

# Combustion By-products: An Overview of Sampling, Analysis & Remediation

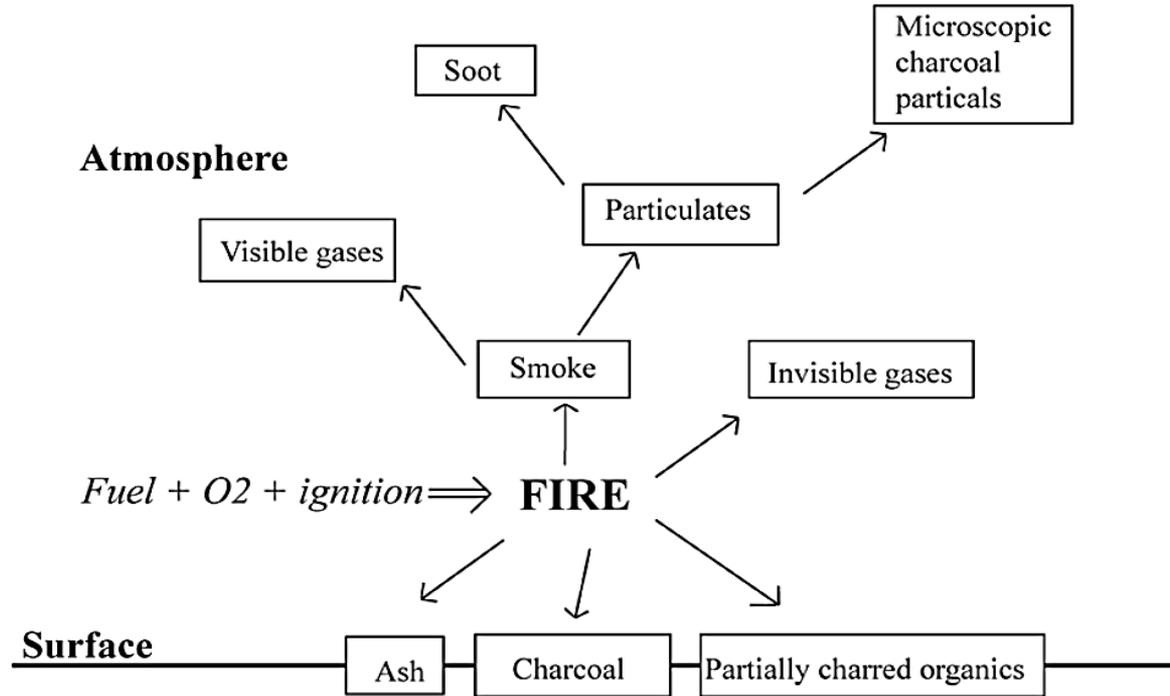
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# How Fires Work?



# What are Combustion-by-Products?

Gases and small particles that are emitted through the incomplete burning of fuels such as oil, gas, kerosene, wood, coal, and propane

- Common Gases
  - Water Vapor
  - CO
  - CO<sub>2</sub>
  - VOCs
  - sVOCs

# Combustion By-products: Soot, Char & Ash

Combustion by-products include a complex mixture of gases and particles released from incomplete burning of fuels. The particulate fraction consists of soot (black carbon), char and ash – each with distinct morphology and composition.

## Char (>1 $\mu\text{m}$ )

Particulate larger than 1  $\mu\text{m}$  from incomplete combustion. May retain cell structure & minerals; carbon predominates.



## Ash (Mineralised)

Advanced combustion of char yields mineral-rich ash with brittle particles and high calcium, potassium, magnesium & silicon.



## Soot (<1 $\mu\text{m}$ )

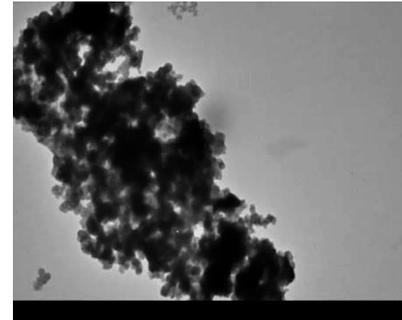
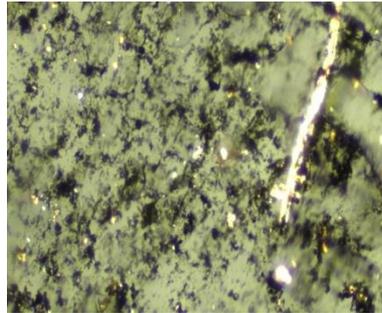
Submicron black powder produced as an unwanted by-product of combustion. Consists of carbonaceous and inorganic solids with adsorbed tars & resins.



