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Forensic profiling of chemical dispersion devices

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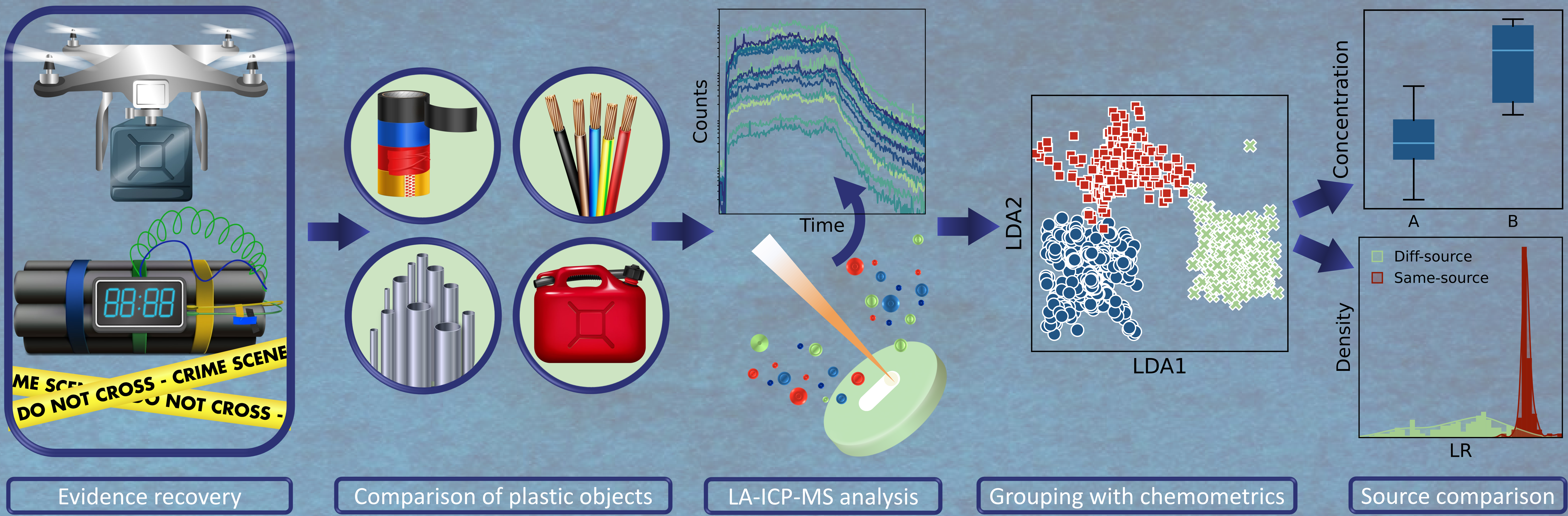


Objectives

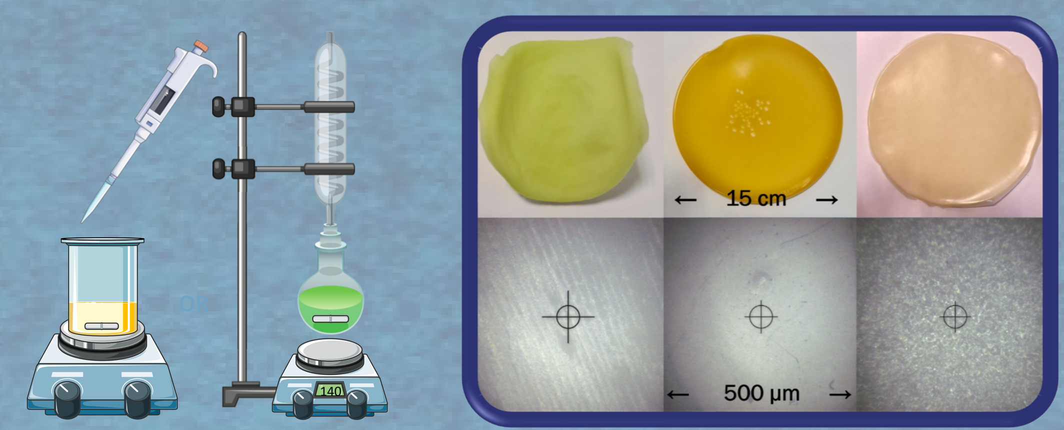
- To determine the origin of plastic materials used in CBRN attacks.
- To match an unknown sample from a crime scene to evidence confiscated from a suspect.

