ASSOCIATION OF PLASTIC RECYCLERS

SORTING POTENTIAL TEST METHOD:

Preliminary Evaluation of the Near Infrared (NIR) Sorting Potential of a Whole Plastic Article with High Coverage Label

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Introduction

Scope, Significance, and Use

This test is one in the series of "Sorting Potential Test Methods" developed by the Association of Plastics Recyclers (APR). This method was developed to enable a means to evaluate the potential impact of a high surface area coverage label on NIR optical sorting using a benchtop or hand-held NIR spectrometer. This evaluation can be conducted prior to investing more significant time & cost using APR's SORT-EE-01 Snap Test, or the full APR SORT-S-01 Evaluation of the Near Infrared (NIR) Sorting Potential of a Whole Plastic Article benchmark test. **The SORT-S-01 test is the only "must-pass" test to prove sortation is viable at production scale**

This test provides an initial assessment on whether a high coverage label will negatively impact the sort potential of the container it is covering. Please see the APR Design® Guide for current guidance on when label surface area might impact NIR optical sorting performance and so benefit from testing. In some instances – a high coverage label can interfere with sortation by industrial optical sorters through two pathways:

i. Optical sorter reads label material (e.g. polystyrene) and not container material (e.g. HDPE) – leading to a misclassification.
ii. Optical sorter reads a mix of label and container materials that can not be evaluated – leading to no classification for sorting.

Some examples of label features that can increase this interference are:

i. High reflectance of NIR light (e.g. from metallic coatings or pigments)
ii. High absorbance of NIR light (e.g. from carbon black pigments)
iii. Low NIR transmission (e.g. from thick paper labels)

This evaluation procedure can be used by those that develop or specify labels to understand variables that can impact the ability of NIR optical sorters to detect the package material beneath a high coverage label. The test can be used to help select materials and label designs that are likely to perform well in optical sorting, or which are likely to not perform well. But confirmation testing on pilot scale optical sorters using APR SORT-S-01 is recommended for definitive evaluations. Information supporting this methodology is presented in the attached Appendix.

Test Method Summary

A Near Infrared (NIR) Spectroscopy measurement is taken of a label applied to a container, and compared to a NIR measurement of the container alone. A statistical spectral match calculation is made to quantify the label's impact on the NIR spectrum of the container – and therefore its impact on the sort potential of the entire label-container product.

Equipment Required

- Benchtop or hand-held near Infrared Spectrometer with available Optical Window between 1400nm -2500nm
    - Examples of equipment that has been used for evaluation: trinamiX Mobile NIR Spectroscopy Solutions, Jasco V-770, Metrohm/Foss XDS Rapid Content Analyzer, Perkin Elmer Lambda 900, Shimadzu UV-3600i.
- Computer with Microsoft Excel or other spreadsheet program

Materials Required

- Flat sample of container material (at least 2" x 2") Sample might be cut from the wall of a container. Sample might be an injection molded color chip made with the plastic and color concentrate intended for a commercial product. The color of the container material must match that intended for commercial use and be of similar wall thickness. If there are a range of colors that might be used for a container product line, the container color that provides the lowest level of NIR reflection, or highest NIR absorbance, can be employed.
- Sample of label material (at least 2" x 2")
- Black Background Material (e.g. conveyor belt material, dark stone, black ceramic tile)

Test Method Steps

Test steps are:

1. **Data Acquisition**
    a. Capture NIR reflectance spectra of container material. Following specific instrument instructions, take a NIR measurement of a flat surface of the container material. Make all measurements over the black background material. Even though a plastic sample may appear opaque, it may not be fully opaque to NIR energy.
    b. Lay shrink label or apply pressure sensitive label to the exact same container material sample used in 1a. Take a NIR measurement of the label on top of the container. The order should be NIR Measurement Window of the NIR Spectrometer

Label → Container → Black Background

** Note that a variety of black background materials are suitable, so long as the same exact material is used as the background between 1a and 1b. We are assessing the difference when applying the label, so take care to keep everything else as consistent as possible.

