Magnetic supraparticles for sustainable delivery systems: release, disintegration, and leaching evaluation

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Agriculture has faced challenges due to climate change and population growth. In this context, nanotechnology emerges as a promising area in the agricultural sector, using nanoparticles to improve the efficiency of delivering agricultural inputs in the field. The design and manipulation of nanoparticles enable the preparation of larger structural building blocks from clusters of colloidal nanoparticles, called supraparticles (SPs). Supraparticles can retain the properties of individual nanoparticles, enabling controlled release of agrochemicals with low mobility in soil. In this study, inorganic supraparticles were fabricated and characterized from magnetic nanoparticles coated with citrate (Fe_3O_4@Citrate NPs) using the evaporation-induced self-assembly method on a superhydrophobic surface. Scanning Electron Microscopy analyses, coupled with Energy Dispersive Spectroscopy and Stereoscopic Microscopy, highlighted the morphology of the SP and demonstrated the SP's evaporation process over time. An *in vitro* release kinetics study at pH 4 revealed slower release of the micronutrient associated with SPs than with the nanoparticle suspension. Furthermore, the disintegration capacity of the SPs was investigated in different buffers (pHs 4, 7, and 10), and the SPs showed greater disintegration in an acidic medium. Also, studies on the leaching of SPs, NPs, and iron sulfate in soil columns showed reduced mobility of SPs compared to the other formulations, helping minimize environmental impacts from leaching. Therefore, SPs have demonstrated potential as controlled-release systems for micronutrients, with reduced mobility in soil, thereby contributing to agricultural sustainability.

Keywords: supraparticles; nanoparticles; controlled release; sustainable agriculture

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