Detection and identification of microplastics directly in water by hyperspectral imaging

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Abstract. We use hyperspectral imaging to identify the plastic types constituting mixtures of microplastics directly in water. For the current study we used known microplastics made by milling original pristine plastic sheets and mixed them in water. Using database information and spectral information measured on those pristine plastic we created a decision table enabling the identification. This technique is used under these conditions paving a way towards on-field and in-line measurements.

1 Introduction

Microplastics (MP) are plastic particles of size ranging from 1 µm to 5 mm. They originate from various sources such as industrial use (primary MPs) or from larger plastic parts, found in open environment, that have undergone erosion by sand, sun, wind, waves. These latest ones are the secondary MPs and are found nearly everywhere in nature. They can be of different shape, types, and size. They can carry some biofilm and are hosts for bacteria, viruses, and other organic or metallic particle. Water streams are carrying them in all possible places from ground to ocean and bring them back up to tap water. There is a need for an efficient method and protocol to detect and identify MPs directly in water.

Until now, most of the robust methods providing reliable measurements and analysis of MPs are based on Fourier Transform Infrared (FTIR) spectroscopy and Raman spectroscopy [1-3]. These two techniques are definitely the most precise ones but request a high level of expertise, a laborious sample preparation and filtering process, and must be handled manually, which delay considerably the procedure of identification.

We recently proposed to investigate the potential of a commercial device for a direct detection in water of MPs [4], mainly for industrial applications. We observed MPs very clearly and we were able to provide a method of pre-screening using ultra-high resolution imaging cameras. However, the identification itself remains difficult, although it is a crucial issue since MPs may come from plastics that contains now-prohibited molecules (bisphenol, for instance).

In this current work we propose to explore hyperspectral imaging (HSI) cameras [5] capabilities to perform a direct detection of MPs in water samples. If such a method has already been used for MP identification from dry samples, this is the first time that it is exploited for the observation in water.

2 Experimental procedure

The HIS device used in this work is a line scan camera (Specim N25) [6] allowing to capture in a wavelength range from 925 nm to 2.5 µm. MP samples are prepared in-house by grinding pristine plastic sheets. These MPs are disposed in specially made cuvettes containing water and allowing large imaging surface.

Several experiments have been carried out in order to measure first each MP type separately and then mixture of MPs. Some plastics are floating, some plastics are immersed but all are covered with at least a thin layer of water. Cuvettes with different samples are aligned on referenced white background and illuminated on both side to avoid shadowing during the acquisition of the images. The cuvettes are designed so that 8 mm of water over a glass microscope plate can host the MP particles.

After taking the images, the spectral cube is constituted and is used to determine identify the type of materials in each pixel of the image using spectral features characteristic of the plastics. Each spectral frame is normalized by the water spectrum taken from a cuvette without particles.

Further processing is made on the data in order to extract spectral features of the MP. This is explained together with the results for clarity purpose.

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3 Results and discussion

Figure 1 shows the spectra and the normalized spectra of the different MP types in water. They have been extracted from images and normalized with that of water.

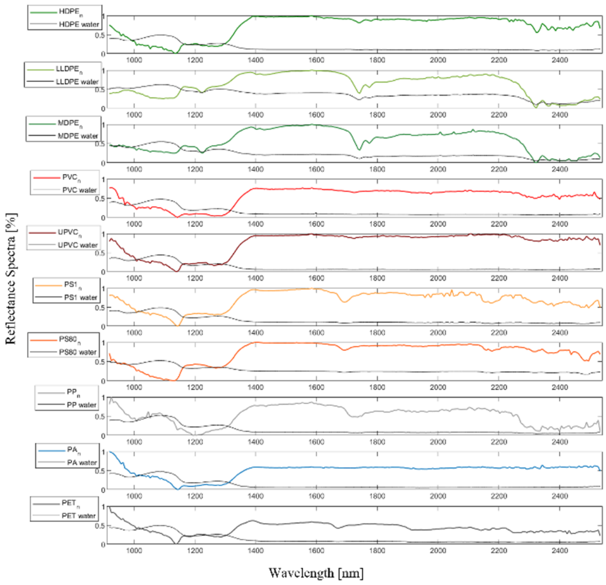

Fig. 1. Comparison of the reflectance factor in the range 920 – 2530 nm of 10 MPs in water (black curves) and the reflectance spectra after subtraction of water and normalization with 1550 nm intensity (colored curves).

By carefully choosing the principal spectral features, e.g., a peak, a dip, or a gradient, and comparing with the spectra obtained with standard spectrometer on pristine plastics and other database, we can draw a logic table enabling the determination and identification of the plastic type, pixel per pixel. It is to be noted that using the first derivative of the curves presented in Fig. 1 allows for better precision in the measure.

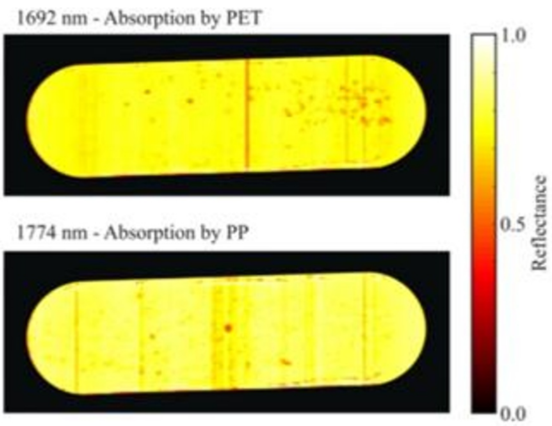

Fig. 2. Top view images of the cuvettes at two characteristic wavelength showing the presence of PET MPs (top figure) and PP MPs (bottom figure).

For each pixel, the created decision table is interrogated and enables to determine the plastic types at each pixel and therefor locate, count, define the size and shape of the different MPs in the measured sample. Figure 2 shows two examples of images taken by HSI, i.e., simultaneously on the same sample and at two different wavelengths, on a mixture of MPs in water. We re-colorized the plastic particles (PET and PP) for better visualization.

4 Conclusion

HSI is a fast and easy technique to identify materials when coupled to machine learning or data processing algorithms. We demonstrated in this work that one can determine the type of MPs is a mixture of many particles in water environment.

This technique is known for the storage memory it requires for each sample. However, in our concept, only a few wavelengths or features are needed to retrieve the nature of a pixel. Therefore, one can discard the data after measurements.

We believe this technique can further improve the detection and identification of MPs in complex water and help discriminating between the plastic types and other organic or non-organic materials constituting the matrix. It would then be a promising method to perform a rapid screening of samples prior robust chemical/optical analysis.

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