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Nano Clay Polymer Composites - A Potential Control Delivery System for Nutrients and Agrochemicals

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Abstract

Nanoclays are nanoparticles containing layered mineral silicates. Polymer composites are a combination of polymers (*i.e.*, thermosets or thermoplastics) with various continuous and non-continuous reinforcements/ fillers, principally added to polymers to improve the material performance. Nanoclays are recently being used for preparation of polymer/ clay super-absorbent composite formulation resulting lower production cost, excellent water retention and considerable applications in agriculture and horticulture. Conventional super-absorbent network synthesized from polymers such as poly sodium acrylate and polyacrylamide often poses limitation owing to poor biodegradability under natural environmental condition and restricts its wider use. Synthesis and formulation of novel biodegradable molecules with intelligent delivery system are being attempted in recent times. Nanoclay polymer composite (NCPC) based fertilizer and pesticide formulation with controlled release property has been reported worldwide. Such formulations might have good potential for agricultural use as controlled release fertilizer or agrochemicals formulation. However, it needs to be evaluated in long-term experiment in various soil types and cropping system for evaluating benefit: cost ratio and wide scale farmers' adaptability.

Introduction

Agricultural nanotechnology has become one of the most effective tools in modern agriculture because of its significant application potential and unique properties. In agriculture, water and nutrients are essential components that need to be utilized more efficiently to preserve these limited resources by the development of superabsorbent nutrient carriers based on nanoclay. Development of a new class of clay polymer nanocomposite was first reported from the patent of Toyota Industries and the first commercial trial was undertaken by using nylon - 6 clay hybrid for automotive use. In soil science, clay fractions include nanoclays, whose particles have a dimension in the nanoscale range (1-100 nm) and whose particle size is < 2 µm in diameter. Soil nanoclay materials are dominated by phyllosilicates and smectites, which have three major sheet arrangements, 1:1, 2:1, and 2:1:1. where the single layer is 0.7 nm thick, while the double layer is 1 nm thick. Purity is most relevant to achieving maximum increases in mechanical properties and optimum clarity for films (Barman *et al.*, 2018). The four types of clay used are kaolinite, montmorillonite, illite, and chlorite, which are arranged according to their crystalline structures and ion distribution within the elementary mesh. Montmorillonite (MMT) $(Na, Ca)_{0.3}(Al, Mg)_2 Si_4 O_{10}(OH)_2, nH_2O$ clay, derived from bentonite phyllosilicate to prepare organoclays because of its excellent properties such as high cation exchange capacity, swelling behavior, adsorption properties, and large surface

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area and advantages include their availability, their ease of processing, functionality, and low cost.

Advantages of Nanoclay Polymer Composite in Agriculture

The nanoclay polymer composite plays an essential role in retaining nutrients and water, increases cation exchange capacity, provides elasticity and acts as a binding agent. Reduces nutrients loses through leaching and enhances the buffering capacity of the soil, contributing many benefits to the physical, chemical, and biological properties of soil. Nanoclay enhances water absorption and retention properties of sandy loam soil, encapsulation of different bioagents, and increases input use efficiency, especially fertilizer and water under abiotic stress conditions. The slow-release pattern of nutrients (helpful to control the deficiency of major nutrients elements in soils like N, P, K) and improves water holding capacities and nutrient release behaviour of nutrients (Das *et al.*, 2017). High surface areas, inexpensive, nontoxic, high cation exchange capacity (CEC), natural abundance, and the ability of anionic, cationic, and non-ionic surfactants to enhance basal spacing.

Application of NCPC in Agriculture

Polymer composites made from nanoclays are used in several applications, including agriculture, antibacterial, environmental, water remediation, dental, and drug delivery. Using nanoclay polymer composite in agriculture enhances water retention and nutrient uptake, remediated contaminated soils and water, immobilized enzymes, decreases irrigation requirements, and packaging of food and agricultural produce. Nanoclay polymer composites are used for improving soil properties, reducing erosion, and combating desertification. Nanoclay polymer composite can act as superabsorbent slow-release nutrient carriers (Merino *et al.*, 2020). Nanoclays could stabilize soil structures, increase aggregation, and decrease soil erosion caused by wind. It found advanced functions such as antimicrobial agents, control and release substance, colorimetric indicator template, and biodegradability stimulator that led to extended its use in the food and agricultural produce packaging research industry (Das and Ghosh, 2021). It has been examined the effect of NCPC on the availability, uptake, fixation, and use efficiency of phosphorus in wheat. Nanoclay polymer composites for slow-release of different nutrients and fertilizers has been presented in Table 1.

Application of NCPC in Drug Delivery

Compared to polymer and carbon nanotubes, nanoclay polymer composite has great potential as a drug delivery vehicle for the controlled release of drugs in medicinal applications. It was examined *in-vitro* drug release of methylcellulose/pectin/MMT (MC/PEC/MMT) nanoclay composite films which show that the rate of release of the drug decreases with the addition of pectin and nanoclay in methylcellulose matrix and best performance, in terms of the controlled release of a transdermal drug, was achieved in the case of five wt. % MMT-loaded MC/PEC/MMT nanoclay films.

Table 1: Nanoclay polymer composites for slow-release of different nutrients and fertilizers

Clay	Polymer Matrix	Nutrients/Fertilizer
Bentonite	Alginate	Microbiol fertilizer *R. planticola*
Bentonite	Acrylic acid and acrylamide	Diammonium phosphate (DAP)
Bentonite	Chitosan, Acrylic acid, acrylamide	Zn^{2+}
Bentonite	Acrylic acid	Urea
Halloysite nanotubes	Acrylic acid and acrylamide	Urea
Montmorillonite	Polyvinyl alcohol (PVA)	Potassium phosphate (K_2PO_3)
Montmorillonite	Poly (acrylic acid-cosodium acrylate)	KNO_3

Application of NCPC in Wastewater Treatment

Nanoclay polymer composite provides an excellent life cycle for wastewater treatment/ remediation due to its easy processability, effective cation exchange, and large surface area. In addition, they are relatively inexpensive and non-toxic. Synthesized nanoclay polymer composites are effective adsorbents with great remediation potential. Thiourea-formaldehyde/ bentonite nanoclay polymer composites are using for Pb (II), Mn (VII), and Cr (VI) adsorption in aqueous solution, and the maximum adsorption values were 13.38, 14.81 and 4.20 mg g^{-1} respectively (Guo *et al.*, 2018). Several nanoclay polymer composites can remove various pollutants from aqueous solutions and have been proven effective in water treatment and remediation.

Conclusion

Nanoclay has a wide range of agricultural applications. Using nanoclay, we can develop slow-release fertilizers and fertilizers, better packaging for food and agricultural products, and remove contaminants from soil, improving nutrient use efficiency, water management, soil fertility restoration, and erosion control. We need to conduct more research to better understand how these nano-size soil materials affect ecosystems and the environment and their reactivity, fate, transport, and behavior. New polymer-

nanoclay composites have been developed with specialized properties that depend primarily on the type of nanoclay modified and the synthesis approach. Polymer-nanoclay composites are showing promise in a variety of innovative applications because of their high-performance properties.

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