# Particulates - Soot

## Soot – ASTM D6602-13

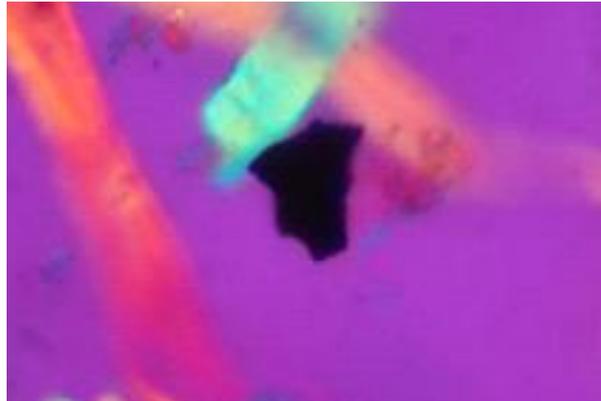
- A submicron black powder generally produced as an unwanted by-product of combustion or pyrolysis.
- Primarily composed of carbon
- Aciniform- Composed of “grape-like” clusters
- A product of incomplete and uncontrolled combustion of hydrocarbons
  - Structure fire
  - Candle burning
  - Automobile exhaust
  - Cooking



# Particulates - Char

## Char – ASTM D6602-13

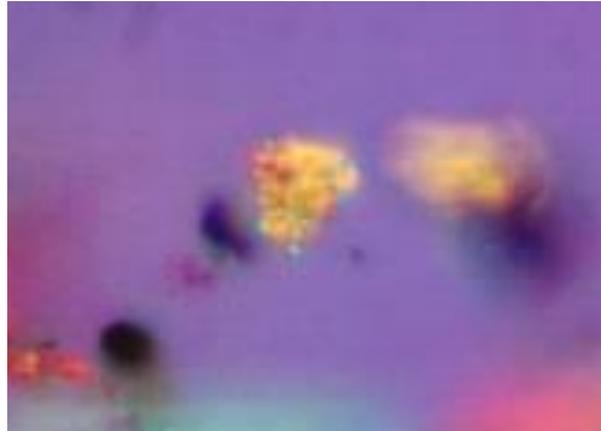
- A particulate larger than 1 um made by incomplete combustion.
- The material has carbon as the main element and its particles can range up to millimeter in size
- A marker for wildfire and structure fire
- May maintain vegetation cell structure



# Particulates - Ash

## Ash – ASTM D6602-13

- A residual material generated by complete consumption of the organic matrix.
- Higher concentration of inorganic components and may not preserve any of the original morphology of the precursor
- A marker for wildfire and structure fire
- Can be corrosive



# Particulates - Ash

The color of wood burning ash varies from black to gray to white with increasing combustion heat.

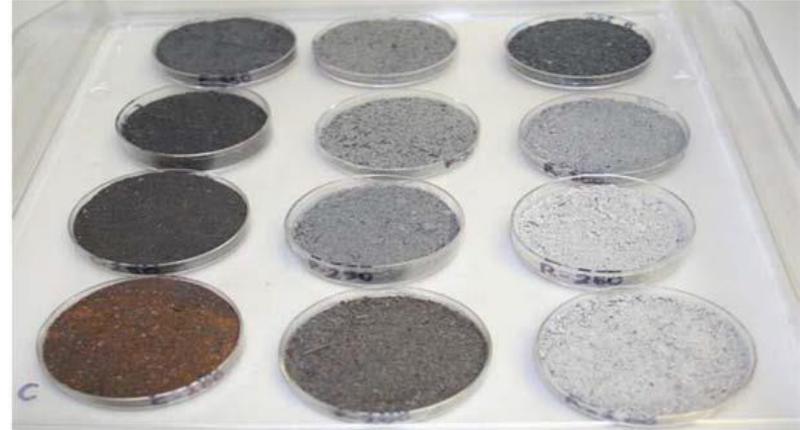
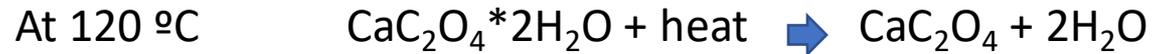


