Solution for the phosphorus crisis: environmental-responsive hybrid LDH serves as controlled release phosphorus fertilizer from the perspective of circular economy

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Abstract

With increasing global population and extreme weather caused by climate change, ensuring sufficient food production, i.e. food security, has become an urgent and critical issue. The phosphorus (P) is one of three essential macronutrients for plant growth. Conventional farming usually applies excessive P fertilizers to pursue the quality and yield of agricultural products, however, only about 15 percent of P fertilizer is taken up by plants. The rest P fertilizer is either fixed by soil, or flowed into rivers and lakes with rainfall and irrigation, leading to eutrophication in water body. Unlike N and K, P reserves are limited and unevenly distributed on the earth and it is a non-renewable resource. For that reason, P would become a limiting factor for food production and P production will peak around 2033, after which demand will exceed supply. The increasing chemical fertilizers price will directly affect food prices. Therefore, the goal of this project is to develop environmental-responsive controlled-release P fertilizers that can regulate the release rate of P. Wherein hybrid layered double hydroxide (LDH) nanocomposites will be developed to manipulate the P release rate, serving as the nanovehicle to deliver P to the rhizosphere, and prevent P from adsorbing on soil minerals. The environmental-responsive LDHs can release P in response to environmental conditions and thus improve the P uptake efficiency of plants, mitigating the loss to environmental water bodies. This study will use two nature polymers including chitosan (CTS) and carboxymethyl cellulose (CMC) to synthesize environmental-responsive hybrid LDHs. By means of various synthesis methods, hybrid LDHs could be formed with specific attributes such as porous nanostructure, exfoliated nanolayer, and controlled-size nanoparticles. Compared with other carriers, LDHs are easy to synthesize and low-cost. The high anion loading density and low biological toxicity make LDHs as idea carriers for intelligent controlled-release fertilizers. In addition, the exploitation of agricultural waste such as CTS and CMC to produce the hybrid LDHs provides a niche opportunity allowing the circular economy to recycle the waste and simultaneously mitigate the agricultural pollution, achieving our ultimate goal of environmental sustainability.

Keywords – phosphorus, LDHs, controlled-release fertilizer, environmental-responsive