Development of nanostructured smart delivery systems for pesticides and fertilizers

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ABSTRACT

Agriculture forms the backbone of third world economies. The global agricultural sector has been experiencing major challenges including an increasing risk of disease, high production costs due to the high cost of fertilizer and pesticides, threats to agricultural production from changing weather patterns and a growing demand for healthy, safe food.

The use of nanomaterials for the controlled delivery of fertilizers and pesticides is nascent technology that has the potential to increase the efficiency of food production and decrease pollution. In this study, the prospect of mesoporous silica nanoparticles (MSN) and purified montmorrilonite (MMT) for storage and controlled release of fertilizer and fungicide molecules was investigated. A series of MSNs with particle sizes, Barrett-Joyner-Halenda (BJH) pore diameters, Brunauer-Emmett-Teller (BET) surface areas and BJH total pore volumes ranging between 50 nm – 900 nm, 2.4 nm - 4.4 nm, 589 m^2g^{-1} - 1013 m^2g^{-1} and 0.61 cm^3g^{-1} – 0.81 cm^3g^{-1}, respectively were synthesized via Liquid Crystal Templating Mechanism (LCT) by varying the molar ratio of reagents. Urea, as a model fertilizer molecule was loaded into the carrier matrices by a simple immersion technique using concentrated aqueous urea solution while metalaxyl, as a model fungicide was loaded by a rotar - vapor method. Successful loading was confirmed by infrared (IR) spectral analysis, x-ray diffraction (XRD) patterns and N_2 sorption studies. The loaded amounts of agrochemicals were evaluated by thermogravimetric analysis (TGA/ DTA). About 15.5 % (w/w) of urea was entrapped into the MSN pores and ~21.4 % w/w intercalated into MMT interlayer space. Metalaxyl entrapment/ intercalation content were 14 % w/w and 8.1 % w/w for MSN and MMT, respectively. Adsorption processes were mainly by physical forces.

The release process of urea-loaded mesoporous silica nanoparticles (UMSN) and urea-loaded montmorillonite (UMMT) in water and soil indicated a sustained slow release-profile. The findings for soil release studies of UMSN revealed at least fivefold improvement in the release period while MMT retarded the release of urea significantly. Release of the fungicide entrapped in the MSN and intercalated into MMT matrix also revealed sustained release behaviour. About 76 % of the free metalaxyl was released in soil within a period of 30 days while only 11.5 % and 11.9 % of the metalaxyl contained in MSN and MMT carriers, respectively were released within the same period. Our study showed that MSN and MMT can be used to successfully store agrochemical molecules and significantly delay their release in soil.