

Abstract

The work presents an ecocatalysis concept that links metal phytomanagement with efficient and green synthesis of organophosphorus compounds. As the metal source, biomass of the hyperaccumulator, *Arabidopsis halleri*, was used. After simple calcination, a polymetallic heterogeneous catalyst Eco-MgZnOx was obtained, in which basic *MgO* sites neighbor Lewis-acidic *ZnO* sites. This bifunctionality gives synergy: simultaneous activation of the nucleophile (*P-H* or *CH* acid) and electrophiles (*C=O*, *C=C*), lowering reaction barriers and increasing selectivity.

The material's effectiveness was verified in three reaction classes: hydrophosphonylation of aldehydes (Pudovik reaction), phospho-Michael addition to activated alkenes, and the Knoevenagel-phospho-Michael cascade run in one- or two-step modes. In all cases, very high conversions (often reaching 95-100%) and clean product profiles were obtained under mild conditions (50-70 °C, solvent-free, with catalyst loading of about 5 mol% relative to *Zn*). A broad substrate tolerance was demonstrated (aromatic, heteroaromatic, aliphatic compounds, various H-phosphonates), multiple recycling of the catalyst with minimal loss of activity, and scale-up to the gram scale without loss of efficiency. DFT calculations and structural analyses confirmed the presence of a solid-solution *Mg(Zn)O* phase responsible for the observed synergy.

This solution addresses the problems outlined in the introduction: declining availability and rising costs of metals, and the high environmental footprint of their extraction. Phytoextraction provides a green metal source, and the product - a durable catalyst - closes the value loop by coupling remediation with useful synthesis. The main limitation is the need for strongly activated alkenes and a moderate sensitivity to sterics. Nevertheless, applicability remains broad. Altogether, the results show that ecocatalysts from *A. halleri* biomass constitute a practical, scalable, and green-chemistry-compliant platform for forming *C-P* and *C-C* bonds.