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Editorial

Solid-Phase Extraction: Modernizing for Greener Analysis

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Abstract

Recent advancements in solid-phase extraction (SPE) techniques are transforming sample preparation across environmental, food, pharmaceutical, and biomedical analyses. Innovations include new sorbent materials like MOFs and MIPs for enhanced selectivity, and miniaturized formats such as micro-SPE and FPSE for reduced solvent use and improved efficiency. Automation significantly boosts throughput and reproducibility, particularly for environmental monitoring. A key trend is the integration of greener approaches, focusing on eco-friendly sorbents and solvent reduction to minimize environmental impact. These developments collectively improve the sensitivity, accuracy, and sustainability of analytical methods for complex matrices.

Keywords

Solid-Phase Extraction; Environmental Analysis; Food Analysis; Bioanalysis; Sorbent Materials; Green Chemistry; Miniaturization; Automation; Molecularly Imprinted Polymers

Introduction

Recent advancements in solid-phase extraction (SPE) techniques have profoundly impacted environmental analysis, particularly in sample preparation. These innovations focus on developing superior sorbent materials and novel extraction formats, enhancing sensitivity and selectivity for complex matrices like water, soil, and air. This progress leads to more efficient and reliable environmental monitoring processes [1].

Solid-phase extraction is pivotal in preparing food samples for analysis, covering food safety, quality control, and nutrient assessment. The field benefits from new sorbents and automated systems that enhance accuracy and throughput. These innovations are crucial for detecting contaminants and beneficial compounds within diverse food products effectively [2].

Magnetic solid-phase extraction (MSPE) has emerged as a powerful bioanalytical sample preparation methodology, offering substantial benefits. It facilitates simpler, faster, and more efficient isolation of analytes from complex biological matrices. MSPE also significantly reduces solvent consumption and improves method greenness in clinical and pharmaceutical applications [3].

Fabric phase solid-phase extraction (FPSE) is a versatile microextraction technique utilizing a flexible, sorbent-coated fabric. This design allows direct immersion extraction, offering advantages in portability, efficiency, and reduced solvent usage. Such attributes make FPSE highly applicable across various analytical disciplines [4].

Metal-organic frameworks (MOFs) are increasingly used as advanced sorbents in solid-phase extraction for environmental monitoring. Their unique structural properties and high surface area make them ideal for selectively preconcentrating pollutants. This capability is vital for analyzing complex environmental samples and improving detection limits [5].

In pharmaceutical and biomedical analysis, SPE techniques have seen continuous innovation. Recent developments include advanced sorbent materials and miniaturized SPE formats. These strides enhance efficiency and selectivity for accurate drug analysis, comprehensive metabolite profiling, and sensitive biomarker detection in biological fluids [6].

Molecularly imprinted polymers (MIPs) serve as highly selective sorbents in solid-phase extraction. Designed with specific recognition sites, MIPs enable precise, targeted extraction of analytes even from intricate matrices. Their application significantly improves method accuracy and effectively reduces interference in various analytical tasks [7].

The integration of automated solid-phase extraction systems has transformed the analysis of emerging contaminants in water samples. This automation significantly boosts sample throughput, enhances analytical precision, and ensures superior reproducibility. Automated SPE is thus an indispensable tool for large-scale environmental monitoring studies [8].

Micro-solid phase extraction methods have advanced considerably for pesticide analysis in challenging matrices. These miniaturized techniques reduce sample and solvent volumes while enhancing sensitivity. Such improvements contribute to more efficient and environmentally friendly analysis of pesticide residues in food, environmental, and biological samples [9].

A significant trend is the shift towards greener solid-phase extraction approaches, driven by sustainability. This involves pioneering eco-friendly sorbents, strategies for solvent reduction, and alternative extraction formats. The goal is to minimize environmental impact while maintaining or improving analytical performance across diverse applications [10].

Description

This article reviews solid-phase extraction (SPE) advancements for environmental sample preparation. It details progress in sorbent materials and new formats, showing how these innovations improve sensitivity and selectivity for complex matrices like water, soil, and air, thus enhancing environmental monitoring efficiency [1].

This review focuses on SPE's role in preparing food samples for analysis. It covers applications in food safety, quality control, and nutrient analysis, emphasizing new sorbents and automated systems that enhance accuracy and throughput for detecting contaminants and beneficial compounds [2].

The authors discuss magnetic solid-phase extraction (MSPE) and its impact on bioanalytical sample preparation. They explain how MSPE offers a simpler, faster, and more efficient way to isolate analytes from complex biological matrices, reducing solvent consumption and improving method greenness for clinical and pharmaceutical uses [3].

This paper explores fabric phase solid-phase extraction (FPSE), a newer microextraction technique. It highlights FPSE's versatility due to its flexible, sorbent-coated fabric format, allowing direct immersion extraction. This offers advantages in portability, efficiency, and reduced solvent usage across various analytical fields [4].

This review examines metal-organic frameworks (MOFs) as SPE sorbents for environmental monitoring. It describes how MOFs' unique structural properties and high surface area make them excellent for selectively preconcentrating pollutants from complex environmental samples, thereby improving detection limits [5].

This article summarizes recent innovations in solid-phase extraction for pharmaceutical and biomedical applications. It outlines new sorbent materials and miniaturized SPE formats that improve the efficiency and selectivity of drug analysis, metabolite profiling, and biomarker detection in biological fluids [6].

The authors review molecularly imprinted polymers (MIPs) as selective sorbents in solid-phase extraction. This work highlights how MIPs, designed with specific recognition sites, provide highly selective extraction of target analytes from complex matrices, significantly improving method accuracy and reducing interference [7].

This paper describes the development and application of automated solid-phase extraction for analyzing emerging contaminants in water samples. Research shows that automating the SPE process improves sample throughput, precision, and reproducibility, making it a powerful tool for large-scale environmental monitoring studies [8].

This review focuses on advancements in micro-solid phase extraction methods for analyzing pesticides in challenging sample matrices. It details how these miniaturized techniques reduce sample and solvent volumes, enhance sensitivity, and improve the efficiency of pesticide residue analysis in food, environmental, and biological samples [9].

This article reviews the shift towards greener solid-phase extraction approaches. It highlights innovations in eco-friendly sorbents, solvent reduction strategies, and alternative extraction formats that minimize environmental impact while maintaining or improving analytical performance for various applications [10].

Conclusion

Solid-phase extraction (SPE) continues to evolve significantly, driven by the need for more efficient, selective, and environmentally friendly sample preparation across diverse analytical fields. Recent advancements highlight innovations in sorbent materials, including metal-organic frameworks (MOFs) and molecularly imprinted polymers (MIPs), which offer enhanced selectivity and detection limits for complex matrices. Miniaturized formats like micro-SPE and fabric phase SPE (FPSE) reduce sample and solvent volumes, improving portability and efficiency. The integration of magnetic SPE (MSPE) simplifies bioanalytical sample preparation, while automated SPE systems boost throughput and reproducibility for large-scale environmental monitoring. Furthermore, a strong emphasis is placed on green chemistry principles, promoting eco-friendly sorbents and solvent reduction strategies to minimize environmental impact. These developments collectively enhance SPE's utility in environmental, food, pharmaceutical, and biomedical analyses, ensuring more accurate and sustainable analytical processes.

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