms may become infected and mobile carriers of diseases. In the modern era, such individuals can cross state lines and international borders in remarkably short time periods and therefore, microbes can travel thousands of miles alongside human passengers to foreign soil. Consequently, the task of tracking and preventing outbreaks of disease is even more formidable than in past years.

Microbes are ubiquitous organisms. They infest a variety of surfaces, from tools to hospital walls. Today, once a surface becomes contaminated, the proper response is to dispose of it. However, cost is a major concern in this procedure and it may not be a long term solution to disinfect the environment. As an example, washing hands becomes relatively ineffective if the working environment is heavily infested with microbes, such as has been the case with methicillin-resistant *Staphylococcus aureus* (MRSA) in hospitals, (Page, Wilson, & Parkin, 2009).

Another concern regarding microbial infestation is on food spoilage. Large food corporations must maintain vast distributions networks, and moreover ensure that the food arrives without spoiling by microbes. If these microbes are present during sealing, then they will proliferate continuously in the presence of nutrition and water before reaching their destination, resulting in spoilage. Once the microbes infest the source, it is a challenging task to stop further contamination.

In naval applications, the humidity provides a suitable environment for microbial growth. Due to the confined space in a vessel, microbial life has the ability to run rampant. Moreover, ships can be restrained to remain at sea for weeks or months at a time. In consequence, there is a strong need to protect food supplies from spoiling to alleviate the risk of endangering the mission.

Similar to the naval missions, the microgravity environment of space presents unique challenges for combatting microbial life. If an infection is able to spread, disposal is not an option since it would require additional cleaning and disinfection materials supplied from Earth, which is a gross time and cost investment. Life support systems, water treatment and sewage need to be carefully monitored in order to prevent the growth of dangerous microbial life, (Balagna et al., 2012).

Traditionally, antibiotics have been utilized to help mitigate complications caused by microbial borne illness. However, a handful of bacteria are no longer susceptible to these agents (Page et al., 2009). Over the past decade, a plethora of research has gone into better understanding the antibacterial properties of various materials to help combat the decline the efficacy of antibiotics. The cost of research and development for new antibiotics has become a diminishing return on investment, where the appearance of drug resistant microbes is outpacing new drug production; studies show that a new drug takes approximately 8 to 15 years of development time and a cost of $800 million dollars (Gwynn, Portnoy, Rittenhouse, & Payne, 2010). Efforts were made in the late 1990's after the first bacteria genome was fully sequenced in 1995 to find a genetic basis for targeted drug development, although the results were poor at best (Payne, Gwynn, Holmes, & Pompliano, 2007).

Besides antibiotics, using other biocidal chemicals such as bleach is not a practical solution for preventing the initial growth of a biofilm since these chemicals are only applied after a growth has taken place. Therefore, antimicrobial biocides can effectively remove the microbes on the surface but the biofilm which serves as the optimal environment for the spread underneath the contaminated surface may remain unaffected. Furthermore, such chemicals are not only toxic to microbes but also to humans. Bleach is one of the most commonly used chemical disinfectant of this type and it is used in many applications including food packaging for sterilization. It is however well documented that bleach similar to the other biocidal chemicals is harmful to human health even if trace amounts are consumed (McGlynn).

As described previously, bacteria have a strong ability to attach to solid surfaces and then form a biofilm, which serves as a reservoir for the development of pathogens, leading to health threats. Once it

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