

## The Analysis for Sources of Soot in a Home

There are a number of potential sources of soot in a home. They include soot from internal combustion engines, diesel engines, smoking of plant matter, cooking, oil lamps, candles, quartz/halogen bulbs with settled dust, house fires, fireplaces, furnaces, local field burning, and other sources. Within any given home a number of sources are active at any given time. These sources are detected by the characteristic distribution of some of the soot, associated pyrolyzed fuel, and other particles from these sources that identify them as active sources in the environment. Sampling, as in any analytical protocol, is critical. Tapelifts are a very useful collection technique because they preserve the deposition pattern at the site sampled, collect particles of all sizes, and retain the spatial relationships between particles and other debris on the surface. Dry swab samples from condensing surfaces are useful in some specific cases where arson is suspected. Solvent swab samples are of more limited value because they are more selective in what they collect. Swab samples don't retain the useful particle association and distribution features retained by tapelifts. Particles tend to be agglomerated, especially if a surface contains condensed oils. Scraping, brushing, or vacuuming particles from a surface cause particle agglomeration and are more damaging (scraping) or more selective (brushing or vacuuming) than swabs or tapelifts.

The sites sampled are just as important as the sampling method. Ideally the number of sites sampled would be large and widely distributed within the environment, but that is not generally feasible due to the cost of the resultant analysis. As a minimum a site near the suspected source and the site of concern should be sampled. Additional potential sources and some locations between the sources and the site of concern should be sampled to document the unique properties of the source, the transport mechanism to the site in question, and how the other sources are ruled out as primary contributors. The samples that are finally collected and those that are submitted for analysis are up to the inspector and their client. The ultimate interpretation of the results will be up to the inspector, based on intimate knowledge of the site and the results from the laboratory. The laboratory can provide information on the basis of the samples submitted for analysis, with the assumption that the samples are representative of the environment.

The general distribution of the soot in the home is a feature that can help indicate active sources. The deposition of soot should be heaviest closer to the source. Farther from the source the distribution becomes less characteristic. Typical black deposits marking nail-heads, studs, and ceiling/wall or floor/wall junctures (ghosting deposits) tend to be more uniform depositions that may or may not be caused primarily by soot, and that lack a source driven deposition pattern. An inspection of the home may indicate a deposition gradient in the ghosting patterns that may be useful, but thermal and airflow effects can be the dominant factor on the general deposition pattern.

Sources generate soot particles that are associated in a pattern typical of that source though not unique to that source. Tapelifts preserve that distribution. Distributions are sometimes so general in nature that they can not be used to rule out a source, however some distributions are more specific. Gas phase fuels tend to produce very fine, dry soot.

Liquid phase fuel combustion begins by producing a vapor phase of the fuel that is actually burned. Depending on the delivery of oxygen and the fuel some of the vapor may escape combustion, some fuel may be charred (reduced) rather than oxidized, and some of the products may be blended by the turbulent flow around the flame. This pattern is typical of candle and oil lamp flames. Injected liquid fuels, such as in a diesel engine or an oil-fired boiler, tend to generate cenospheres as unique particles that label that source. Solid fuels, such as wood, decompose on heating, thereby producing a gas phase fuel for the most part. This decomposition is not uniform and as a result fragments of charred wood are released. The table below indicates distributions of soot typical of each source.

|                              |   |
|------------------------------|---|
| Internal Combustion Engines: | Finely divided dry soot                   |
| Diesel Engines:              | Finely divided dry soot                   |
| Cigarette Smoke:             | Finely divided dry soot                   |
| Other Plant Smoke:           | Finely divided dry soot                   |
| Field Burning:               | Finely divided dry soot                   |
| Quartz/Halogen Bulbs:        | Finely divided dry soot                   |
| Fireplaces (wood burning):   | Finely divided dry soot                   |
| Fireplaces (natural gas):    | Finely divided dry soot                   |
| Candles and Oil Lamps:       | Agglomerated soot mixed with hydrocarbons |
| House fires:                 | Agglomerated soot mixed with hydrocarbons |
| Cooking:                     | Agglomerated soot mixed with hydrocarbons |
| Natural Gas Furnace:         | Finely divided dry soot                   |
| Oil Furnace:                 | Agglomerated soot mixed with hydrocarbons |

Generally much more useful for the identification of the source of soot are the associated particles or phenomena indicating that a specific source is active. A brief list is given below of associations or observations that are common, depending on specific conditions in the home.

|                              |   |
|------------------------------|---|
| Internal Combustion Engines: | Tire wear, Tailpipe corrosion products, Wear metals   |
| Diesel Engines:              | Cenospheres, Tire wear, Tailpipe corrosion products, Wear metals  |
| Cigarette Smoke:             | Highly birefringent ash particles with charred leaf structures  |
| Other Plant Smoke:           | Charred dicot leaf structures   |
| Field Burning:               | Charred grass (monocot) stem and leaf structures  |
| Quartz/Halogen Bulbs:        | Charred skin, charred paper fiber, etc.   |
| Fireplaces (wood burning):   | Charred wood  |
| Fireplaces (natural gas):    | Thermally modified glass fiber, Thermal insulation, Elevated CO when first ignited, etc.                                    |
| Candles and Oil Lamps:       | Agglomerated soot mixed with hydrocarbons   |
| House fires:                 | Charred wood, Large irregular cenospheres, Agglomerated soot mixed with hydrocarbons, "Tarry" soot spheres, etc.            |
| Cooking:                     | Agglomerated soot mixed with minimally pyrolyzed hydrocarbons, Oil gradient from Kitchen on cooler surfaces (windows, etc.) |
| Natural Gas Furnace:         | Elevated CO when furnace is turned on   |
| Oil Furnace:                 | Cenospheres with oily deposits, "Oily" smell in home  |

The report based on the microscopical analysis of the tapelift should be compared to the site itself for consistency. Sources excluded from the initial analysis may need to be evaluated and additional samples may need to be submitted to clarify any ambiguity. The report may need to be harmonized with other results. What appear to be discrepant or contradictory results on closer examination can often be found to be in agreement, with differences the result of sampling or the analytical procedure used. There is often much more information available in the sample than is included in the report, this is also a cost issue. The analyst responds to the questions ask with regard to the sample. Questions not originally ask will generally not be answered by the report.