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Perspectives on the Direct Use of Mineral Phosphorus Recovery Products as Slow-Release Fertilizers

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Opinion

"Phosphorus is an element of life and thinking". With this quote the Russian scientist Alexander Fersman expressed both the importance of phosphorus (P) for life on earth and his fascination for the role of P in numerous processes. Human activity, and especially agriculture during the last decades, drastically changed the global P cycle while intensifying crop production. In 2008, the agricultural dependency on P sources was highlighted with a global P crisis, when stagnating rock phosphate production drastically increased P fertilizer prices. The majority of the current commercial P fertilizers, such as mono-ammonium phosphate (MAP) or triple super phosphate (TSP), is acidification products of rock phosphate and contains P in highly soluble forms. The application of soluble P fertilizers to soils initially results in a fast increase of the orthophosphate concentration in the soil solution, thereby exposing large amounts of the applied P to irreversible sorption on soil particles, or to leaching and runoff, what limits the P use efficiency. To partly overcome these losses, researchers focused on the development of slow-release fertilizers (SRFs), as the application of small and frequent amounts of solution Pto soil has been proven to be more efficient than full dose application at sowing [1].

Over the last century, agricultural intensification caused an increasing abundancy of P in the hydrosphere, leading to problems of excessive primary production in aquatic ecosystems. The treatment of wastewater, with e.g. the removal of excessive P, has become an important tool to prevent surface water eutrophication. The contradictory view of P as a pollutant in surface waters, but as a valuable nutrient in agricultural systems is the basis of the idea of P recycling. However, effective removal of P from liquid waste streams inherently requires a transformation of available/soluble P to stable solid P forms. Focusing on chemical P removal techniques, this transformation can be achieved by the addition of metal cations for the formation of poorly soluble precipitates [2], or by the presence of a adsorbent with a high affinity towards P [3]. From this point of view, it is indeed expected that the direct use of mineral P recovery products as fertilizer is often characterized by a relative slow release of P in comparison with soluble fertilizers. Recovery techniques are often characterized by a trade-off relationship between the removal efficiency of P in wastewater and fertilizer value of the obtained product, and only few technologies manage to balance between both ends, allowing direct P recycling. A successful example is the crystallization of struvite ($MgNH_4PO_4.6H_2O$) in wastewater of different sources after the addition of a magnesium salt, now a well-established P removal technique. Struvite is a SRF because of a low water solubility compared to that of soluble P fertilizers. Another example is the use of layered double hydroxides (LDHs) as selective adsorbent for P in waste water. The obtained product, a P-exchanged LDH, has been proven to be a SRF with a P release based on anion exchange and/or material dissolution [4].

During the last decade, several pot trial studies have been conducted on the direct use of mineral P recovery products as P-SRFs, such as struvite or P-exchanged LDHs, often in comparison with soluble fertilizers (MAP, TSP). To the best of our knowledge, the advantage of the slow-release properties of P recovery products has not been observed in terms of higher yield or P uptake by crops. An interesting point is the effect of the fertilizer application form (powdered or granular application) on relative P availability in soils. When P recovery products are applied as powders to a soil, the kinetics of the P release are comparable to that of powdered soluble fertilizers, with smaller differences in yield and P uptake as result. Fertilizers are very often applied in granular form. It has been shown that, in comparison to the powder application, the difference in release kinetics between mineral P recovery products and soluble fertilizers, both in granular form, is much larger when applied to a soil. Surprisingly, the fast P release even appeared to be advantageous to plant yield and P uptake, as a result of the local saturation of P sorption sites on soil particles in strong P sorbing soils [5,6]. These results oppose the idea that the use of mineral P recovery products with slow-release properties can help to overcome the problems of low P use efficiency of the commercial soluble P fertilizers in strong P sorbing soils. Taken together, the slow-release properties of mineral P recovery products in soils have to be perceived as a reality rather than an advantage in terms of P use efficiency. Nevertheless, he sustainable approach of the direct use of P recovery products as fertilizer, as well as the possibility to reduce P leaching and runoff due to slow P release, assures the potential of these recycling techniques for the decennia to come.

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