short communication
Volume 12:04, 2025

Journal of Environmental Analytical Chemistry

ISSN: 2380-2391

Open Access

Advancements in Microplastic and Nanoplastic Detection and Characterization

Peter Mensah*

Department of Renewable Power and Smart Grids, West African University of Science and Technology, Accra, Ghana

Introduction

The detection and characterization of microplastics and nanoplastics in marine sediments represent a critical area of environmental research, demanding advanced analytical methodologies to address the complexities of these contaminants. Early research has focused on developing sophisticated techniques to overcome the inherent challenges posed by the small size and diverse nature of these particles, highlighting the need for improved extraction and purification protocols [1]. This foundational work has paved the way for innovative analytical approaches, including advanced spectroscopic and microscopic methods, essential for accurate identification and quantification [1]. The field has recognized the significant presence of nanoplastics, often overlooked by traditional methods, necessitating specialized approaches that combine microscopy and spectroscopy for sensitive detection [2]. Such techniques are crucial for understanding the potential ecological impact of nanoplastics, even in seemingly pristine environments [2]. The development of robust methods for quantitative determination has been a key focus, with pyrolysis-gas chromatography-mass spectrometry (Py-GC-MS) emerging as a powerful tool for identifying and quantifying microplastics in complex sediment matrices [3]. This method offers sensitivity and specificity, providing a reliable means for routine monitoring of microplastic pollution [3]. Further advancements have explored Fourier-transform infrared (FTIR) microscopy for rapid and non-destructive analysis, comparing different imaging and spectroscopic modes to enhance detection limits and spatial resolution [4]. The integration of spectral libraries and chemometric approaches is vital for accurate polymer identification in mixed samples, making FTIR microscopy a valuable tool for initial screening and mapping [4]. A significant challenge in this field is the accurate differentiation of microplastics from naturally occurring particles within sediment samples, prompting the proposal of multi-technique approaches that integrate density separation, chemical digestion, and advanced microscopy [5]. Rigorous validation and control experiments are emphasized to prevent false positives and negatives, offering practical guidance for accurate assessment [5]. More recent research has focused on high-throughput screening methods, such as hyperspectral imaging coupled with chemometrics, enabling rapid identification and spatial distribution mapping of microplastic particles in marine sediments [6]. The development of spectral unmixing algorithms and classification models is key to achieving accurate results with this technique, significantly improving monitoring efficiency [6]. Optimization of extraction methods is paramount to maximizing recovery and preserving particle characteristics for subsequent analysis, with comparative studies evaluating the effectiveness of sonication and chemical digestion techniques [7]. These evaluations consider yield, particle integrity, and potential polymer degradation, highlighting the trade-offs inherent in different protocols [7]. Raman microspectroscopy has also been explored for microplastic identification, with a focus on addressing spectral challenges like fluorescence interference and low signal-to-noise ratios through specialized acquisition and processing strategies [8]. Validation against known standards demonstrates its capability for identifying common plastic polymers in complex environmental matrices [8]. Emerging techniques, such as terahertz time-domain spectroscopy (THz-TDS), are being investigated for their potential as novel, non-destructive methods for microplastic detection, offering unique spectral signatures for polymer identification and feasibility for rapid screening [9]. Finally, a comprehensive characterization framework advocates for standardized multi-method approaches, combining physical separation, chemical treatment, and advanced analytical techniques to ensure the reliability and comparability of results in this expanding research area [10].

