Analysis of Polymers Using the Agilent Resolve Tactical Handheld Raman Analyzer

Rapid, non-destructive, in-situ analysis of polymers and the contents of plastic containers

Authors

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Abstract

Polymers are a diverse class of macromolecules composed of repeating structural units that underpin many natural and synthetic materials. Their unique mechanical, thermal, and chemical properties arise from variations in molecular architecture, including chain length, branching, and crosslinking. The versatility of polymer technology has made these materials integral to modern society, from packaging and consumer goods to medical equipment and construction. However, this dependence, along with environmental concerns about waste materials and microplastics, is driving the transition towards circular, sustainable polymer life cycles. This application note investigates how Raman and Spatially Offset Raman Spectroscopy (SORS) technology can support this shift.

Introduction

Polymers are fundamental to modern materials science, shaping everything from packaging and textiles to medical devices and aerospace components. Built from long chains of repeating molecular units, their versatility comes not only from the chemistry of the monomers themselves but also from how these units are arranged. Copolymers—polymers formed from two or more different monomers—extend the possibilities for molecular design, allowing scientists to fine-tune properties like flexibility, thermal stability, and chemical resistance.

Polyethylene (PE), for example, is one of the world's most widely used polymers, formed through the polymerization of ethylene. Its properties vary greatly depending on its molecular weight and architecture. Low-molecular weight grades are softer while higher molecular weight grades develop exceptional toughness, chemical resistance, and tensile strength due to PE chain entanglement. The behavior of PE can also be changed by mixing ethylene with other monomers, known as copolymers. For example, mixing the polar monomer vinyl acetate with non-polar ethylene creates copolymers that disrupt regular chain packing, lower crystallinity, and add new functional characteristics such as flexibility, adhesion, or polarity. These copolymers broaden PE's performance profile, enabling applications from films and adhesives to impact-modified materials. They also illustrate how subtle changes in molecular structure can dramatically influence macroscopic properties.

Yet as polymers become more sophisticated, so do the challenges associated with their end-of-life management. Recycling is no longer just a matter of melting down plastic; copolymers often contain chemically distinct segments that degrade differently, resist separation, or form incompatible blends. Additives, dyes, and crosslinking further complicate the process. As a result, many advanced polymers are sent to landfill or incineration sites, prompting researchers to explore strategies such as chemical recycling, depolymerization, and designing materials that can be more easily disassembled.

Raman spectroscopy is a useful analytical technique that is widely used by material scientists involved in all aspects of the plastics industry. It is a bulk technique that analyzes vibrational signatures of polymers to give fingerprint measurements that can be used to identify monomers, track copolymer composition, and monitor reactions like oxidation or crosslinking.

The Agilent Resolve Tactical handheld Raman analyzer (Figure 1) is a powerful, flexible, battery operated tool that can be used to identify many common polymers through comparison of spectra contained in comprehensive onboard libraries. These libraries are available in three packages: Standard, Toxic and Hazardous, and Comprehensive. In addition to surface analysis, the Resolve uses Agilent proprietary Spatially Offset Raman Spectroscopy (SORS) technology to identify materials concealed behind barriers such as colored and opaque plastics, as well as dark glass, paper, and fabric. The configuration of the SORS optics also means that the Resolve analyzer produces high-quality data and reliable results for materials on site, avoiding the costs associated with laboratory testing.

Figure 1. The Agilent Resolve Tactical handheld Raman analyzer which is preloaded with the Toxic and Hazardous spectral library package.

In this study, the Resolve Tactical analyzer, which is preloaded with the Toxic and Hazardous spectral library, was used to confirm the polymer identity of six containers. Any potentially hazardous contents of containers that must be disposed of before recycling were also identified. The library includes reference spectra for common containment plastics, dyes, and pigments, as well as for various hazardous and non-hazardous materials. The Resolve was also used to identify subtle changes in copolymer structure when the concentration of the monomers was changed and to investigate if PE density and color would impact plastic detection.

Polymers in the Agilent Resolve library

There are over 90 different polymers in the Agilent Resolve Toxic and Hazardous spectral library package, which is preloaded on the handheld analyzer. Library spectra for some common plastics are shown in Figure 2.

