J14 Characterization and Differentiation of Document Papers Based on Element Profiles

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After attending this presentation, attendees will become familiar with the use of element profiles as a means to characterize document papers, as well as the use of statistical procedures to differentiate the papers based on these element profiles.

This presentation will impact the forensic science community by demonstrating an additional method for questioned document comparisons. The elemental profiles potentially offer greater discriminating power than the current methods used, and statistical analysis of the profiles provides a more objective method of comparison.

Currently, the analysis of document papers typically involves a comparison of physical and chemical features such as dimensions, color, and brightness. However, with advances and improvements in the paper-making process, differentiation based solely on these features can be limited. As a result, alternative methods that exploit different properties of the paper would be beneficial in the analysis and comparison of document papers. Recently, the potential of trace elements for the differentiation of paper samples has been investigated. These elements originate in the paper as a result of impurities in the raw materials, as well as from processes used during manufacture. Thus, it is possible that a profile of the elements present may be used to not only differentiate paper types, but also to associate paper of the same type produced by the same manufacturer.

Since the elements are present at trace levels, sensitive instrumental techniques are necessary for the analysis. Previous research has used inductively coupled plasma mass spectrometry (ICP-MS) to analyze trace elements in paper samples. This multi-element technique meets the requirement for high sensitivity; however, the instrumentation is complex and high running costs are associated with the analysis. An alternative technique is inductively coupled plasma optical emission spectroscopy (ICP-OES), which is a less expensive multi-element technique. While not as sensitive as ICP-MS for many elements, ICP-OES may offer a viable alternative for element determination in document papers.

The purpose of this research was to further investigate the differentiation of document papers based on the trace element profiles generated using ICP-OES. Three reams of four different types of paper (copy, laser inkjet, multipurpose, and office paper) produced by the same manufacturer were obtained. Samples were microwave digested in nitric acid and hydrogen peroxide prior to analysis. The resulting digests were analyzed by ICP-OES to identify characteristic elements for each paper type. The elements selected were those that were present above the instrument detection limits, were not present at significant levels in the blank digest, and did not vary significantly within a ream of paper. The selected elements were then quantified using ICP-OES. The sample digests were also analyzed by ICP-MS, quantifying the same elements.

The element concentrations determined were firstly normalized to the initial mass of paper used in the digestion. The element profiles that were generated using each instrument were treated as two separate data sets and each data set was firstly subjected to hierarchical cluster analysis (HCA). This is a multivariate statistical procedure used to identify similarities among samples in a data set. The dendrograms generated were used to assess similarity among reams of the same paper type, as well as dissimilarity of different paper types, based on the concentrations of the elements present.

Profiles in each data set were also subjected to principal components analysis (PCA). While this procedure is also multivariate in nature, PCA identifies sources of variance in a data set, rather than similarities, as is the case in HCA. The two main outputs of PCA are scores plots and loadings plots. The former plots are scatter plots in which chemically similar samples are positioned closely and distinctly from chemically different samples. Loadings plots are used to identify the variables contributing to the variance described by the principal components. In this research, the scores plots were used to assess the association of reams of paper of the same type and differentiation of different paper types. The loadings plots were then used to identify the elements responsible for the differentiation observed.

Finally, results from HCA and PCA were compared to determine if one technique, ICP-OES or ICP-MS, offered improved association and differentiation of the paper samples based on the elemental profiles generated.

Trace Elements, Questioned Documents, Statistics

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