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## Phytoremediation of Emerging Contaminants: Phytoremediating Pharmaceuticals, Microplastics, and PFAS

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### Abstract

As the list of environmental pollutants increases, phytoremediation is faced with new challenges in the remediation of recalcitrant and complex emerging pollutants such as pharmaceuticals, personal care products (PPCPs), per- and polyfluoroalkyl substances (PFAS), and microplastics. Traditional remediation techniques are often not effective in removing these compounds from the environment, whereas phytoremediation is a green and sustainable option. This review provides a current synthesis of how some plant species can take up, degrade, or immobilize such emerging contaminants. The emphasis is placed on the processes of phytotransformation, phytodegradation, and rhizodegradation, particularly in riparian and wetland ecosystems. The synergistic role of rhizosphere microorganisms in the degradation of complex chemical compounds is discussed. Case studies demonstrate success with *Vetiveria zizanioides*, *Populus* spp., and *Lemna minor* species for reducing contaminant load in wastewater and river sediments. The challenge of bioaccumulation, toxicity of metabolites, and detection by analysis are addressed, and suggestions for future research on transgenic and hybrid systems are made. Phytoremediation is shown to be an intriguing solution for combining environmental rehabilitation with contaminant-specific detoxification strategies.

**Keywords:** Emerging contaminants, PFAS, Pharmaceuticals, Microplastics, Phytodegradation, Wastewater treatment

