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Case Report

A review of modern challenges in fire debris analysis

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ABSTRACT

The continually-evolving field of fire debris analysis presents challenges to examiners on a regular basis. This article combines an overview of the scientific literature with novel samples that illustrate the current issues faced by fire debris examiners. Unusual liquids that contradict current classification schemes are discussed, as are complex matrices with noteworthy interferences. The matrix effects range from inherent interferences to the degradation of ignitable liquids. Finally, non-routine analyses are discussed, including the analysis of vegetable and lubricating oils and novel ignition methods. Through open discussion of complex samples and individual experiences, the problems in fire debris analysis can be overcome, resulting in the production of accurate and authoritative information.

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The area of fire debris analysis is a continually evolving field. In recent years, there have been developments by manufacturers resulting in new types of liquids that challenge classifications schemes and new materials in household items that result in complex matrix interferences. Additionally, fire debris examiners are increasingly called upon to analyze samples outside the typical ignitable liquid analysis. Some laboratories may be currently limited in their instrumental capabilities; however, these non-routine analyses are becoming more common.

Previously, this vital information has been spread easily by word-of-mouth during meetings of forensic science organizations, ranging from local to international, and from experienced examiners to new examiners within laboratories. Due to lack of funding and attrition of experienced examiners, this method of information exchange has lost its original efficacy, and information is now generally shared during occasional email exchanges with colleagues about difficult samples. An additional method of information exchange has been publication of fire debris research, which has been quite prolific. Some papers in particular have addressed individual problematic samples, liquids, or matrix effects [1–8]. This article is intended as a consolidation of the written information and cumulative experiences of several fire

debris examiners in order to continue the tradition of open discourse about potentially problematic samples.

1. Materials and methods

All liquid samples were diluted with carbon disulfide (Fisher Scientific, Pittsburgh, PA). Matrix interference samples were extracted by passive headspace concentration [9]. Half of an activated carbon strip (Albrayco Technologies, Inc., Cromwell, CT) was suspended from the lid of each can using a magnet and paper clip. The cans were heated in an oven at approximately 65 °C for 16 h. After the cans were removed from the oven and allowed to cool, the strips were removed, and each was eluted with 350 µL of carbon disulfide.

Sample dilutions and extracts were analyzed using an Agilent 6890N GC with 5973 MS (Agilent Technologies, Santa Clara, CA) equipped with a J&W DB-1MS, 30 m × 250 µm × 0.25 µm column (Restek Chromatography Products, Bellefonte, PA). Sample volumes of 1.0 µL were injected at 250 °C with a split ratio of 30:1. Helium carrier gas was used at a constant flow of 0.6 mL/min. The oven temperature started at 37 °C (2 min), ramped at 5 °C/min to 120 °C, and finally ramped at 12 °C/min to 280 °C (4 min). The transfer line to the mass spectrometer was maintained at a constant 280 °C, the ion source at 300 °C and the MS quadrupole at 150 °C. The mass spectrometer was set for a full scan in electron ionization mode over an *m/z* range of 15.0–100.0 amu prior to solvent elution and 33.0–300.0 amu after solvent elution. The source was turned off during solvent elution. Each component was

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identified based on comparison of its mass spectrum to the National Institute of Standards and Technology mass spectral library.

2. Discussion

2.1. Liquids

While liquids can be some of the simplest samples analyzed by a fire debris examiner, due to the lack of matrix interferences, they can present their own challenges. Variation in petroleum product compositions and classification protocols can introduce questions about the ‘most correct’ classification of a particular liquid. It is important to determine the classification that is most representative of the submitted evidence to ensure accurate information for possible leads for investigators. As an agency with forensic laboratories across the United States, the Bureau of Alcohol, Tobacco, Firearms and Explosives (ATF) is exposed to a wider range of sample variation than a city or regional laboratory, and cross-country peer reviews have demonstrated that regional differences can affect an examiner’s perception of what is considered to be within the normal range of a given class. Because of this, the importance of a broad reference collection of ignitable liquids and open communication between examiners across the country, and even internationally, cannot be overstated. Several liquids will be discussed in this section; however, this section is by no means comprehensive.

2.2. Liquids: challenges in classification

The majority of liquids and samples encountered are easily classified using the ASTM classification system [10]. However, in several cases, liquids have been encountered that are difficult to classify. These liquids may not exhibit a typical petroleum pattern or may differ in chemical content from an established classification. It is important to be aware of these liquids so that they can be correctly identified, particularly in samples complicated by matrix interferences or weathering.