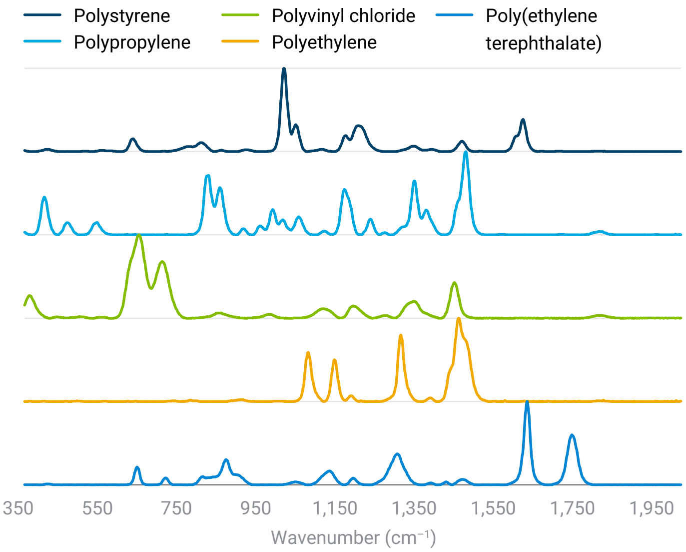


Figure 2. Agilent Resolve Tactical handheld Raman analyzer entries for five common plastics in the onboard Toxic and Hazardous spectral library package.

The Resolve was used to analyze six plastic containers in surface mode, and the resulting screens from each analysis are shown in Figures 3A to 3F. Three clear, colorless containers were measured (A, B, and C). Despite the similar appearance, the three containers were identified as three different plastics: (A) polyethylene terephthalate (PET), (B) polypropylene (PP), and (C) a polyvinylidene chloride-based polymer. The three colored containers, (D) amber PET, (E) orange PP, and (F) green PET, were correctly identified irrespective of the coloring used. Furthermore, the green PET container was identified in surface mode despite the native oil content.

