Microplastic analysis through machine learning techniques

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Despite the rapidly growing body of scientific literature on microplastics (MPs), the field continues to lack an efficient and reliable framework for their detection and characterization. Conventional MP analysis relies heavily on collecting and interpreting spectra from individual particles, a process that is not only highly labor-intensive but also impractical when dealing with complex environmental or biological samples. In many cases, a single filter may contain millions of particles, rendering manual spectral collection and analysis prohibitively time-consuming and error-prone. These methodological bottlenecks limit the scalability of current approaches and pose significant challenges to advancing our understanding of MP prevalence, composition, and potential health impacts. To address this challenge, we propose two machine learning-driven strategies to advance MP analysis.

First, we introduce a support vector machine (SVM) model trained on a selected subset of four wavenumbers. This model demonstrates strong predictive performance, achieving 91.33% accuracy in classifying nylon versus non-nylon MP particles. By streamlining the classification process, this approach markedly improves both the speed and reliability of MP analysis.

Second, we present a deep learning-based automated detection and localization workflow. Using a YOLO (You Only Look Once) v8 model trained on optical images, we achieve a mean average precision (mAP) of 93.8% for particle recognition. To further enhance automation, we developed a Python script to directly acquire YOLO-derived coordinates and extract corresponding spectra. This integrated workflow not only improves the accuracy of MP detection but also minimizes manual intervention, thereby enhancing efficiency and scalability.