Chapter 1
Convergence of Nanotechnology and Microbiology

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ABSTRACT

The convergence of nanotechnology with microbiology is a nifty interdisciplinary research area that could amplify the limits of technology, enhance global health through formation of different drugs that can be effective against different infectious diseases, and for treatment of drinking water to kill the pathogens and make it safe for public use. Bacteria, fungi, actinomycetes, and plants have been successfully used for the formation of nanoparticles of silver, gold, zinc, etc. As the microorganisms, especially bacteria, are becoming resistant to the commonly used antibiotics, an alternative antimicrobial agent that can be effective against the antibiotic-resistant bacteria is needed. In the present chapter, the author highlights the relationship between these two mighty disciplines. The chapter deals with many aspects like antimicrobial activity of nanoparticles, formation of nanoparticles using microorganisms, etc. The green synthesis of nanoparticles is emerging as a new field of science; hence, it is discussed in detail.

INTRODUCTION

Nanotechnology is emerging as one of the leading subject of interest for researchers. Nanoparticles preparation and application in various fields like catalysis, electronics, environmental, pharmaceutical and biotechnology has been expanded significantly. Microbiology relates to nanotechnology at number of levels. It is well known that many organisms can produce inorganic materials either intra or extracellularly. For example, unicellular organisms such as magnetotectic bacteria produce magnetic nanoparticles and diatoms synthesize siliceous materials. Many bacterial entities are nano-machines in nature, including molecular motors like flagella &pilli. Bacteria also form biofilms by the process of self-assembly (e.g the formation of curti film by E.coli). Nanotechnology can be used to study the process of biofilm formation, a key medical problem. It can also be used to study the self-assembly of viral capsids as we desperately need anti-viral drugs.

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World is facing a new problem of water scarcity. The availability of drinking water is decreasing rapidly due to water pollution and climatic change. Microorganisms like bacteria viruses and protozoa are a great threat to the available fresh water resources. These organisms can contaminate the water bodies resulting in different kind of water born diseases like cholera hepatitis etc. overcoming this challenge is becoming increasingly difficult as the demand of safer water grows with the increasing in world population and climate change threatens to take away a large fraction of already scarce fresh water. Nanotechnology can enable both safer and sustainable solutions to these problems. By the help of nanotechnology we can develop new processes and enhance the performance of existing treatment process. Nanotechnology can address emerging disinfection challenges to make water safe for consumption (e.g., photocatalytically enhanced disinfection, biofouling-resistant membranes, biofilm and corrosion-resistant surfaces, and sensors for pathogen detection)

Bacteria which are not exposed to large concentrations of metal ions may also be used to synthesize nanoparticles. It has long been reported that among the eukaryotes yeasts are explored mostly in the biosynthesis of semiconductor nanoparticles. Fungi have also been used for the synthesis of nanoparticles. The use of fungi is potentially excited since they secret large amounts of enzymes and simpler to deal with in the laboratory.

Biosynethesis of nanoparticles from plants, bacteria, fungi is gaining interest as the process is less time consuming and economical compared to chemical synthesis. Many bacteria have been successfully used for the preparation of gold, silver, zinc and other nanoparticles. Biologically synthesized nanoparticles are being widely used in the field of medicine. For the last two years extensive work has been done to develop new drugs from natural products because of the resistance of microorganisms to the existing drugs.

Liposomes discovered in mid 1960s were the original models of nanoscaled drug delivery devices. They are spherical nanoparticles made of lipid bilayer membranes with an aqueous interior but can be unilamellar with a single lamella of membrane or multilamellar with multiple membranes. They can be used as effective drug delivery systems. Cancer chemotherapeutic drugs and other toxic drugs like amphotericin and hamycin, when used as liposomal drugs produce much better efficacy and safety as compared to conventional preparation.

Viral vectors used for gene transfer have the limitations of safety concerns and stimulation of immune system with production of antibodies against the viral vectors. Further, naked DNA cannot cross the negatively charged cell membrane as these are also negatively charged (Peters A et al 2000). Hence,there is a need for other modes of transfer of genetic material such as nanoparticles based gene therapy. Liposomes measuring less than 100 nm can be used for the delivery of genetic material into cells. Liposomes incorporated with polyethylene glycol and galactose target livercells effective due to their rapid uptake by liver Kupffer cells. Thus gene therapy may be tried with such liposomal nanoparticles for various liver disorders such as Wilson's disease and hereditary hemochromatosis.

The rapid and sensitive detection of pathogenic bacteria at the point of care is extremely important. Limitations of most of the conventional diagnostic methods are the lack of ultrasensitivity and delay in getting results. A bioconjugated nanoparticle-based bioassay for *in situ* pathogen quantification can detect a single bacterium within 20 minutes. Detection of single-molecule hybridization has been achieved by a hybridization-detection method using multicolor oligonucleotide-functionalized QDs as nanoprobes. In the presence of various target sequences, combinatorial self-assembly of the nanoprobes via independent hybridization reactions leads to the generation of discernible sequence specific detection of multiple relevant sequences