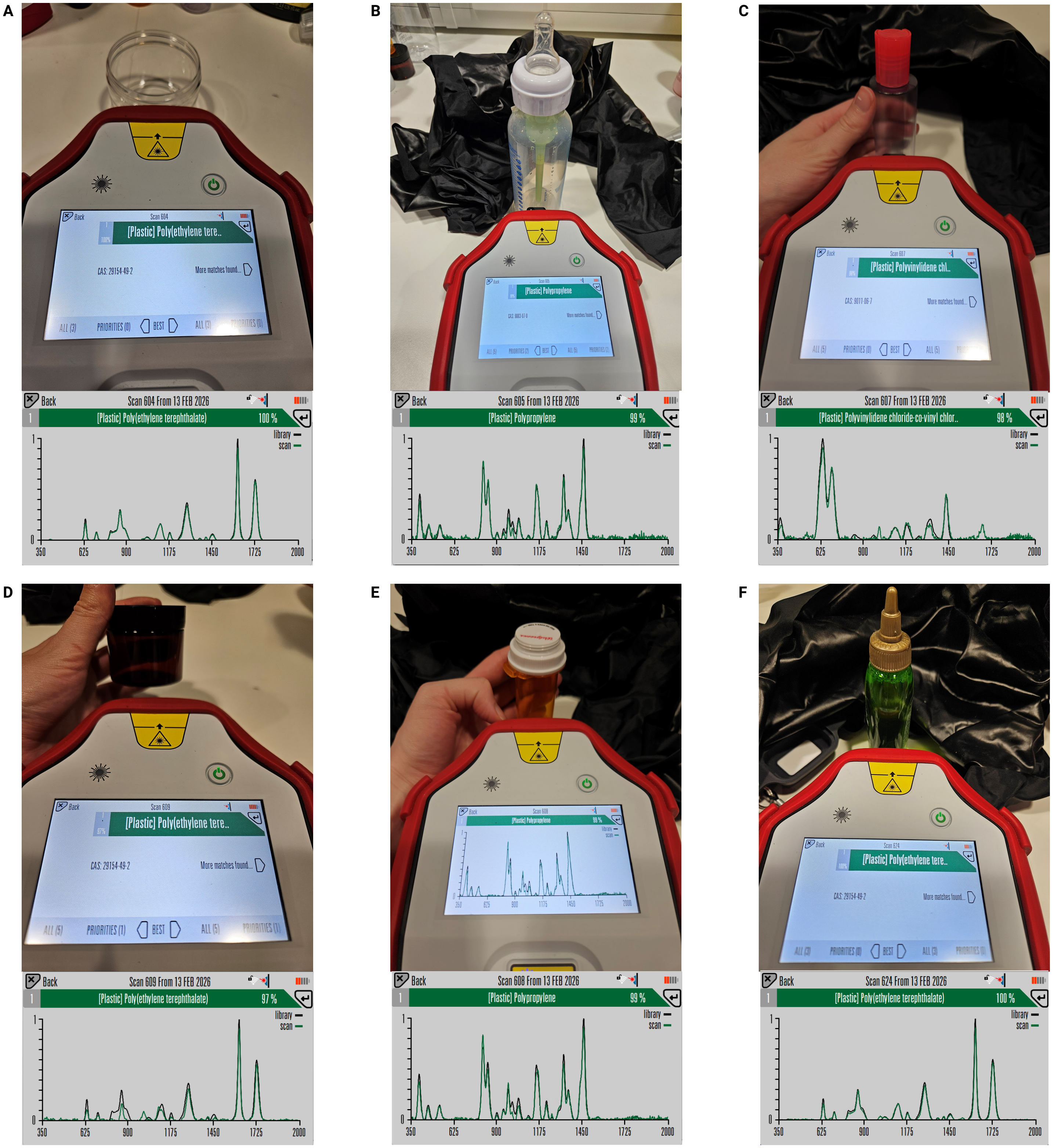
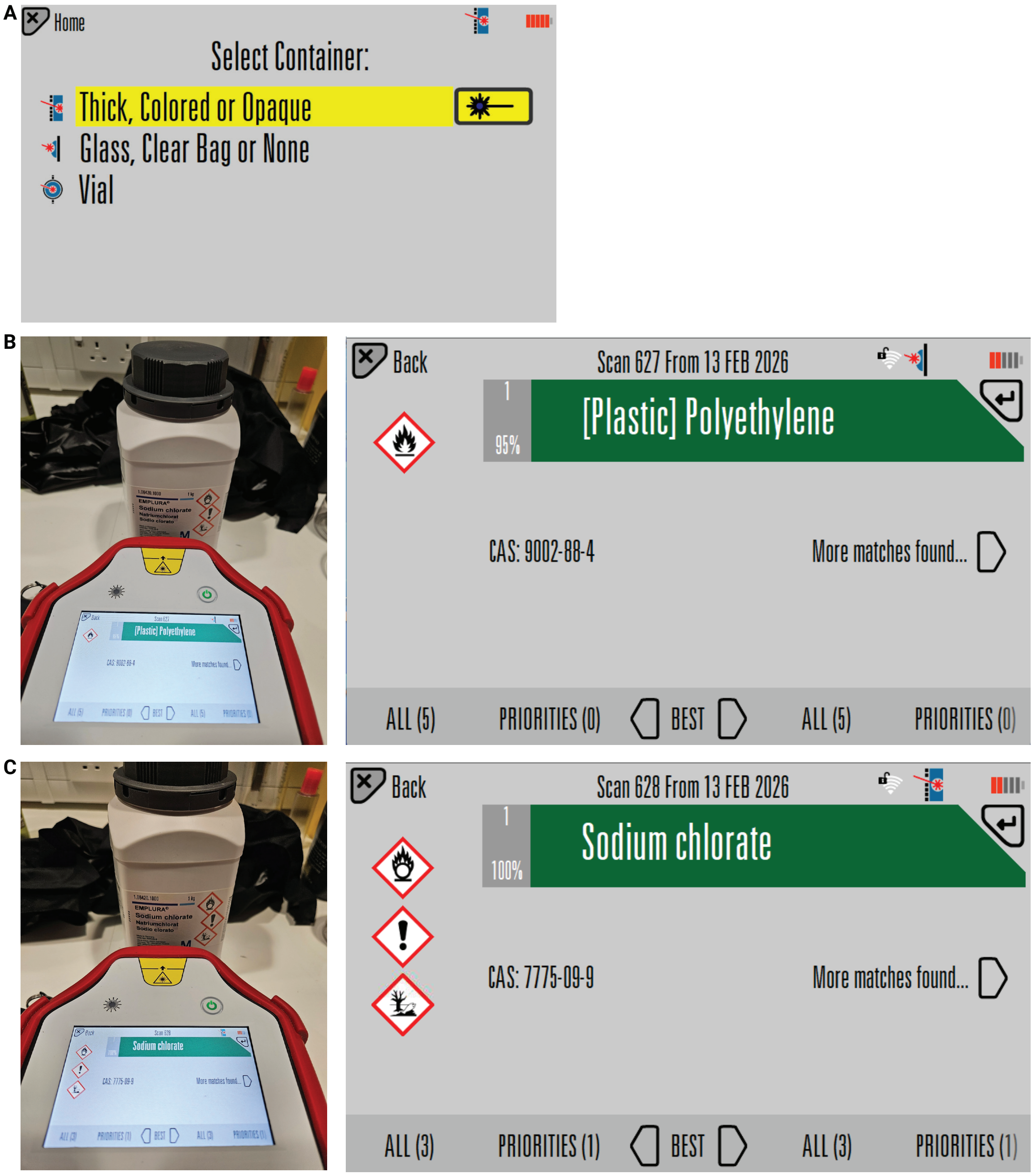