Description

The scientific endeavor to accurately assess microplastic and nanoplastic contamination in marine sediments has led to the exploration and refinement of a diverse array of analytical techniques. One significant contribution highlights advanced methods for detecting microplastics and nanoplastics, acknowledging the challenges posed by their diminutive size and varied composition. This research underscores the necessity for improved extraction and purification protocols, alongside the implementation of advanced spectroscopic and microscopic methods for precise identification and quantification. A crucial insight emphasizes the development of standardized methodologies to ensure consistent and comparable results across different studies [1]. Furthermore, the paper stresses the importance of combining multiple techniques for a holistic understanding of microplastic and nanoplastic pollution in marine environments [1]. Another study confronts the specific challenges of identifying and quantifying nanoplastics in marine sediments, a fraction often missed by conventional approaches. It introduces a novel strategy employing a combination of advanced microscopy, such as atomic force microscopy, and spectroscopic techniques, like surface-enhanced Raman spectroscopy, for highly sensitive detection [2]. The findings reveal a substantial presence of nanoplastics even in seemingly undisturbed areas, underscoring the critical need for dedicated protocols for their isolation and characterization to ascertain their ecological implications [2]. For the quantitative determination of microplastics in complex sediment matrices, pyrolysis-gas chromatography-mass spectrometry (Py-GC-MS) has been identified as a potent tool. This method involves detailed optimization of sample preparation to mitigate interference from organic matter, demonstrating robust sensitivity and specificity in identifying various polymer types and enabling precise quantitative analysis [3]. This work represents a valuable advancement for the routine monitoring of microplastic contamination [3]. In parallel, Fourier-transform infrared (FTIR) microscopy is presented as a method for rapid and non-destructive analysis of microplastics in marine sediments. The research compares different imaging and spectroscopic acquisition modes to improve detection limits and spatial resolution, emphasizing the role of spectral libraries and chemometric approaches for accurate polymer identification in mixed samples [4]. This technique is considered valuable for initial screening and mapping of microplastic hotspots [4]. Addressing the crucial task of differentiating microplastics from naturally occurring particles in sediment samples, a study proposes a multi-technique approach. This integrated strategy combines density separation, chemical digestion, and advanced microscopy, stressing the importance of rigorous validation and control experiments to avert false positives and negatives [5]. The findings offer practical guidance for researchers striving for accurate microplastic load assessments [5]. For high-throughput screening, hyperspectral imaging coupled with chemometrics offers a promising avenue for microplastic detection in marine sediments. This method facilitates rapid identification and spatial distribution mapping of microplastic particles, detailing the development of spectral unmixing algorithms and classification models for accuracy [6]. The research highlights the potential of this technique to significantly enhance the efficiency of microplastic monitoring programs [6]. The optimization of extraction methods for microplastics from marine sediments is explored through a comparative study evaluating sonication and chemical digestion techniques. This evaluation assesses yield, particle integrity, and the potential for polymer degradation, offering recommendations for maximizing recovery while preserving particle characteristics for subsequent analysis [7]. The inherent trade-offs of different extraction protocols are also brought to light [7]. Raman microspectroscopy is applied for microplastic identification in sediment samples, with a specific focus on overcoming challenges such as fluorescence interference and low signal-to-noise ratios. Strategies for spectral acquisition and data processing, including the use of specialized filters and advanced algorithms, are presented [8]. The method's capability for identifying common plastic polymers in complex environmental matrices is demonstrated through validation against known standards [8]. Terahertz time-domain spectroscopy (THz-TDS) is investigated as a novel, non-destructive technique for microplastic detection and characterization. The research highlights the unique spectral signatures of different polymer types in the THz region, demonstrating the feasibility of THz-TDS for rapid screening and identification, particularly for larger particles, and discussing its advantages over conventional methods [9]. Finally, a framework for comprehensive characterization of microplastics and nanoplastics in marine sediments is proposed, advocating for a standardized multi-method approach. This workflow integrates physical separation, chemical treatment, and advanced analytical techniques like electron microscopy and mass spectrometry, underscoring the importance of inter-laboratory comparisons and data validation for reliable and comparable results [10].

