ISSN: 2641-6379
World Journal of
Agriculture and Soil Science

DOI: 10.33552/WJASS.2021.06.000649
Iris Publishers

Short Communication

Effects of Nanoparticles on Soil Microorganisms

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Received Date: April 12, 2021

Published Date: April 26, 2021

Abstract

Nanoparticles, one of the most important benefits of nanotechnology, are solid particles with sizes between 1-100 nm. The usage areas of nanoparticles including cosmetics, paints and coatings, plastic additives, communications, electronics, sensors, packaging, biomedical diagnostics, textiles, antibacterial agents are quite wide. For this reason, the release of nanoparticles to the soil directly or indirectly through air and water is gradually increasing. Therefore, the soil is contaminated with nanoparticles in the long term and soil microorganisms can adversely be affected by these accumulated nanoparticles. Soil microorganisms play vital roles in soil carbon cycling, nitrogen fixation, and nutrient acquisition for plants. Nanoparticles can show different toxic effects on soil microorganisms according to their physical and chemical structures. Also, the humic acid, organic matter, pH, and ionic in the soil strengths affect the toxicity of nanoparticles. Nanoparticles may show toxic effects on soil microorganisms directly or indirectly, such as changes in the bioavailability of toxins or nutrients, toxicity due to their interaction with natural organic compounds or toxic organic compounds. Also, nanoparticles can have a lethal effect on soil microorganisms by causing the production of reactive oxygen species by damaging the membrane permeability, cell signaling processes, and the stability of enzymes and protein structures. The effect of nanoparticles such as C_60 fullerenes, Fe_2O_3, Ag, ZnO, CeO_2, TiO_2 on soil microorganisms and the mechanisms of their toxicity are comprehensively reviewed and discussed in this mini-review.

Keywords: Nanoparticles; Soil microorganisms; Toxicity

Abbreviations: C60: Carbon 60; Fe_2O_3: Hematite iron oxide; Fe_3O_4: Magnetite iron oxide; Ag: Silver; ZnO: Zinc oxide; CeO_2: Cerium Oxide; TiO_2: Titanium dioxide

Introduction

Nanoparticles, the most important products of nanotechnology, have an increasing use in almost every sector due to their unique properties. Nanoparticles exhibit features such as high catalytic activity, high absorption, high reactivity, high conductivity compared to bulk materials due to their low particle size and large surface area/volume ratio. Due to these properties, nanoparticles are increasingly used in areas such as cosmetics, medicine, communication, paint, agriculture, packaging, consumer products, food additives, construction, animal feed, remediation, textile, composite material, energy [1-4]. Environmental contamination of nanoparticles is also increasing in parallel with the increasing usage amounts. Nanoparticles can contaminate the soil directly or indirectly via air and water. Therefore, soil microorganisms also interact with these nanoparticles.

Soil microorganisms, which are vital for organic matter dynamics and nutrient cycle, biogeochemical cycling, biodegradation of pollutants, crop production, are very important for the ecosystem [5]. Nanoparticles can interact with bacterial cells in different ways including electrostatic attraction, Van der Waals forces, receptor-ligand, and hydrophobic interactions to exhibit antimicrobial activity [6-8]. Nanoparticles, which follow a path from the outside to the inside, cross the bacterial membrane, affect the function and shape of the bacterial membrane, and then come into contact with cell components such as DNA, lysozyme, ribozyme enzyme. Mechanisms that may result in cell death, such as oxidative stress, heterogeneous changes, cell membrane permeability changes, electrolyte balance disorders, enzyme inhibition, protein inactivation, gene expression changes, may occur with the contact of nanoparticles with bacterial cell components [9,10].

In a study examining the effects of C60 fullerenes on soil microorganisms for 14 days, it was reported that respiratory and microbial biomass were not significantly affected in 0, 5, 25, and 50 mg C60 fullerenes (50 nm≤ size) / kg dry soil applications and the number of rapidly growing bacteria decreased 3-4 fold [11]. Use of Fe2O3 (10.2 nm) nanoparticles stimulated urease and invertase activities, whereas Fe3O4 nanoparticles (10.5 nm) did not induce any modification of enzymatic activities at high concentrations (420, 840, and 1260 mg kg-1 soil) [12].

Significant adverse effects of 0.01 mg Ag nanoparticles per 1 kg of fertile soil on soil microbial biomass and bacterial ammonia oxidizers, the leucine aminopeptidase activity and abundance of nitrogen fixing microorganism were reported at the end of the 1 year study period [13]. In another study, It has been reported that there is a decrease in Acidobacteria (p=0.007) (14.5%), Bacteroidetes (p=0.005) (10.1%) and beta-Proteobacteria (p=0.000) (13.9%) at the end of a 1-year study period with administration of 0.01 mg AgNP/kg loamy soil [14].

In a study conducted to examine the effect of ZnO nanoparticles on soil microorganisms, it has been reported that 1 mg of ZnO nanoparticles (10-80 nm) significantly prevented ammonification (37.8%) in neutrol soil during a 3-month study, and 1 mg, 5 mg and 10 mg ZnO nanoparticles applications in acidic, neutral and basic soil inhibited dehydrogenase activity and fluorescent diacetate hydrolase activity during the one-month study period. In the same study, it was also reported that the toxicity was higher in acidic soil than in neutral soil [15].

It has reported that 1 mg ZnO (15 nm) and CeO2 (10 nm) nanoparticles/1 g agricultural soil application hinder thermogenic metabolism, reduce numbers of soil Azotobacter, P-solubilizing and K-solubilizing bacteria and inhibit enzymatic activities and 1 mg TiO2 (10 nm) nanoparticles /1g agriculture soil application reduced the abundance of functional bacteria and enzymatic activity (urease, catalase) at end of 30 days [16].

Concluding Remarks

Current studies on the effects of the most widely used nanoparticles on soil microorganisms reveal that toxicity can vary according to soil, nanoparticle and application properties (especially time). In addition, according to the studies, it is seen that metal and metal oxide nanoparticles have more negative effects on soil microorganisms compared to organic nanoparticles. However, the present data are not sufficient to clearly demonstrate the effects of nanoparticles on soil microorganisms and for the acceptable nanoparticle amount parameter in the soil. Therefore, more research is needed in this area.

Acknowledgement

None.

Conflict of Interest

No conflict of interest.

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