Figure 3. Identification of plastic type for various clear and colored containers using the Agilent Resolve Tactical analyzer in surface mode. The screens show the match, match score, and comparison of the respective scan spectra (green) against the library spectra (black).

Contents identified with additional through-barrier measurement

Recycling is an important step in creating a circular polymer life cycle. This process requires emptying and cleaning containers of contamination, correct identification of materials and contaminants, and subsequent sorting of plastics by type.

The Resolve coupled with the onboard library algorithm can be used to identify bulk contaminants and potential hazards inside sealed, thick, colored, and opaque plastics using SORS (thick, colored, or opaque) mode. First, the Resolve was used in surface (glass, clear bag or none) mode to identify the PE container (Figure 4B). A subsequent through-barrier measurement identified the content of the container as sodium chlorate. Hazard symbols were also displayed on the screen to aid appropriate content disposal before recycling the container (Figure 4C).



Scan 627 From 13 FEB 2026
1 [Plastic] Polyethylene 95%
CAS: 9002-88-4

Scan 628 From 13 FEB 2026
1 Sodium chlorate 100%
CAS: 7775-09-9

Figure 4. (A) The Agilent Resolve Tactical analyzer performs three types of measurements: through-barrier (thick, colored, or opaque), surface (glass, clear bag, or none), and vial mode. Using surface mode (B), the onboard algorithm matched the scan of the container to polyethylene. In SORS through-barrier mode (C), the Resolve detected the contents of the container and displayed the relevant hazards. This information enables appropriate measures to be taken before plastic disposal.

A through-barrier measurement (Figure 5) was conducted on the intact commercial green PET sample shown in Figure 3. The analysis identified the contents as polysorbate 20, a listed ingredient commonly used as a surfactant in cosmetic products.

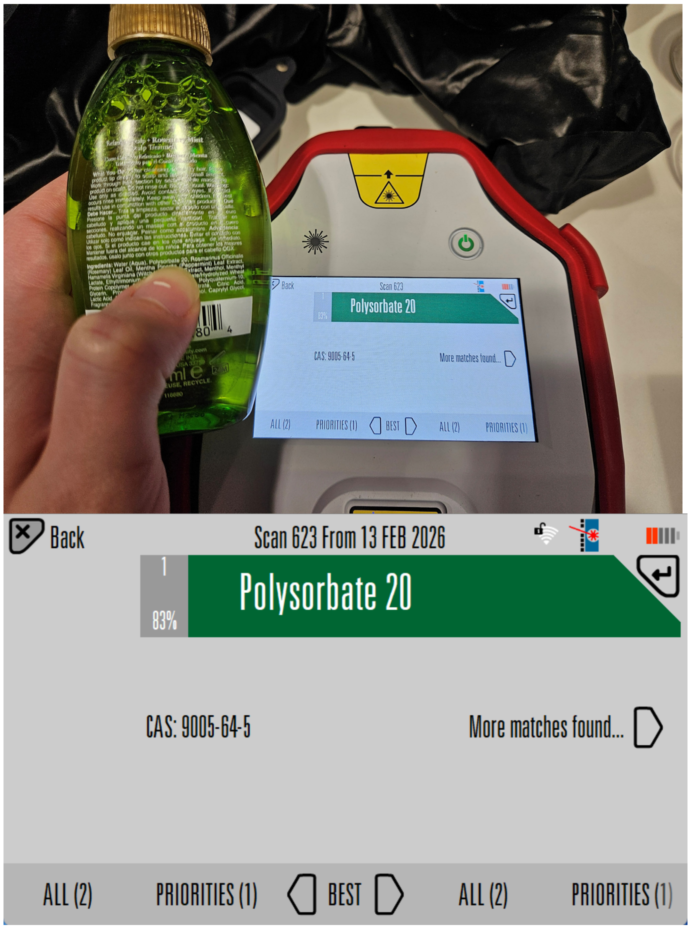


Figure 5. In SORS through-barrier mode, the Agilent Resolve Tactical analyzer identified the contents of a common consumer item through the colored PET container.