An example of a product that resists classification under ASTM E1618 is Power Service Diesel Fuel Supplement (Power Service Products, Inc., Weatherford, TX). This liquid has been encountered in casework and is included in the Ignitable Liquid Reference Collection (ILRC) [11]. According to the ingredients listed by the manufacturer, the product contains “petroleum distillates and aromatic hydrocarbons,” and exposure of the neat liquid to an open flame showed that it was easily ignited. The product contains aromatic and indane components commonly found in ignitable liquids, but the total ion chromatogram (TIC) and extracted ion profiles (EIPs) do not show a recognizable petroleum pattern (Figs. 1a, 2a, and b). The product has a strong indane EIP in a pattern that is somewhat similar to that seen in petroleum distillates or gasoline; however, the ratios of the C₂- and C₃-alkylbenzenes in the aromatic EIP are not consistent with a petroleum product. This product definitely highlights the need for a flexible classification system to include a “miscellaneous” or similar category, which may not be currently included in the classification protocols of some laboratories. Without this category, an examiner may not be able to identify an ignitable liquid, even with a suitable reference. As a result, this may be misleading to an investigator who may believe that no ignitable liquids were present, rather than none could be identified. Additionally, it should be noted that the description of a product in the Material Safety Data Sheet (MSDS) or ingredient listings as a petroleum distillate does not necessarily indicate that the liquid is a petroleum distillate, only that it is likely petroleum-based.

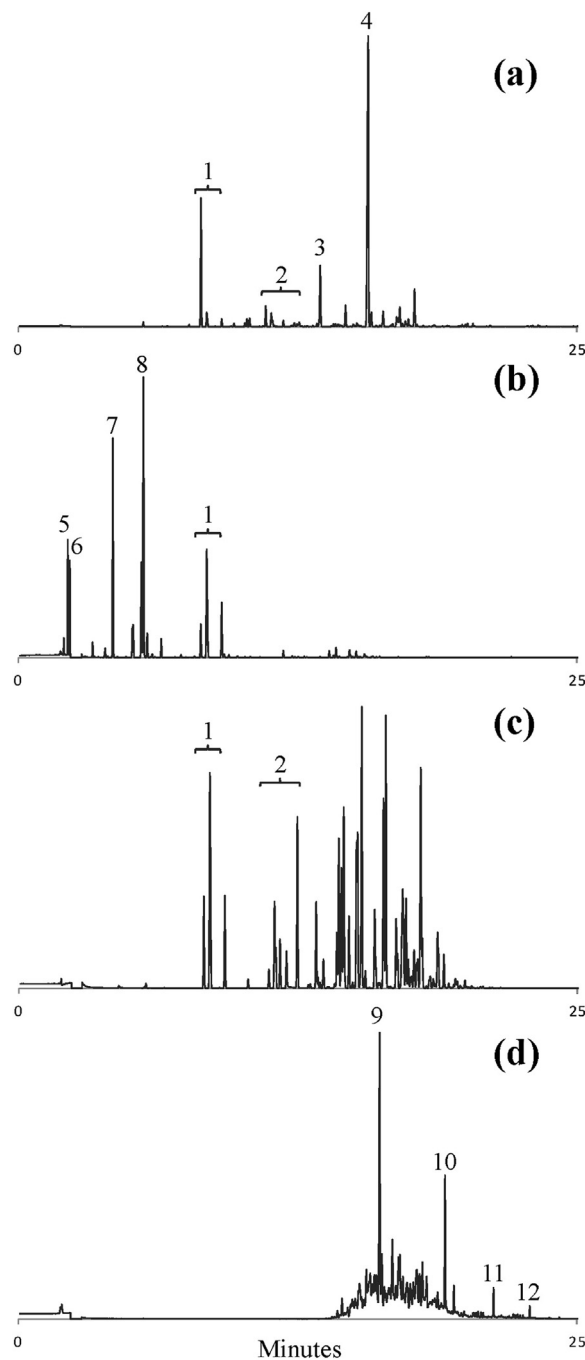


Fig. 1. Total ion chromatograms for (a) Power Service Diesel Fuel Supplement, (b) TruFuel, (c) Everbrite Protective Coating, and (d) Klean Strip Green Safer Paint Thinner. Peaks: (1) C₂-alkylbenzenes, (2) C₃-alkylbenzenes, (3) indane, (4) methylindane, (5) methylbutane, (6) *n*-C₅, (7) dimethylhexane, (8) toluene, (9) *n*-C₁₁, (10) *n*-C₁₂, (11) *n*-C₁₃, (12) *n*-C₁₄.

A less extreme example of the need for a “miscellaneous” classification is TruFuel (TruSouth Oil, Shreveport, LA) (Fig. 1b). This product contains toluene, C₂-alkylbenzenes, branched alkanes similar to a light isoparaffinic product, and low abundance C₄–C₆ *n*-alkanes. The presence of *n*-alkanes precludes classification as a light isoparaffinic product, but the lack of cyclic alkanes where normally present may complicate classification as a light petroleum distillate, in addition to the light aromatic product.

Everbrite Protective Coating (Everbrite Inc., Reno, NV) is another example of a product that may be problematic in classification as it differs from the typical aromatic product.

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