A110 Uncertainty Considerations for Measuring the Refractive Index of Glass

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After attending this presentation, attendees will understand the need for assessing uncertainty in glass refractive index measurements.

This presentation will impact the forensic science community by further validating the need to assess uncertainty in all areas of forensic science.

Refractive index has been used for comparison of glass analysis for many years. In this project, refractive index measurements were performed on 63 samples from 41 sources of glass using a glass reflective index system. Each sample was characterized by eight Refractive Index (RI) measurements collected at different places on the sample and some sources were characterized by up to three samples collected at different places on the source. Refractive index is traditionally thought of as a means of classifying and differentiating glasses, but it is a numerical measurement and as such, should always be accompanied by an estimation of the uncertainty associated with the measured value. This is consistent with the recommendations made in the 2009 National Academy of Sciences Report. This project focused on determining a reasonable and defensible uncertainty estimate for refractive index measurements as taken in a typical forensic setting.

The results of this project reiterated the issue of inherent heterogeneity. This issue becomes more pronounced as the capabilities of the measurement process improve; the readability of RI measurements observed using double polarization light microscopy and refractive index oils may go to three decimal places while the glass reflective index system is capable of reliably determining five decimal places. There were several instances where samples taken from the source produced statistically significant different RI measurements. In casework, the ability to have many samples from a larger source may not be possible and, as a result, such differences could conceivably lead to an incorrect classification of a glass sample. A primary goal of this project was to establish the minimum number of RI measurements that should be taken across a sample to establish reasonable and defensible measurements of intra-sample variability.

Homogeniety of the glass sample is not the only factor of uncertainty in this study; other contributing factors including the calibration curve and instrument drift over time should be considered. In this project, these factors were incorporated into an uncertainty budget table. Here, a conservative approach was taken in which all contributing factors were kept in the budget; rounding at the end to the correct number of significant figures insured that factors were incorporated as their relative magnitudes dictated.

To evaluate the impact of retaining an uncertainty value for each RI measurement, pairwise comparisons of all 41 sources were analyzed to determine when the range of the two results overlapped. Here, the range around each RI was determined in two ways: first, from the standard deviation of the replicate measurements from each sample; and second, from the uncertainty budget, which led to the combined standard uncertainty value. This value was multiplied by a coverage factor of k=2, which roughly corresponds to the 95% confidence level. The number of pairwise comparisons more than tripled from 18 pairwise comparisons using one standard deviation to 74 pairwise comparisons using the expanded uncertainty. This clearly demonstrates the utility of using an uncertainty budget approach for RI measurements. In the event of casework and just the standard deviation was evaluated and used for RI determination, false positives or exclusions could have been made.

Statistical tests were performed on the three major categories of glass in this study; car windows, house windows, and bottles. Only car windows and house windows were found to have a statistically significant difference in their mean RI values; however, when the expanded uncertainty is considered, there is notable overlap between the three categories of glass. Therefore, the results of this study indicated that an RI measurement alone is insufficient to categorize glass based on source. Although this set of 41 sources does not comprise all of the possible sources that one could encounter in casework, the major categories of glass are present. This is also a smaller sample size compared to the larger picture, but the same types of trends are found here that are seen in the FBI study of float glass dating back to the 1960s.

Uncertainty, Refractive Index, Glass

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