Table 1. Other Physical and Chemical Properties Based on Combustion Temperature

Temp °C	Classification	Common Color	Size	Density ~g/cc	Elemental / Chemical Transition
<350	Char	Brown - reddish	coarse	1.0 – 2.0	Water/ low density char/ iron oxide
350 - 700	Char/Ash	gray/brown	finer	2.0 – 2.5	Transition to calcite / other elements
500 - 700	Ash	gray	fine	2.5 – 2.7	Primarily silica and carbonates
>900	Ash	light gray/white	fine/dense	~2.8	Primarily silica and oxides

# Particulates - Ash

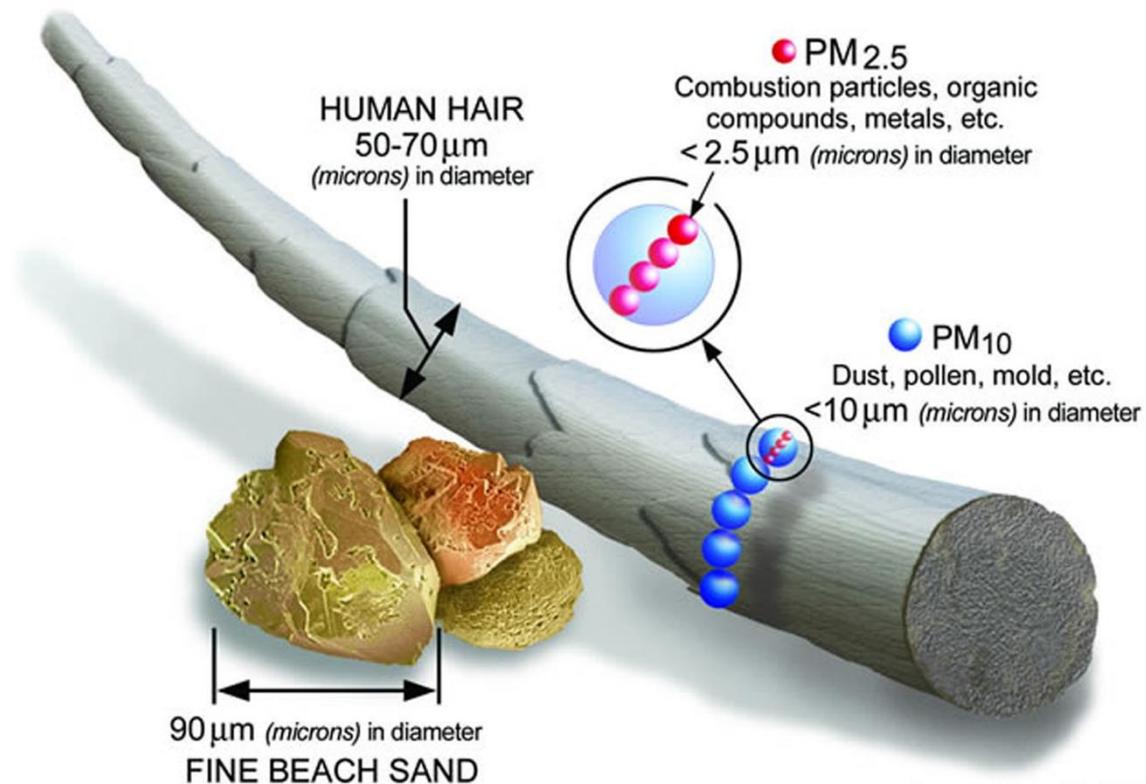
## Chemical Reactions During Wood Burning Process



# Common Contaminants Associated with CBP

- Fine (PM<sub>2.5</sub>) and Ultrafine particles (PM<sub>0.1</sub>)
- Toxic gases (HCl, SO<sub>2</sub>, NO<sub>x</sub>, NH<sub>3</sub>, CH<sub>2</sub>O, H<sub>2</sub>S, HCN, etc.)
- VOCs
- SVOCs (PAHs, dioxins, furans)
- PCBs
- Heavy metals (Pb, Hg, Cu, Zn, As, Sb, Cr, etc.)

