CHAPTER 1
INTRODUCTION

In recent years, nanotechnology is emerging as cutting-edge technology interdisciplinary with physics, chemistry, biology, material science and medicine. The prefix *nano* is derived from Greek word *nanos* meaning “dwarf” that refers to things of one-billionth \((10^{-9} \text{ m})\) in size. The primary concept of nanotechnology was presented by Richard Feynman in a lecture entitled “There’s plenty of room at the bottom” at the American Institute of Technology in 1959. Nanoparticles are usually 0.1 to 1000 nm in each spatial dimension and are commonly synthesized using two strategies: top down and bottom up (Fendler 1998). In top-down approach, the bulk materials are gradually broken down to nanosized materials whereas in bottom-up approach, atoms or molecules are assembled to molecular structures in nanometer range. Bottom-up approach is commonly used for chemical and biological synthesis of nanoparticles.

Unlike bulk materials, nanoparticles have characteristic physical, chemical, electronic, electrical, mechanical, magnetic, thermal, dielectric, optical and biological properties (Schmid 1992; Daniel et al. 2004). Decreasing the dimension of nanoparticles has pronounced effects on the physical properties that significantly differ from the bulk material. These physical properties are caused by large number of surface atoms, large surface energy, spatial confinement and reduced imperfections. Nanoparticles have an array of advantage over bulk materials due to their surface plasmon resonance (SPR), enhanced Rayleigh scattering and surface enhanced Raman scattering (SERS) in metal nanoparticles, quantum size effect in
semiconductors and supermagnetism in magnetic nanomaterials. Therefore, nanoparticles are considered as building blocks of the next generation of optoelectronics, electronics, and various chemical and biochemical sensors (Wong and Schwaneberg 2003; Ramanaviciusa et al. 2005).

Optoelectronic, physicochemical and electronic properties of nanoparticles are determined by their size, shape and crystallinity (Shankar et al. 2005; Chandran et al. 2006). Monodispersed nanoparticles with particular shapes have wide applications in the areas of optics, biology and computation, medical diagnostics, \textit{in vitro} assays, \textit{ex vivo} and \textit{in vivo} imaging, cancer therapy and drug delivery. Therefore, the synthesis of monodispersed nanoparticles with different size and shape has been a matter of research interest. Although various physical and chemical methods are extensively used to produce monodispersed nanoparticles, the stability of nanoparticles and the use of toxic chemicals for synthesis is the subject of paramount concern. Some toxic chemicals and hydrophobic solvents have the ability to reduce and stabilize the nanoparticles. These chemically synthesized nanoparticles carry some reactive functional groups, which can be toxic to biological system. Hence, the development of clean, biocompatible, non-toxic and eco-friendly methods for the synthesis of nanoparticles deserves merit. Biological methods are regarded as safe, cost-effective, sustainable and environment friendly processes. However, biological methods have some drawbacks in culturing of microbes, which is time-consuming and difficult in providing better control over size distribution, shape and crystallinity. The biologically synthesized nanoparticles are not monodispersed and the rate of biological synthesis is also slow. These are the problems that have plagued the biological synthesis approaches, but the insights gained
from strain selection, optimizing the conditions such as pH, incubation temperature and time, concentration of metal ions, and the amount of biological material have come up to give hope in implementation of biological approaches in large scale and for commercial applications. There are also the possibilities of producing genetically engineered microbes that overexpress specific reducing agents and thereby, controlling the size and shape of biological nanoparticles. The combinatorial approach such as photobiological methods also will help to increase the rate of production as reported in the case of biological synthesis of silver nanoparticles using the fungus, *Fusarium oxysporum* (Mohammadian et al. 2007).

While exploring the natural secrets for the biological synthesis of nanoparticles by microbes and plants, which are regarded as potent eco-friendly green nanofactories, scientists have discovered several nanomaterials such as magnetite particles by magnetotactic bacteria (Lovley et al. 1987; Dickson 1999), siliceous materials by diatoms (Pum and Sleytr 1999), gypsum and calcium layers by S-layer bacteria (Milligan and Morel 2002), and gold nanoparticles by plants, *Brassica juncea* (Marshall et al. 2007) and alfalfa sprouts (Gardea-Torresdey et al. 2002). Plant biomasses of alfalfa and *Triticum aestivum* passively bind and reduce Au$^{3+}$ to Au$^{0}$ (Gardea-Torresdey et al. 1999; Armendariz et al. 2004). Plant extracts of neem leaf, gooseberry, and tamarind leaf synthesized extracellular silver and/or gold nanoparticles (Mohanpuria et al. 2008). Interactions between metals and microbes or plants have been exploited for various biological applications in the fields of bioremediation, biomineralization, bioleaching, and biocorrosion (Klaus-Joerger et al. 2001). Thus, biological synthesis of nanoparticles has been emerged as a promising field of research as nanobiotechnology interconnecting biotechnology and nanotechnology.
Therefore, the objectives of the present investigation were formulated as follows:

1. Screening of plants and microbes that bioreduce the metals, silver and gold to nanoparticles
2. Synthesis of biogenic nanoparticles by bioreduction process
3. Characterization of biogenic nanoparticles by X-ray diffraction, gravimetric, microscopic and spectroscopic analyses
4. Preparation of fungal mycelia based silver- and gold-bionanocomposites
5. Evaluation of biogenic nanoparticles for the degradation of nitroaromatic pollutant, 4-nitrophenol
6. Determination of chemical kinetics of biogenic nanoparticle-mediated degradation of 4-nitrophenol