Background

Plastic materials are often used in improvised explosive devices and chemical dispersion devices. After the explosion or release of chemical, biological, radiological, or nuclear (CBRN) weapons it might be difficult to find traces of the intact compound. In this case, determining the trace-elemental composition of specific plastic parts of the device could potentially provide leads for the forensic investigation. Elemental impurity profiling has the potential to provide a connection between traces discovered at separate locations that share a common origin. In addition, items from seemingly unrelated incidents can be matched through forensic databases.

Approach

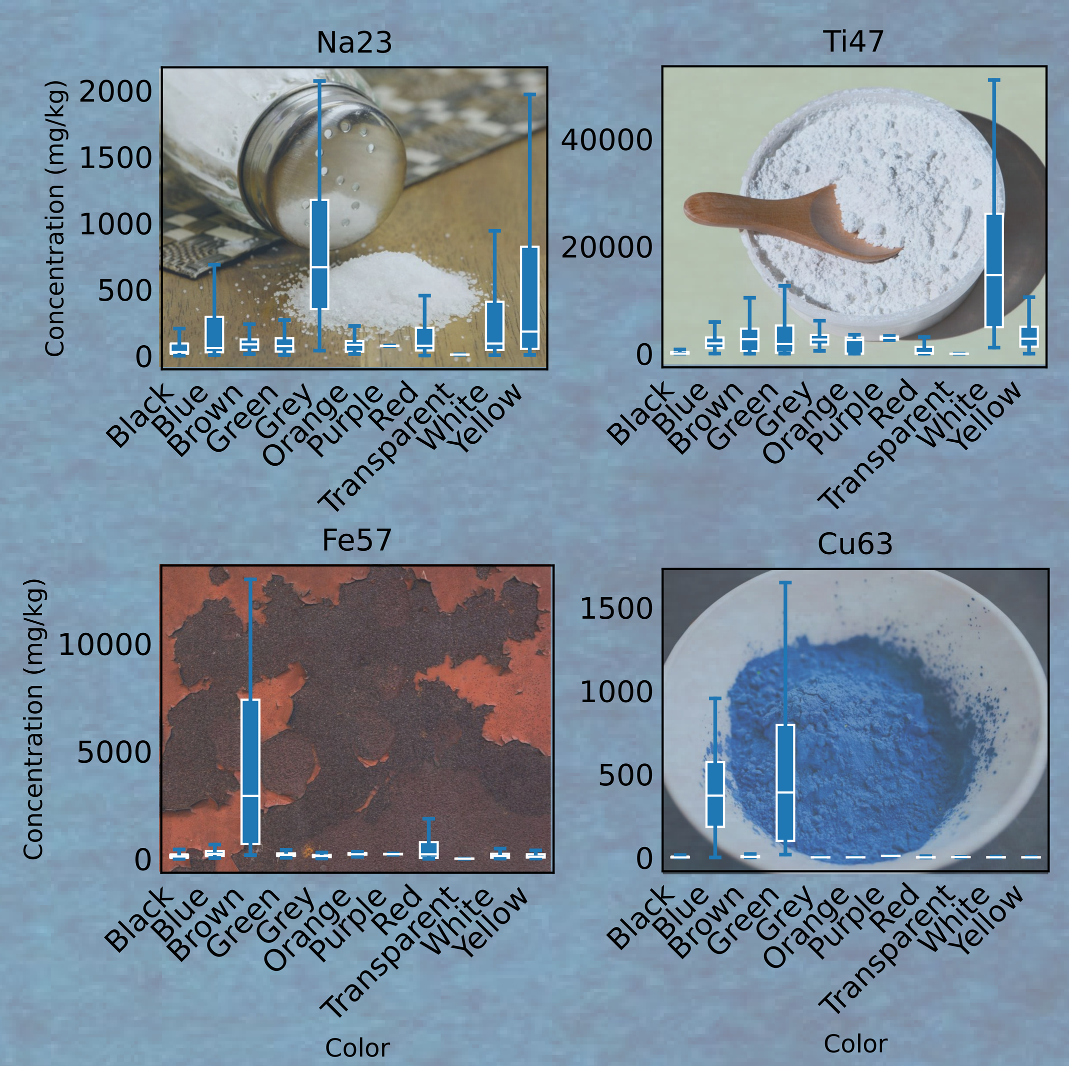
Laser ablation-inductively coupled plasma-mass spectrometry (LA-ICP-MS) is a well-established technique for obtaining an elemental profile for forensic glass analysis. However, the lack of polymer reference materials hampers the accurate quantification of elements in plastics. Therefore, new polyvinyl chloride (PVC), polyethylene (PE), and polystyrene (PS) reference standards were developed to improve quantification.