# Size of Particulates



# Health Impacts of Smoke



## Respiratory & Cardiovascular

PM<sub>2.5</sub> irritates the eyes & lungs, reduces lung function, triggers bronchitis & asthma attacks, and increases risk of heart failure.



## Sensitive Populations

Children under 5, adults  $\geq 65$ , pregnant people & those with asthma, COPD or heart disease are especially vulnerable to smoke exposure.



## Broader Effects

Smoke may lower birth weight & preterm birth risk, impair the immune system, and cause lingering odors & contamination far from fires.

# Combustion By-products: Where ?

## **Pathways:**

- outdoor-to-indoor infiltration; HVAC entrainment; surface deposition

## **Airflow:**

- As smoke moves throughout a space, CBPs deposit in locations where the airstream meets obstructions or is slowed.
- A buildings ventilation system can cause CBPs to distribute throughout a structure.
- Elevators in a building can act as a pump to spread CBP and odor throughout a building.

## **Temperature/ Pressure:**

- Differences in temperature can create pressure changes that induce air currents.
- Areas of negative pressure will draw in air and cause accumulation of CBP particles.
- As smoke cools the air molecules become less energized causing the air to slow and deposit more CPB.
- Differences in surface temperatures may induce accumulation of CBP particles onto a cooler surface (Thermophoresis)

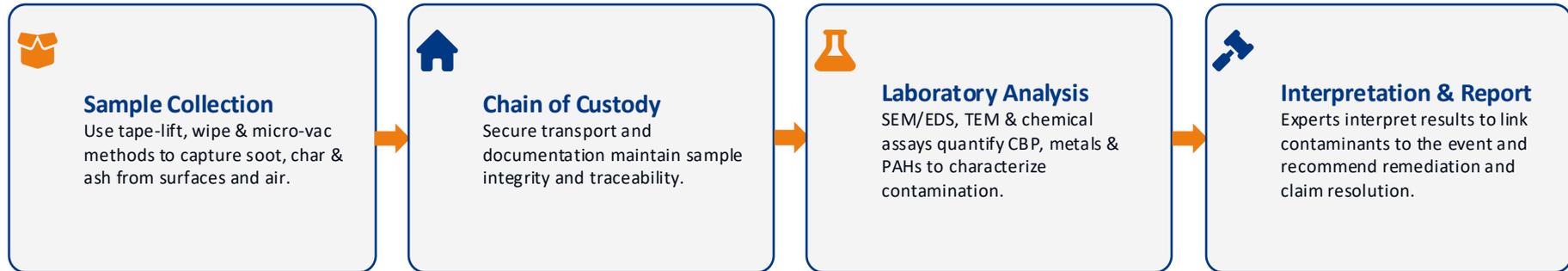
# Sampling & Analysis Workflow

## From Field to Findings

Ensuring defensible claims and safe remediation requires following a rigorous sampling and analysis workflow. Each step—from collecting residues to interpreting laboratory results—must be handled carefully to preserve evidence and link contamination to the loss.

## Sampling Strategies

Sampling strategies matched to materials & questions, e.g., Surface tape-lift/wipe; micro-vac for porous; targeted HVAC & attic. Define decision criteria before sampling (background vs impact).



# Sampling Approaches

Accurate sampling and analysis underpin credible CBP claims and remediation. Typical surface and air sampling methods include tape-lifts, wipes and micro-vacuum. Samples are analysed via optical microscopy, TEM/EDS and chemical assays.

## Tape-Lift

- Defined sample area
- Good efficiency on dusty surfaces
- Maintains particle integrity
- *Low efficiency on rough surfaces*
- *Adhesive may obscure soot*



## Wipe

- Large area & smooth surfaces
- Allows TEM confirmation & PAH analysis
- *Not suitable for porous surfaces*
- *Solvents can dissolve particles*



## Micro-Vac

- Ideal for porous & uneven surfaces
- Supports TEM & chemical analysis
- *Ineffective on smooth surfaces with low loading*
- *May damage delicate structures*



# Sampling Approaches Summary

	Dust Wipe	Microvac	Tape Lift
Collection Efficiency	75% (wet) 40% (dry)	20%	95%
Best Used For	Solid surfaces when pH or TEM analysis is required	Rough surfaces like carpets	Solid surfaces when pH or TEM analysis is not required
Not Recommended For	Rough surfaces like carpets	Surfaces where dust wipe or tape lift can be utilized	Rough surfaces like carpets Samples where pH and TEM analysis are required.

