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Short Communication

Microplastics Detection and Estimation by Electrical Impedance Spectroscopy Advances: Recent Trends

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Evando S Araújo[1]*, Diogo Gomes[2], Georgenes MG Silva[1], Solange Magalhães[3], Maria G Rasteiro[3] and Pedro M Faia[2]

[1]Research Group on Electrospinning and Nanotechnology Applications, Department of Materials Science, Federal University of São Francisco Valley, Brazil

[2]CEMMPRE - Electrical and Computer Engineering Department, FCTUC, University of Coimbra, Portugal

[3]CERES - Chemical Engineering Department, University of Coimbra, Portugal

***Corresponding author:** Evando S Araújo, Research Group on Electrospinning and Nanotechnology Applications, Department of Materials Science, Federal University of São Francisco Valley, 48902-300, Juazeiro, Brazil

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Abstract

Plastics are vital for society, but its usage has grown exponentially and contributes to the growth of pollution worldwide. For example, synthetic textile fibers are released due to extensive clothes washing, being the source of one of the most common microplastics, MPs, found in the environment. The World Health Organization, WHO, already reported that MPs particles are found everywhere, in waste and fresh water, and in the air and soil. Classic procedures for MPs detection are still quite laborious, and usually involve several steps and expensive equipment. So, in this short communication authors discuss recent developments involving faster and robust Electrical-based methodologies for the detection/estimation of MPs in water.

Introduction

Plastic consumption has exponentially grown during the last decades. Microplastics, MPs, are mainly formed by the fragmentation of large plastic materials [1], and an important negative contribution arises from textile industry [2]. Evidence shows that MPs have a negative impact on marine and aquifer environments. Typically, high-density MPs sink and accumulate as sediments, while the low-density one's float. Traditionally, wastewater and drinking water treatment systems are based on sedimentation, filtration, and on biological treatments, and the existent approaches to minimize MPs dissemination are clearly deficient. In the case of wastewater, waste-water treatment plants only minimize the problem trapping only larger size particles, while smaller ones remain in oxidation ponds or sewage sludges, or even in the treated effluent. Meanwhile, to evaluate the efficiency of the treatment procedures, the presence and quantification of MPs in wastewater and drinking water is vital. Classic procedures for MPs detection and quantification are still quite laborious, and usually involve several steps and expensive equipment. So, there is an urgent need for systems that can quickly evaluate the existence of MPs in wastewater and drinking water.

Microplastics detection/quantification: traditional vs recent methodologies

For many years, scientists have been trying to deal with the complexity of MPs detection and quantification, including the probability of getting results that are either false positives or false negatives. As stated, conventional MPs detection/quantification methodologies are complex and time consuming. Traditional analytical techniques for MPs evaluation are presently divided into three main groups [3]: 1) visual inspection methods - selection and classification by color or size of MPs particles is made using naked eye or microscope images (such as light reflected or Scan electron microscopes); 2) thermal analysis methods, such as Gas chromatography/mass spectrometry for pyrolysis, thermal extraction desorption-gas chromatography-mass spectrometry (which combines thermogravimetric analytical solid phase extraction and thermal desorption-gas chromatography-mass spectrometry), or calorimetry with differential scanning.; 3) spectral analysis techniques like Raman spectroscopy. The inelastic scattering of light is the foundation of the vibrational method called Raman and Fourier Transform Infrared spectroscopy.

More recently, efforts have started on the use of electrochemical methods, particularly on Electrical Impedance Spectroscopy, EIS, ideal for creating transportable devices with a faster response time, enabling real-time water sample monitoring [4]. In EIS, impedance between a pair of electrodes is measured at diverse frequencies. When different particles are present between the electrodes, they change the measured complex impedance according to their relative permittivity [5]. Consequently, impedance changes at high frequency reflect both the material properties and the size of the particles, reason why measurements are conducted both at high and low frequencies (at low or zero frequency, the impedance change is proportional to the particles volume). Nevertheless, this is a recently "born" approach and, consequently, literature reports are scarce, but still, this technique is highly promising. For instance, Meiler et al. [6], combined EIS with machine learning (support vector machines, SVMs) for detecting microplastics: electrical measures were carried out in static water samples containing different plastic concentrations in a cylindrical measuring cell, in the frequency range from 20Hz to 2MHz (prepared samples, contained plastic mass fractions varying from 0 to 10g in steps of 1g). The plastics tested were polypropylene, PP, and a polyolefin, PO, a mixture of different plastics, mainly consisting of low-density polyethylene. The classification task, consisting of distinguishing different plastic materials and particle sizes, was achieved with a success accuracy of over 98%. They also conducted measurements at 2MHz with water flows carrying microplastic particles of different materials and sizes, which served to investigate the dynamic capabilities of the measurement method: for this case the classification accuracy achieved was of 85%.

Another dynamic approach was conducted by Colson and colleagues [7]. In a rectangular tube with a pair of measuring electrodes, they demonstrated the use of an EIS based flow-through sensing procedure, for the identification of microplastics directly in water. They were able to quantify polyethylene MPs' particles based on their dimension (sizes ranges of 212-250, 300-355, 425-500, 500-600, 600-710, and 850-1000 µm, were used in the experiments). Microplastics were reliably detected, sized, and differentiated from biological materials, with a false positive rate for the misidentification of the biological material as plastic of 1%.

Conclusion

Literature reports show that EIS can be used as a fast, portable, low-cost, and efficient method to detect and estimate microplastic particles. Thus, the perspectives regarding its usage are high, even if the efforts have just begun. The evaluation of the acidity of the water, or the use of coated electrodes, are parameters needed to be evaluated in the future, which might influence the sensitivity and consequent development of these sensors.

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Conflict of Interest

The authors declare no conflict of interest.

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