Chapter 3
Role of Nanoparticles on Soil Microbial Community and Functionality

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ABSTRACT

In soil microbial communities, nanoparticles—particularly those containing essential metals—have a variety of functions. They promote microbial growth and nutrient cycling by increasing nutrient availability. On the other hand, toxicity results from high quantities of certain types, which lowers variety and jeopardises soil function. Because of their antibacterial qualities, silver nanoparticles benefit plants while also having the ability to affect unintended microbes. Moreover, soil structure is changed by nanoparticles, which impacts microenvironments. Some cause stress reactions, but long-term exposure damages microbial communities. Using nanoparticles responsibly is essential to preventing environmental hazards. The goal of ongoing study is to comprehend interactions and develop guidelines for the sustainable use of nanoparticles in agriculture while taking environmental complexity into account.

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1. INTRODUCTION

Nanotechnology involves the exploration and manipulation of materials within the dimensional range of 1 to 100 nm. If a particle's diameter falls within this span, it is classified as a nanoparticle (Klaine et al., 2008). The term "nano" finds its roots in the Greek word denoting "dwarf." The introduction of the term nanotechnology in a published paper is credited to Norio Taniguchi from the University of Tokyo in 1974 (Taniguchi, 1974). The conceptualization of nanotechnology was initially presented by physicist Richard Feynman in 1959. Eric Drexler coined the term "nanotechnology" in his 1986 book Engines of Creation (Drexler, 1986). Nanoparticles (NPs) have recently garnered significant attention due to their unique characteristics, positioning them between individual molecules and bulk materials. NPs can be either natural or artificial, and their fundamental nature distinguishes them.

Nanotechnologies encompass the design, characterization, manufacturing, and application of structures, electronics, and systems at the nanometer scale. The core of nanotechnology lies in the manipulation and control of the size of atoms and molecules. Regarding transport and attributes, a nanoparticle is defined as a minute entity that functions as a cohesive unit. NPs exhibit distinct characteristics, such as high mobility in free space, substantial surface areas, and the potential for displaying quantum phenomena. Two primary approaches to nanotechnology exist: the first is the bottom-up technique, wherein materials and devices are constructed from molecular components that self-assemble chemically through molecular recognition. The second approach is the top-down method, where nano-sized entities are fabricated from larger structures without atomic-level control.

Any formulation that includes elements of the nm size range and/or claims novel capabilities associated with these small size ranges is considered a nano-pesticide. Nano-pesticides are plant protection compounds that use nanotechnology to develop either the active components or the carrier molecules. The primary goal of nano-pesticide development is to reduce the environmental dangers of a pesticide-active component by boosting chemical performance. A nanoparticle's size typically ranges from 1-100 nanometers, and a nanometer is one billionth of a meter. When particles are thus small, they have a relatively big surface area and so more insecticides come into contact with the action surface. The characteristics of nano-materials (NMs) differ greatly from those of ordinary materials due to two major factors. First one is increased relative surface area; as nano-scale materials have far bigger surface areas than larger masses. As the surface area per unit mass of a material increases, more of the material can interact with the surrounding substances, influencing its reactivity. Another significant factor is quantum effects, particularly the quantum size effect: as the size of particles decreases, the electronic characteristics of solids undergo a transformation. When comparing the properties of solid particles at the visible scale, as seen through a standard optical microscope, there is minimal difference. However, when particles with nano dimensions are created, the material characteristics deviate significantly from those at larger scales. Various properties, including melting point, fluorescence, electrical conductivity, magnetic permeability, and chemical reactivity, exhibit variations with particle size. Materials reduced to the nanoscale can manifest unique properties not observed at the macroscale, leading to innovative applications. For instance, opaque substances may become transparent (e.g., copper), stable materials can become combustible (e.g., aluminum), solids may transform into liquids at room temperature (e.g., gold), and insulators can turn into conductors (e.g., silicon).

Among the uses of nanotechnology that can boost agricultural output are management after harvest, animal breeding, animal health, and poultry production, diagnostics for plant diseases, nanotechnology for genetically altering plants, The use of nano sensors in crop protection to detect pesticide residues