Data quality enables offline analysis of subtle changes in polymer structure

Ethylene-vinyl acetate is a copolymer of ethylene and vinyl acetate monomers. The vinyl acetate content determines the polymer's flexibility, polarity, and appearance. The Resolve analyzer was used to measure ethylene/vinyl acetate standards ranging from 14 to 40% vinyl acetate content (Figure 6). The data was then bulk exported into a CSV format for further analysis using the Agilent Command Fleet Management software.

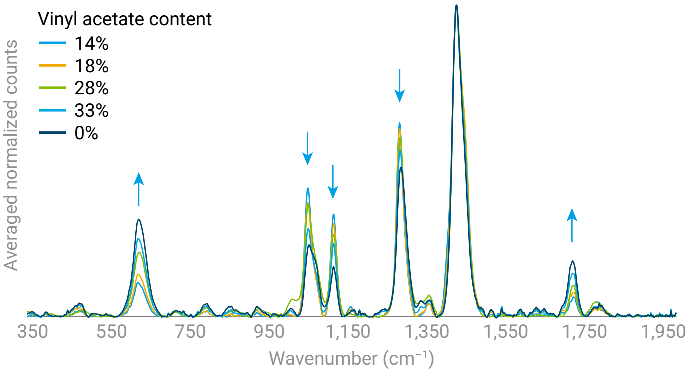


Figure 6. Raman spectra of ethylene/vinyl acetate copolymers as the vinyl acetate content changes. There are clear changes in peak height as the vinyl acetate content changes.

The Resolve 2.0 can export three levels of processed data for offline analysis using the Agilent Command Fleet Management software: raw, calibrated and baselined data. Here, baselined data was exported from the instrument and normalized to the largest peak (Figure 6). From the PE library spectrum shown in Figure 2, the peaks at 1066, 1130, 1297, and 1440 cm^{-1} are common to both pure PE and the copolymer. As the vinyl acetate content increases (and the PE content decreases), the height of the peaks at 1066, 1130, and 1297 cm^{-1} diminish. In contrast, the peaks at 636 and 1738 cm^{-1}, which are not present in PE, intensify as the vinyl acetate content increases.

Polyethylene analysis of commercial containers

Both the high-density (HDPE) and low-density (LDPE) grades of polyethylene are widely used for commercial containers due to their moldability and chemical inertness. The Resolve was used to investigate if PE density and color would impact plastic detection. Sixty containers (41 HDPE and 19 LDPE) of various colors were analyzed. A few of the containers are shown in Figure 7A. Strong responses from the four main PE peaks were observed in fifty-five of the containers, with three of those matching to PE with a pigment. These matches included a dark purple container, a thin bright orange bag, and a thin pink bag, which is shown in Figure 7B. Five containers matched to the pigment alone: three blue, one green container, and one gray bag.

Figure 7. (A) Selection of plastic containers measured using the Agilent Resolve Tactical analyzer in surface mode. (B) Identification of the pink LDPE bag as polyethylene and a pigment. (C) Scan results for the plastic antistatic bag.

An example spectrum of a blue LDPE container that matched to Pigment Blue 15 is shown in Figure 8, plotted alongside a PE reference spectrum (green trace) for comparison. There is good alignment between the measurement and the Pigment Blue 15 peaks, and the two larger PE peaks at 1350 and 1450 cm^{-1}. Two of the four PE peaks (1150 and 1450 cm^{-1}) overlap with pigment peaks. However, when these pigment measurement peaks were compared against the Pigment Blue 15 library entry, the ratios differed, suggesting a PE contribution. By identifying the pigment peaks, it could be possible to subtract the contribution from the measurement in an offline analysis, leaving a residual spectrum that could then be compared against different plastic spectra.

This method was used for the analysis of historical sample artifacts at the Natural History Museum in London using the Resolve.[1] It should therefore be possible to apply this offline methodology to identify either the pigment or the polymer. With both polymer and pigment spectra available in the library, the dominant contributor—in this case, the pigment spectrum from Figure 8—can be identified and subtracted from the measured spectrum during offline processing. The resulting residual spectrum can then be compared against the polymer library entries to support polymer identification.

