

Preface

Nanotechnology is an emerging and dominating area that includes a novel class of nanomaterials that are being considered for various applications including electronics, smart devices, sensors, and biomedicine. Nanotechnology has huge potential in all fields of science and technology, because of their morphology-dependent unique physical, chemical, electronic, catalytic, and biological properties. Nanotechnology has already begun to have a huge impact on various perspectives of beneficiary aspects, and is drastically revolutionizing the industries and pharmaceutical companies with great emphasis on human health, environment safety, and sustainability. Nanotechnology has already begun to pervade several aspects of our day-to-day life, and researchers are revisiting several useful aspects with a nanoperspective for a better lifestyle. This phenomenon is likely revolutionizing medical sciences, and many chemotherapeutics are being reconsidered for possible improvements using engineered nanoparticles.

This book will emphasize issues related to the safe use of nanoparticles, keeping in mind the biotic environment. Nanoparticles in various forms are tremendously being implemented in several products as additives and therefore are getting released into the environment as pollutants. Interactions between the nanoparticles and microorganisms in the environment are unavoidable, but the pandemic consequences of such interactions are beginning to be investigated. This brief book will illustrate on how naturally occurring microorganisms and man-made nanoparticles interact, and the consequences of such interaction, using suitable examples from our studies published in several peer-reviewed international journals. This book will not only be helpful for the scientific and industrial community but will also attract wide attention of students and researchers in different areas of sciences such as microbiology, biotechnology, nanotechnology, toxicology, materials science, biomedical engineering, and cell and molecular biology.

The several objectives of this brief book are to introduce nanobiotechnology along with “nanotoxicology” aspects, and make the readers aware of the potential interactions of engineered nanoparticles with microorganisms. Impacts of toxic metal and metal oxide nanoparticles such as silver and zinc oxide on the growth

and viability of several bacteria are presented. Differences in the bacteria–nanoparticle interactions using different forms of nanoparticles, nanoparticles synthesis methodologies are described with emphasis on the influence of surface coatings. The use of various analytical and physical characterization techniques that are often used to analyze nanoparticle bacteria interactions are outlined. Mechanistic insights into the relationship between the bacterial growth inhibition, reactive oxygen species generation, and up- and/or downregulation of transcriptional stress-responsive genes are also discussed. Finally, how advanced and emerging imaging techniques such as transmission electron and atomic force microscopes can be made use to assess their interactions are discussed, which will have impacts toward better understanding on the overall microbial–nanoparticle interactions.

The book contains four chapters; Chap. 1 includes a general introduction to various nanoparticles that are considered lethal to microbial cells (bacteria, virus, and fungus) with emphasis on metal and metal oxide nanoparticles. Interactions of various nanoparticles with microbes along with the influence of additives in the form of solvents, surfactants, and capping materials are described using suitable examples. Various proposed mechanisms by which the nanoparticles induce toxicity and the bacterial stress response toward nanoparticles are described using multiple examples. Chapter 2 describes the commonly used laboratory experimental, analytical, and physical characterization techniques to evaluate and determine the toxicity of nanoparticles toward different microorganisms. Comparative assessments on the differences between these procedures are described correlating to nanoparticle properties. The role of multianalytical assays and techniques used for understanding the interactions of nanoparticles with microbial cell systems are presented. The growth and viability on the bacteria relative to nanoparticles size, growth media, and dosage are discussed. Details of the bactericidal impacts assessed using multiple assays such as minimum inhibitory concentration, colony-forming units, disk diffusion tests, and live/dead assays are provided. Discussions of advanced tools such as inductively coupled plasma–mass spectroscopy, scanning electron microscopy, transmission electron microscopy, dark-field microscopy, and atomic force microscopy that are used to understand the response mechanism of the bacteria are outlined. Chapter 3 describes the bactericidal properties of zinc oxide nanoparticles and the detailed mechanistic of their interaction with regard to the bacterial viability, reactive oxygen species (ROS) generation, and surface alterations on the bacterial cell. The relation between the nanoparticle and bacteria interaction with respect to transcriptional genome stress profiling is described. Analysis on the various up- and downregulation of genes based on microarrays to evaluate the bacterial genetic response mechanism is described. Chapter 4 describes the influence of various surface coatings of nanoparticles in dictating bactericidal toxicity. Various surface stabilizing agents often used to synthesize nanoparticles, along with their roles with respect to particles size and shape control, particles over all charge, particles stability, interaction abilities with the biomaterials, and/or cells, etc., are discussed. How engineered nanoparticles are incorporated with various surface coatings during their synthesis, along with details of the various physical characterization techniques including zeta potential,

Fourier transform infrared spectroscopy, and X-ray photoelectron spectroscopy are described. Finally, comparative studies on the effects of various surface-coated nanoparticles on the toxicity of bacteria are discussed.

I am pleased that I have been invited to contribute this second brief book published by Springer within the Springer Briefs in Biometals series by Prof. Larry Barton, edited by Dr. Sonia Ojo. I am glad to submit this book and I hope that you will enjoy reading it more than I did while writing.

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Anil K. Suresh

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Suresh, A.K.

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