

Green Analytical Chemistry in Pharmaceutical Analysis: Recent Advances, Challenges and Alignment with Sustainable Development Goals

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Abstract:

Increasing environmental concerns and global sustainability initiatives have necessitated a critical evaluation of conventional analytical practices in pharmaceutical analysis. Traditional methods, though reliable and regulatory compliant, often involve the extensive use of toxic organic solvents, energy-intensive instrumentation, and the generation of significant hazardous waste. Green Analytical Chemistry (GAC) has emerged as a sustainable approach aimed at minimizing environmental impact while maintaining analytical accuracy, precision, and robustness. GAC emphasizes reduced solvent and reagent consumption, safer and renewable alternatives, miniaturization of techniques, and energy-efficient analytical workflows. Recent advancements include aqueous or ethanol-based mobile phases, micro-extraction techniques, and solvent-free sample preparation strategies. Furthermore, greenness assessment tools such as the Analytical Eco-Scale, Green Analytical Procedure Index (GAPI), and AGREE metric enable quantitative sustainability evaluation of analytical methods. Importantly, GAC aligns strongly with global sustainability frameworks, particularly those related to health, clean water, responsible production, and climate action. This presentation discusses recent advances, challenges, and future perspectives for integrating sustainability into pharmaceutical analytical laboratories.

Keywords:

Green Analytical Chemistry, Pharmaceutical Analysis, Greenness Assessment, GAPI, AGREE Metric, Eco-Scale, Sustainable Development Goals.