# Laboratory Analytical Method

## Modified ASTM D6602-13:

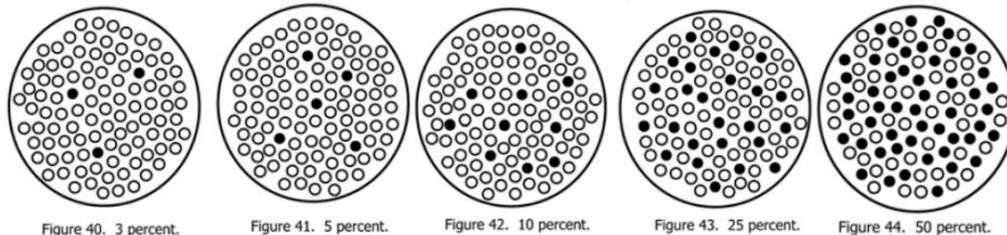
Standard Practice for Sampling and Testing of Possible Carbon Black Fugitive Emissions or Other Environmental Particulate, or Both

## Quantification

Semi quantitative

Calibrated Visual Estimate (EPA 600/R93/116)

Figure 10.5 Visual Estimate Comparison Chart from [McCrone](#)



# How do we analyze for CBP?

## **Polarized Light Microscopy (PLM):**

- Identify combustion-by-products based on color, morphology, optical properties under transmitted light
- soot is *presumptive*

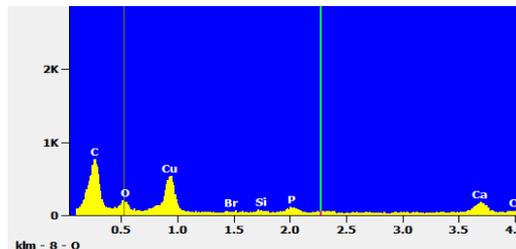
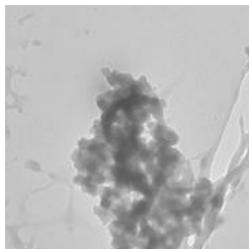
## **Epi-Reflected Light Microscopy (RLM):**

- Identify combustion-by-products based on particle reflectivity (luster), color, etc. using reflected light