2. Data Analysis

- **a.** Download the x,y coordinates (Wavelength, Absorbance) data for 1a and 1b
- **b.** Using Microsoft Excel or another spreadsheet program, take the 2nd Derivative of both 1a and 1b
- **c.** Calculate the Pearson Coefficient between the 2nd Derivative of 1a and the 2nd Derivative of 1b

** See Attached Worksheet for simple calculation of 2nd derivatives and Pearson Coefficient**

APRlabels_Pearson_Worksheet.xlsx

3. Test Assessment:

Pearson Coefficient	Indication
> 0.90	Low probability of label interference
0.70 – 0.90	Indeterminate label interference
< 0.70	High probability of label interference

Values of the Pearson Coefficient greater than 0.90 indicate that the label material has negligible impact on the NIR spectrum of the container material and so there is a low probability that the label will interfere with optical sorting of the container. Labels and containers with this result are excellent candidates for testing using PET-B-01 to confirm that the package/label combination can be categorized as preferred .

Pearson Coefficients < 0.70 represent a label/container stack that has a major impact on the spectrum of the container material. In this case, the label is likely to lead to at least a detrimental categorization, and may even render the package not recyclable if the optical sorting unit cannot detect the container material.

Results in which Pearson Coefficients fall between 0.70 – 0.90 are intermediate between low and high probability of label interference on bottle sortation and yield an inconclusive result if intending to use coverage above the APR recommended threshold. The coefficient values indicate that the label has an impact on the spectrum of the container material, but there is not sufficient experience to know if the impact is sufficient to create an identification problem, or not. The innovator shall decide if innovations falling within this range should be tested with APR PET-B-01.

For further reading on interpretation of Pearson Coefficient and NIR results of 1a and 1b, please see the Appendix given below.

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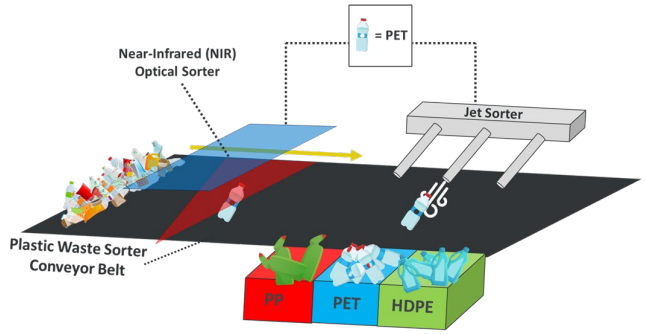
DOCUMENT VERSION HISTORY

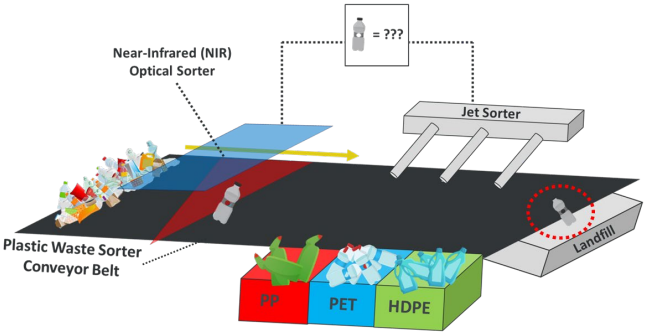
Version	Publication Date	Revision notes
1	January 23, 2024	Original

Appendix



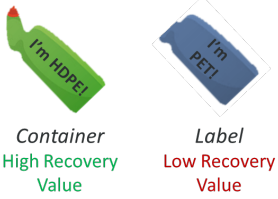
Identification of plastic type is an essential component of recycling.

Near Infrared (NIR) Spectroscopy is the predominant method for industrial **identification** of plastic waste for **sortation.**



Packaging Design has a significant impact on a product's **sortability**, and therefore recyclability

If a container cannot be **identified properly by NIR**, it has a likelihood of ending up in a landfill.