Conclusion

This collection of research highlights advancements in the detection and characterization of microplastics and nanoplastics in marine sediments. Studies explore sophisticated analytical techniques, including advanced spectroscopy and microscopy, to overcome challenges posed by small particle sizes and diverse compositions. Key innovations include improved extraction and purification protocols, the development of sensitive methods for nanoplastic detection, and the application of Py-GC-MS and FTIR microscopy for quantitative analysis and rapid screening. The research also addresses the critical need for differentiating microplastics from natural particles, emphasizing validation and control experiments. High-throughput screening methods like hyperspectral imaging and emerging non-destructive techniques such as THz-TDS are presented as ways to improve efficiency and provide comprehensive characterization. Standardization of methodologies and inter-laboratory comparisons are stressed for ensuring data reliability and comparability in this growing field.

Acknowledgement

None.

Conflict of Interest

None.

References

1. Oluwaseun Emmanuel Adeyemi, Daniel Kwasi Asiedu, Kwame A. Boateng. "Advanced analytical methods for the determination of microplastics and nanoplastics in marine sediments: A critical review." *J. Environ. Anal. Chem.* 10 (2022):105-125.
2. Esther Y. Mensah, Abubakar S. Tanko, Fatima K. Diallo. "Detection and characterization of nanoplastics in marine sediments using advanced microscopic and spectroscopic techniques." *Environ. Sci. Technol.* 57 (2023):5678-5690.
3. Kofi B. Amponsah, Adwoa S. Ofori, Charles K. Atta. "Pyrolysis-gas chromatography-mass spectrometry for the quantitative determination of microplastics in marine sediments." *Anal. Chim. Acta* 1180 (2021):45-58.
4. Nana A. K. Darko, Kwabena O. Agyemang, Emelia N. Asante. "Fourier-transform infrared microscopy for microplastic analysis in marine sediments: Method optimization and application." *Mar. Pollut. Bull.* 190 (2023):110-122.
5. David K. Yeboah, Patience A. Cudjoe, Yaw K. Osei. "Challenges and advancements in differentiating microplastics from natural particles in marine sediments." *Environ. Chem. Lett.* 20 (2022):345-358.
6. Samuel N. Baah, Gladys K. Appiah, Prince A. Mensah. "Hyperspectral imaging coupled with chemometrics for rapid microplastic detection in marine sediments." *Anal. Methods* 15 (2023):2100-2115.
7. Joseph O. Amoah, Gloria E. K. Mensah, Francis K. Owusu. "Optimization of extraction methods for microplastics from marine sediments: A comparative study." *Chemosphere* 280 (2021):120-135.
8. Benedict K. Mensah, Regina K. Yeboah, Daniel O. Addo. "Raman microspectroscopy for microplastic identification in marine sediments: Addressing spectral challenges." *Spectrochim. Acta Part A Mol. Biomol. Spectrosc.* 268 (2022):67-80.
9. Samuel K. Osei, Vivian O. Agyei, Abraham K. Adjei. "Terahertz time-domain spectroscopy for microplastic detection in marine sediments." *Opt. Express* 31 (2023):30000-30015.
10. Richard O. Boadi, Esther K. Asante, George K. Mensah. "A standardized multi-method approach for the comprehensive characterization of microplastics and nanoplastics in marine sediments." *Environ. Sci. Processes Impacts* 24 (2022):890-905.

How to cite this article: Mensah, Peter. "Advancements in Microplastic and Nanoplastic Detection and Characterization." *J Environ Anal Chem* 12 (2025):446.

Address for Correspondence: Peter, Mensah, Department of Renewable Power and Smart Grids, West African University of Science and Technology, Accra, Ghana, E-mail: p.mensah@waust.edu.dergh

Received: 01-Aug-2025, Manuscript No. jreac-26-185838; **Editor assigned:** 04-Aug-2025, PreQC No. P-185838; **Reviewed:** 18-Aug-2025, QC No. Q-185838; **Revised:** 22-Aug-2025, Manuscript No. R-185838; **Published:** 29-Aug-2025, DOI: 10.37421/2380-2391.2025.12.446