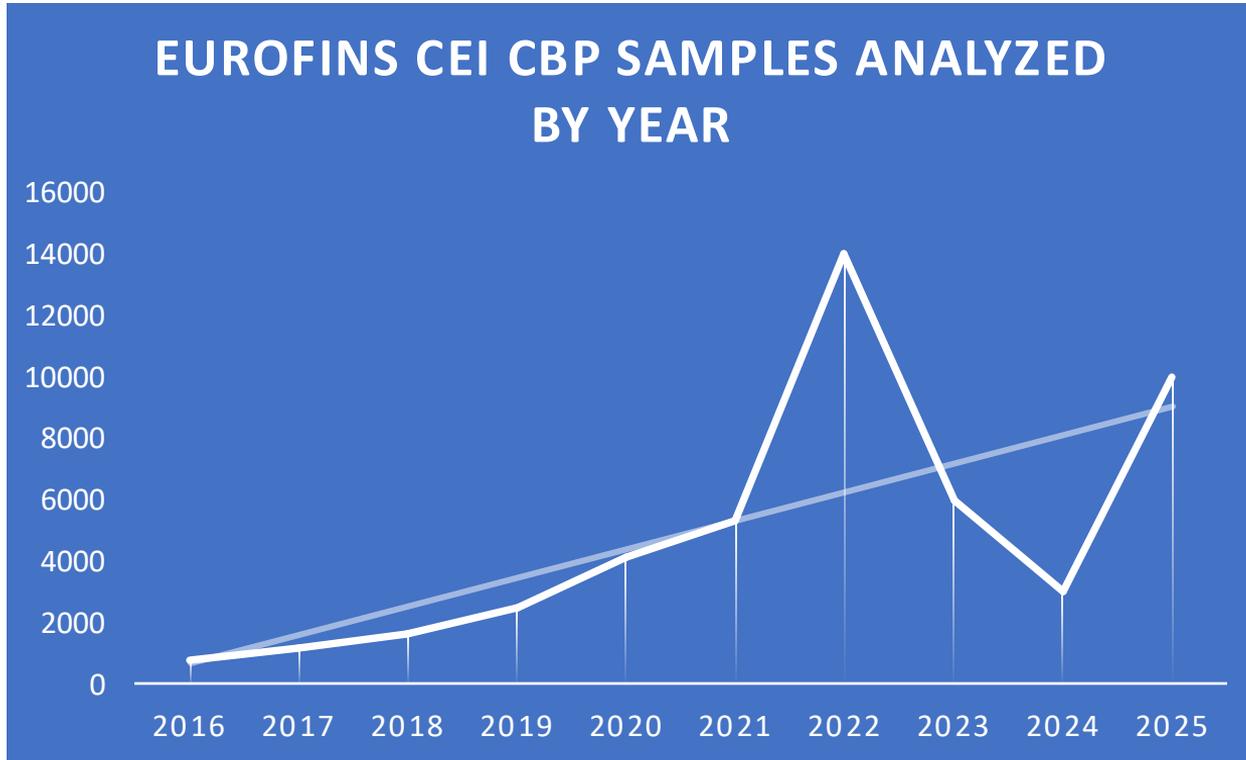


# How do we analyze for CBP?

- **Transmission Electron Microscopy (TEM) w/EDS**
  - Confirm the presence of soot by observing the presence of *aciniform* black particles and by EDS analysis
  - Can differentiate soot from carbon black and other dark particles based on morphology and chemistry



# Eurofins CBP Sample Volume



# Standards & Best Practices: ANSI/IICRC S700 (2025)

## Highlights of the new standard

- New 2025 edition establishes standard of care for fire & smoke damage restoration
- Addresses assessment, residue characterization, cleaning & verification

## Principles & Processes

Assess extent & boundaries of fire/smoke residues

- Prioritize mitigation & remove residues using site-specific methods
- Manage odors & verify success via client inspection rather than arbitrary clearance criteria
- Qualifications: Certified restorers & evidence-based protocols

## Insights

Targeted sampling & test cleaning determine appropriate methods; lab data alone cannot provide clearance due to ubiquitous background.

- Project completion relies on absence of visible residues & odors confirmed with the client.
- Collaboration between RIA & IICRC produced a unified standard after 13 years.

# Factors to Consider for Smoke Damage Remediation

## Distance From the Burn Zone

- Near-field: <1 -10 KM
- Far-field: 10-100KM

## Fuels for the Fire

- Vegetative fuels - organic smoke, less toxic & easier to clean
- Household contents (plastics, synthetic materials, automobiles, etc.) – inorganic smoke containing more hazardous contaminants such as PAHs, heavy metals, etc.

## Weather Conditions

- Wind blow direction and speed.
- Dry weather or raining

# Eurofins Testing: Protecting Properties & People

## Why Test?

- Insurance claims: document damage & support settlement
- Health protection: identify hazardous residues to guide remediation
- Compliance: meet evolving standards & regulatory requirements

## Services

- Fire investigation & combustion by-product analysis
- Surface & air sampling (tape-lift, wipe, micro-vac, air)
- SEM/EDS, TEM & chemical assays for PAHs, metals & VOCs
- Rapid turnaround & nationwide support