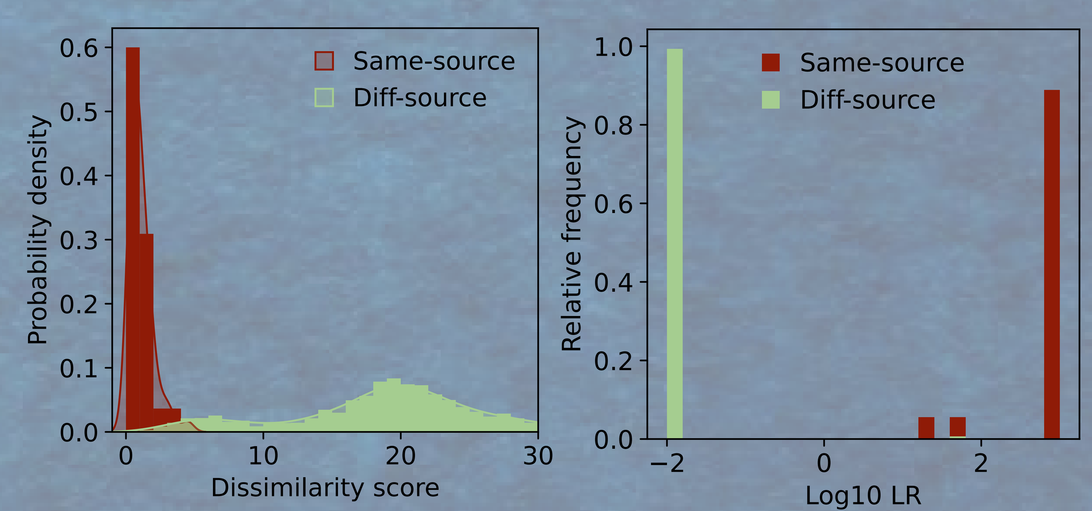
The performance of the standards was evaluated using datasets of tapes, electrical wires, PVC tubing, and jerrycans. Various data analysis methods were applied for classification of the type of object and for comparison of two samples. The traditional 4-sigma and t-test match criteria were compared to the score- and feature-based Bayesian likelihood ratio (LR) models.

Main findings

Na, Mg, Al, Si, K, Ca, Ti, Cr, Mn, Fe, Co, Ni, Cu, Ga, As, Sr, Zr, Nb, Pd, Sn, Sb, Ba, and Pb were detected in plastics by LA-ICP-MS. Jerrycans showed a limited number of elements. Tapes contain high concentrations of Sb, Ba, Pb, and As, whereas tubing was characterized by the presence of Na, Si, and Ti. Additionally, wires showed high levels of Ni, Sr, Mg, and Ca. Specific elements for each color were found. Quantification with the new PVC standard and normalization to ^{13}C greatly improved the stability of the profile.



For forensic comparison, a score-based SVM Bayesian LR model and the t-test overlap method performed better than the feature-based model and 4-sigma criterion. The t-test method showed an overall average false inclusion rate of only 0.45% and a false exclusion rate of 2.4%. Calibrated LRs of 0.014 to 1800 were obtained for tapes.



Conclusions

Different chemical profiles were measured for objects from various suppliers. This indicates the possibility of chemical profiling to determine their origin and match an unknown sample.

Future research can focus on interlaboratory comparisons, polymer degradation, e.g. due to explosions or water, and gaining more understanding about the production process.

[1] M. de Bruin-Hoegée, et al., A novel standard for forensic elemental profiling of polymers by LA-ICP-TOF-MS, *Forensic Chem. 35* (2023), 100515.

[2] M. de Bruin-Hoegée, et al., Evaluating the strength of evidence of elemental profiling of polymers with LA-ICP-MS, *Forensic Chem.* (2024), Submitted.

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