

Cadmium Immobilization in Soil using Sodium Dodecyl Sulfate Stabilized Magnetite Nanoparticles

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Introduction Some methods of contaminated soils remediation reduces the mobile fraction of trace elements, which could contaminate groundwater or be taken up by soil organisms. Cadmium (Cd) as a heavy metal has received much attention in the past few decades due to its potential toxic impact on soil organism activity and compositions. Cadmium is a soil pollutant of no known essential biological functions, and may pose threats to soil-dwelling organisms and human health. Soil contamination with Cd usually originates from mining and smelting activities, atmospheric deposition from metallurgical industries, incineration of plastics and batteries, land application of sewage sludge, and burning of fossil fuels. Heavy metal immobilization using amendments is a simple and rapid method for the reduction of heavy metal pollution. One way of the assessment of contaminated soils is sequential extraction procedure. Sequential extraction of heavy metals in soils is an appropriate way to determine soil metal forms including soluble, exchangeable, carbonate, oxides of iron and manganese, and the residual. Its results are valuable in prediction of bioavailability, leaching rate and elements transformation in contaminated agricultural soils.

Materials and Methods The objective of this study was to synthesize magnetite nanoparticles (Fe_3O_4) stabilized with sodium dodecyl sulfate (SDS) and to investigate the effect of its different percentages (0, 1, 2.5, 5, and 10%) on the different fractions of cadmium in soil by sequential extraction method. The nanoparticles were synthesized following the protocol described by Si et al. (19). The investigations were carried out with a loamy sand topsoil. Before use, the soil was air-dried, homogenized and sieved (<2 mm). All experiments were performed in three replications. 200 ml of $\text{Cd}(\text{NO}_3)_2$ solution (500 mg Cd l^{-1}) was spiked into 100 g soil to artificially increase the total soil Cd concentration by about 1000 mg kg^{-1} . After being air-dried and homogenized again by 2 mm sieving, 2 g of Cd contaminated soil was weighed into each 50 ml centrifuge tube (15 tubes) and 25 ml of suspension with different percentages of stabilized nanoparticles was added. To avoid exposure to oxygen, the procedure was also conducted in the anaerobic chamber and the tubes were tightly capped. To test the change in Cd speciation in soils, the sequential extraction procedure developed by Tessier et al. (22) was employed, before and after the nanoparticle amendment, to quantify the fractions of various operationally defined Cd species. Those soil samples included the untreated soils and the treated soils was centrifuged and supernatant-removed. After being treated with the procedure in each step, the mixture was then centrifuged at 5000g for 10 min. The supernatant was decanted and filtered through a $0.45 \mu\text{m}$ filter. The filtrate was stored for Cd analysis. The soil residue was retained for the next step.

Results and Discussion The SEM measurements demonstrated that the particle size of nanoparticles was about 40-60 nm. The observation was reasonable given the high carbonate content of the soil. The results showed that the increasing of nanoparticles in soil, significantly led to decreasing of cadmium concentration in soluble and carbonate forms, so that the maximum reduction of the cadmium concentration was related to 10% nanoparticles treatment (80% in soluble form and 28% in carbonate form compared with treatment of zero percent of nanoparticles). The amount of cadmium bound to iron oxide increased with increasing the percentage of nanoparticles, so that bounded to the iron oxide form in 10% treatment reached to three times compared with control treatment. Cadmium concentrations in the exchangeable and residual phases had not extensively variations by changing the amount of nanoparticles. In the treatment of 10% of nanoparticles, mobility and bioavailability of cadmium in soil was also reduced 17%. The distribution of the extracted forms of Cadmium in all treatments was as follows: carbonate > exchangeable > oxide > residual > soluble. By increasing the amount of nanoparticles in the soil, cadmium bioavailability parameter in soil was reduced from 91 percent (in control treatment) to 74 percent. In other words, 17 percent of cadmium stabilized in soil. So, stabilized magnetite nanoparticles could reduce the solubility and bioavailability of cadmium in the soil.

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Conclusion In spite of high calcium carbonate in soil (38.25%), carbonate form of Cd was significantly reduced in the nanoparticles treatments. Generally, the nanoparticles ability to cadmium immobilization can be attributed to its ability to cation adsorption and its large specific surface area.

Keywords: Cadmium, Soil Contamination, Sequential Extraction, Nanoparticles

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