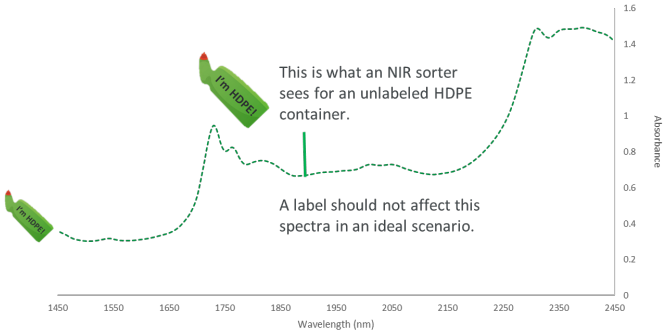


Container
High Recovery Value

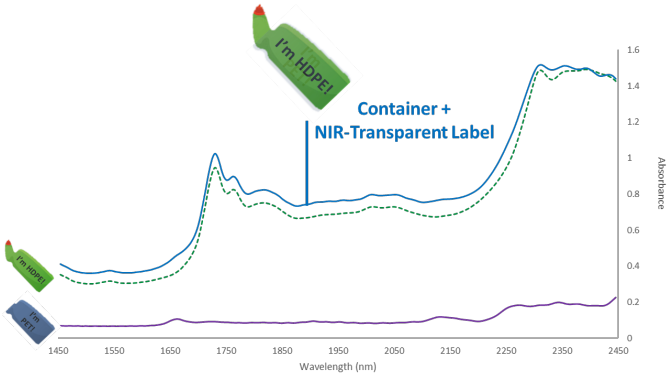
Label
Low Recovery Value

In the case of Plastic Articles with Labels, a recycler is interested in recovery of the container rather than the label.

Since NIR sortation commonly takes place prior to any de-labeling process, it is important to properly identify the underlying container – not the label.



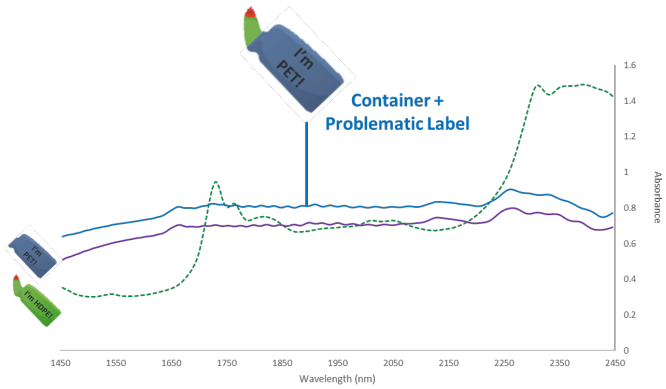
The data to the left is an NIR spectra of an HDPE container.



The purple line on the left is the NIR spectra of a PET label.

The blue line on the left is the NIR spectra of the PET label over the HDPE container.

There is minimal difference seen between the HDPE spectra (Green) and the combination spectra (Blue). This case represents a *low probability of label interference* result and has a Pearson Coefficient of 0.98.



In an opposing situation, the combination spectra on the left (Blue) is significantly affected by the label and no longer resembles the HDPE spectra (Green).

This case represents a *high probability of label interference* result and has a Pearson Coefficient of 0.33.

It is likely this combination would result in sortation as PET, or potentially not sorted at all.

Assessment of spectral match both qualitatively (graphs) and quantitatively (Pearson Coefficient) provides a guiding snapshot of how the affixed label is impacting the NIR characteristics of the underlying container. The Pearson thresholds were built off a study of 25 varied labels on 2 different container types and benchmarked against two industrial leading optical sorters. Through this work, this guideline was developed to help design packaging that will be properly sorted irrespective of what optical sorting line is used.