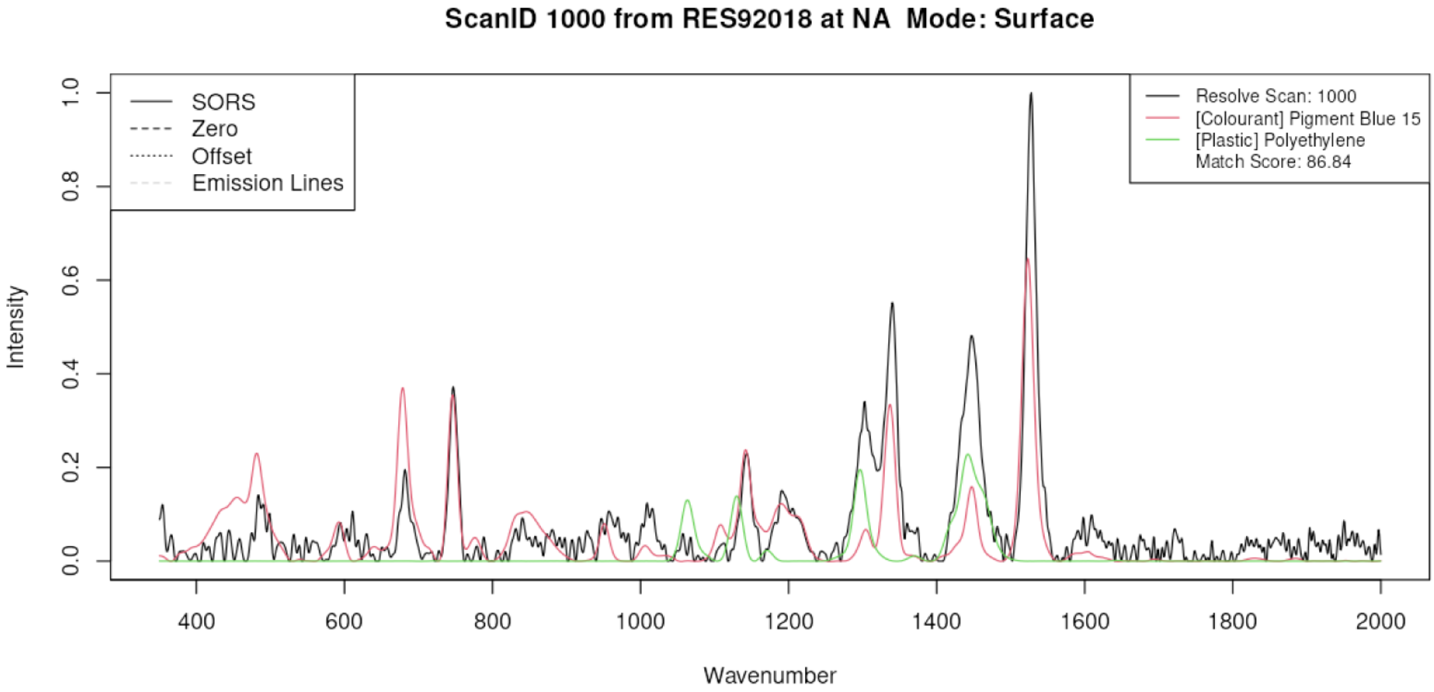


Figure 8. Analysis of a blue LDPE container that matched to Pigment Blue 15 (red line) using the Agilent Resolve Tactical analyzer in surface mode. For comparison purposes, the polyethylene (black line) was overplotted.

Conclusion

This study outlines the excellent potential of the Agilent Resolve Tactical handheld Raman analyzer for polymer testing applications and for identifying potentially hazardous materials inside containers. The system's comprehensive onboard Toxic and Hazardous spectral library package enabled the successful identification of clear and colored plastic containers using surface analysis, while its unique SORS technology identified the contents inside two containers. These results provide valuable information to help improve recycling rates of plastics.

Exporting the Resolve data into a CSV format for further analysis using the Agilent Command Fleet Management software enabled copolymerization monitoring, as well as pigment analysis for both light and heavily colored items.

Reference

1. Blanco, A.; Montgomery, W.; Walker, S.; McKibbin, C.; Stokes, R.; Matousek, P.; Mosca, S. In Situ Analysis of Historical Preservation Fluids in Sealed Containers with Spatially Offset Raman Spectroscopy. *ACS Omega* **2026** Jan 13, *11(3)*, 4216–4225.

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