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Hyperspectral imaging of irregular-shaped black microplastics in water

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Abstract. We utilize hyperspectral imaging (HSI) technique for detecting and characterizing black microplastics (BMPs) in water samples directly. We fabricated nine BMP samples from common daily life plastics using a metal work file with a diameter of approximately 200 mm. We discovered that, regardless of all these samples appearing black to the human eye, different BMPs have distinct spectral profiles observable in the visible, and near-infrared regions. Furthermore, we explored the impact of varying BMP quantities in the water samples and found that the reflectance of black microplastics may be influenced by the quantity of BMPs present in the sample.

1 Introduction

Microplastics (MP) are plastic particles of size ranging from 1 µm to 5 mm. Primary MPs originate from industrial sources while secondary MPs are formed when larger plastic parts break apart under the effects of the environment. To achieve black appearance certain additives are added to polymers. About 0.5 to 3 percent of the mass of black polymers consists of soot or black masterbatch [5]. The presence of various additives, such as fibres, or soot, can significantly alter the spectra of these polymers, thereby complicating BMP identification. Moreover, BMPs' high absorption of light challenges many conventional sensors' signal to noise ratios [6]. All this creates complications for BMP detection and identification highlighting the need for efficient methods and protocols to identify BMPs directly in water.

The two most precise techniques used for measurements and analysis of MPs are based on Fourier Transform Infrared (FTIR) and Raman spectroscopies [2, 4, 5]. These methods are robust and reliable however, they require time-consuming MP pre-treatment, expertise, and well-controlled laboratory conditions.

Recently we investigated the potential of a commercial device for direct detection of MPs in water [3]. Using ultra-high-resolution cameras we were able to observe MPs and pre-screen them for industrial applications. In another study we detected and identified ten MP types directly in water using hyperspectral imaging (HSI) and an identification table [1]. In this current work we propose to explore hyperspectral imaging (HSI) cameras capabilities to differentiate BMPs in water samples. If such a method has already been used for BMP identification from dry samples, this is the first time that it is exploited for the observation directly in water.

2 Experimental procedure

The HSI device used in this work is a line scan camera (Specim V10E) operating within the 400 to 1000 nm wavelength range. BMP samples were prepared in-house from nine common household plastic items (see Figure 1). After cleaning the items were ground using metal work file with a diameter of approximately 200 mm. By creating the BMPs in such way we simulated irregular-shaped MP creation occurring in nature. Following the grinding process, the resulting microplastics or plastic powder were utilized for further analysis.

Fig. 1. Samples: 1) Coca Cola lid, 2) spray lid, 3) tennis ball box lid, 4) knife, 5) tomato ketchup lid, 6) clothing hanger, 7) biscuit box, 8) food container, 9) washing gel box

To capture a hyperspectral image a plate was placed on a moving table below the line scanner. The plate was filled with tap water and small quantities of BMPs were incrementally added to the plate. This stepwise procedure enabled the evaluation of three different quantities of black microplastics. After taking the images, the spectral cube is constituted and is used to study spectral features characteristic of the different black plastics. Each spectral frame is normalized by the water spectrum taken from a cuvette without particles.

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3 Results and discussion

Figure 2 shows the reflectance spectra of the nine BMPs in water and same spectra after normalization.

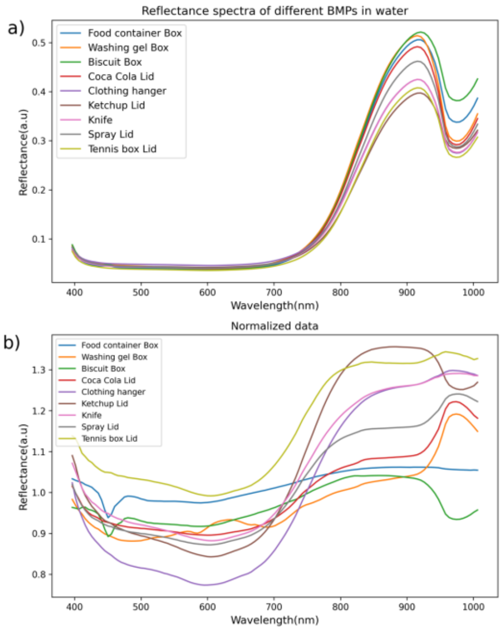

Fig. 2. a) Reflectance spectra of different black micro plastics in water b) Normalization of reflectance spectra of different black micro plastics in water

A notable observation within figure 2a is the subdued nature of the reflectance spectra within the visible range of 400nm to 700nm, which contrasts with their substantial augmentation, reaching a peak around 900nm. In figure 2b, each individual sample's distinct spectral signature is evident, signifying the presence of unique optical characteristics within the dataset. Noteworthy among these observations is the elevated reflectance exhibited by the biscuit box sample, setting it apart as the most reflective among all samples. Conversely, the ketchup bottle lid demonstrates the lowest reflectance spectra in comparison to the other examined samples. This observation suggests that the reflectance of BMPs may be influenced by the quantity of BMPs present in the sample. Figure 3 shows that as the quantity of BMPs increased, a noticeable decrease in the reflectance peak is observed. This suggests that a greater amount of light is being absorbed by the BMPs as their quantity increased.

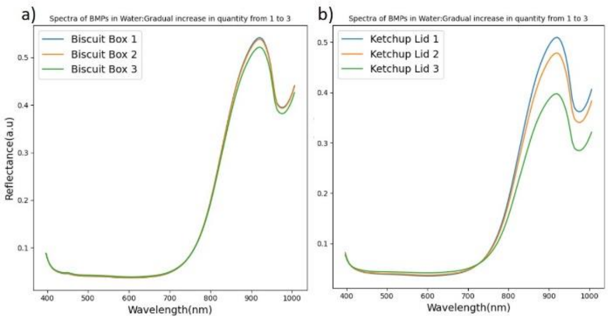

Fig. 3. Reflectance of BMPs in water with increased quantity. made of pieces of a) Biscuit box, b) ketchup bottle lid

4 Conclusion

In this work we revealed the distinct spectral profiles for nine BMP samples fabricated in-house using common daily life plastics. Furthermore, we identified the impact of varying sample quantities. This comprehensive approach enhances our understanding of the reflectance properties of BMPs and the influence of their quantity broadening the knowledge needed for applying photonics-based devices in detection and identification of BMPs.

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