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From nature to innovation: layered double hydroxides as photocatalytic materials for the degradation of estrogens

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Layered double hydroxides (LDHs) are anionic clays with a unique layered structure made up of positively charged brucite-like layers intercalated with anions and water molecules. Their general formula, $[M^{2+}_{1-x}M^{3+}_{x}(OH)_2]^{x+}$ $[A^{n-}]_{x/n}$ features divalent and trivalent metal cations (M^{2+}, M^{3+}) and interlayer anions (A^{n-}). Naturally occurring LDHs, such as hydrotalcite, are rare and found in ultramafic rock weathering zones, hydrothermal deposits, and alkaline environments. However, their limited availability, impurities, and variable composition restrict their application. Synthetic LDHs address these challenges by offering precise control over chemical composition and structure. Tailored for applications like photocatalysis, environmental remediation, drug delivery, and materials science, they feature optimized properties for high performance.

Estrogens, natural or synthetic hormones regulating physiological functions, enter water systems through wastewater, agricultural runoff, and improper disposal. Even in trace amounts, they disrupt aquatic ecosystems by altering wildlife hormonal balances, causing reproductive and developmental issues. Photocatalysis offers a sustainable solution to remove estrogens from water by degrading them into harmless substances using light and photocatalysts, ensuring effective environmental protection.

In this research, Ag-doped Zn-Cr LDH was synthesized in the presence of graphitic carbon nitride (GCN) to form a heterostructure. This project is a continuation of work on crystalline layered Zn-Cr LDH/GCN photocatalysts[1] and aims to modify these materials to increase their photoactivity. The modified materials were used for photocatalytic degradation of two estrogens – natural estrone (E1) and synthetic ethinylestradiol (EE2). The Ag-doped material (1 wt%) removed over 95% of the initial concentration of E1 (1 ppm) within 40 minutes. This result is 33 p.p. higher compared to the pristine Zn-Cr LDH/GCN material, for which the removal efficiency was equal to 62%. For the EE2, the doped material removed 99% of the initial concentration (1 ppm) after 40 minutes of photocatalytic experiment, whereas the pristine material achieved only 70% efficiency.

References:

[1] Jędras, Matusik, Dhanaraman, Fu & Cempura (2024), Langmuir 2024, 18163–18175.

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