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SCOPE OF POLYMER-BASED FERTILIZERS IN AGRICULTURE

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Introduction

It is widely acknowledged that fertilizers are essential for crop growth, but excessive use can lead to environmental issues such as elevated nitrate or phosphate levels in groundwater, contributing to acid rain, and depleting the ozone layer through the release of nitrous oxides from denitrification. To mitigate these concerns, reducing nutrient losses in the field can lower the need for fertilizer application, enhance fertilizer efficiency, and prevent environmental pollution. Advanced methods like slow or controlled release fertilizers offer a progressive nutrient release that matches plant requirements, reduces leaching, and thereby improves fertilizer efficiency compared to traditional methods. Techniques such as coating fertilizers or using controlled-release carriers like polymers, resins, and waxes achieve this slow release. Research interest has grown in clay-polymer composites due to their potential in agriculture and other industrial applications. The chemical surface properties and structure of clays and nanoclays are crucial in various technological fields, particularly in controlled release systems where they serve as effective modifiers. Clay-polymer nanocomposites represent an innovative material category that offers significant performance enhancements over conventional filled polymers, with nano-sized clays dispersed in polymer matrices.

Different approaches of polymer-based fertilizers production

Due to their high surface tension, nanocoatings exhibit stronger material adhesion compared to traditional surfaces. Additionally, these coatings can protect larger particles on surfaces. However, a challenge with clays is the hydrophilic nature of clay minerals conflicting with hydrophobic polymers, often causing clay mineral agglomeration within the polymer matrix. Therefore, modifying the surface of clay minerals is critical in the development of polymer nanocomposites (Alexandre and Dubois, 2000). Organic treatment renders clays hydrophobic, enabling compatibility with specific polymers. These modified clays are commonly known as organoclays. The weak interactions between nanolayers allow for easy exchange of cations with alkyl ammonium or phosphonium salts, ensuring layered silicates are compatible with rubber matrices.

Basak et al. (2012) highlight that incorporating polymers, particularly those with surface cross-linking, enhances the barrier properties of clay composites. These modified clay composites exhibit slow-release characteristics when used with nutrients, which are critical for optimizing crop productivity in agriculture. Combining the superadsorbent qualities of polymeric materials with clays significantly improves water retention capacity. Nano clay-polymer composites also offer controlled release properties that can be tailored to synchronize with different crop growth stages, effectively minimizing nutrient loss (Wu et al., 2001). This slow-release capability of nano clay composites enhances nutrient use efficiency in agricultural applications.

Controlled release fertilizers based on polymers

Several polymers of synthetic and natural origin are used either as coating of soluble fertilizer or as career. Resin, plastic, lac, silica, sulphur, natural rubber, polyolefin, starch, and gypsum were reported to be used for preparing controlled release fertilizers. Water soluble fertilizers are either coated with polymer or distributed in a polymer matrix. Polyethylene, polystyrene, ethylene-propylene co-polymer, ethylene-vinyl acetate co-polymer, natural rubber and starch have been successfully used for the formulation of controlled release urea fertilizers. As early as in nineteen sixties the concept of controlled release was tried and practised in the fertilizer field. Dhanke et al (1963) reported that placing fertilizers in polyethylene capsules effectively controlled the release of fertilizers. Korean Advanced Institute of Science and Technology in collaboration with International Fertilizer Development Centre, had developed several batches of Silicate and Polymer Coated Urea (SPCU) and they had observed satisfactory results for their product on rice (Savant et al, 1983). The dissolution rate was adjusted by varying the thickness of coating. An experimental fertilizer called reactive layer coated urea was developed by International fertilizer development centre (Christianson, 1988), using diphenyl methane diisocyanate and polyester polyol. The rate of release was affected by coating thickness, temperature and to a lesser extent by soil moisture. Polyolefin-coated urea fertilizer (POCU) was developed in Japan (Gandeza et a1 1991). Natural rubber had been used to produce slow-release fertilizers (Yeoh and Soong, 1977 and Hepburn et al 1987). Liang and Liu, (2007) prepared a superabsorbent nano clay polymer composite using poly (acrylic acid-co-acrylamide)/kaolin. This superabsorbent composite acted as as slow-release carrier of urea.

Effect of polymer-based fertilizers application on soil condition

Surface cross-linked products not only exhibit favorable slow-release properties but also demonstrate excellent soil moisture retention capabilities, effectively enhancing the utilization of fertilizers and water resources concurrently. Using these superabsorbent fertilizers improves soil water retention, making them beneficial for arid regions to enhance soil conditions. Clay polymer-coated nitrogen fertilizers are particularly effective in reducing nitrogen losses and improving nitrogen use efficiency in sandy soils, while clay polymer-coated phosphorus fertilizers are advantageous in calcareous soils. Future research efforts should focus on developing suitable polymer composites for in situ modification of soil clays. There is limited research on the impact of these polymer-based fertilizers on various soil and plant characteristics, necessitating further investigation into their effects.

Conclusions

Polymer-based fertilizers, emerging as a novel category of fertilizer materials, have sparked increasing research interest. Presently, the research landscape primarily revolves around the intricate processes involved in synthesizing and refining controlled-release formulations, which are rigorously evaluated within controlled settings such as laboratories or greenhouses. These fertilizers exhibit promising capabilities in optimizing nutrient utilization efficiency, prompting the need for expansive and comprehensive studies across broader operational scales. Such investigations aim to delve deeper into their potential to mitigate environmental impacts, assess their effects on soil health and crop productivity, and scrutinize the economic viability associated with their formulation and application.

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