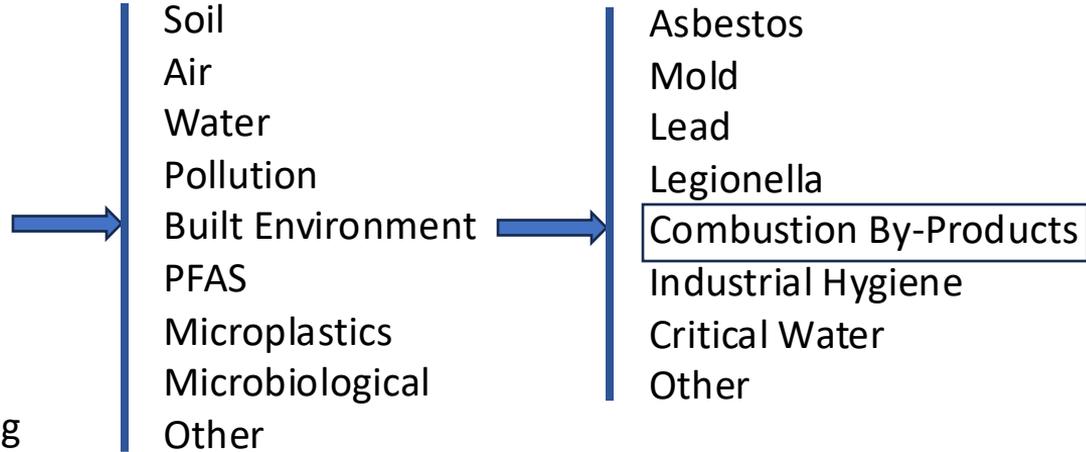
## Proximity Matters

Eurofins operates multiple fire investigation labs nationwide, including high-risk zones in Cary, NC; Tustin, CA; Denver, CO; and Houston, TX. Quick access accelerates sampling, analysis & reporting to return clients to normal sooner.

# Introduction to Eurofins – and to Built Environment testing

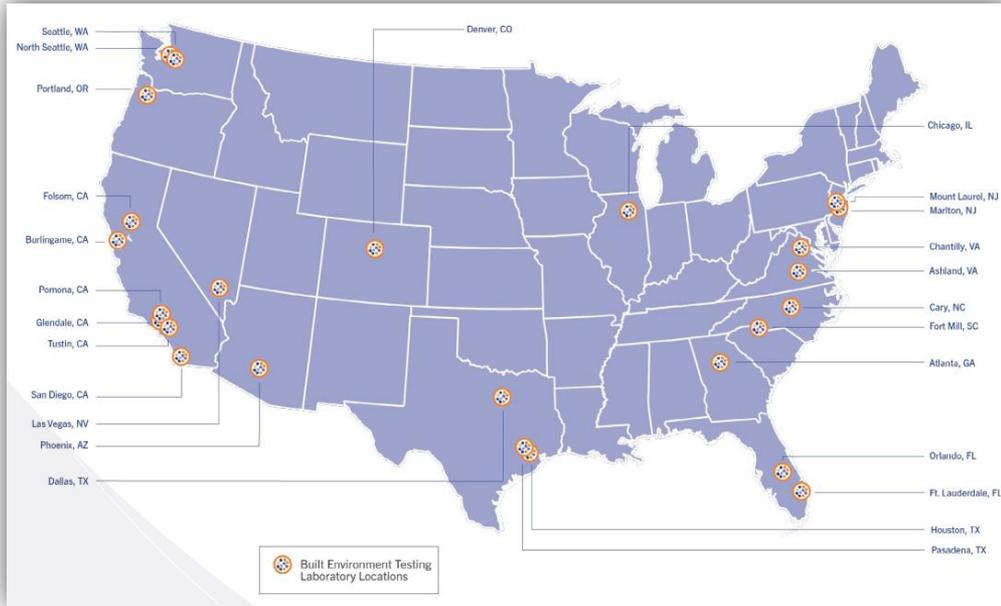
## Worldwide:

- 65,000+ Employees
- 950+ Laboratories
- 60 Countries
- Publicly Traded
- Testing Services
  - Environmental
  - Product Safety
  - Clinical Diagnostics
  - Food / Feed / Agro
  - Material & Engineering
  - Other



Eurofins Provides Scientific Testing for Life

# Eurofins Built Environment Testing Capabilities



Eurofins is the Industry Leader in providing Scientific Environmental Testing services for Indoor Air Quality and Industrial Hygiene

We partner with Industry Consultants who are critical to remediation of fire damage

In 2025 Eurofins tested 10s of thousands of samples for Asbestos and other hazards from buildings impacted by the LA Fires

Eurofins helps Insurers understand risks through Scientific Testing



# Conclusion & Next Steps

## Key Takeaways

- Wildfires and smoke exposures are intensifying, challenging insurers and public health.
- Understanding combustion by-products (char, ash, soot) and proper sampling is essential for defensible claims and health protection.
- The ANSI/IICRC S700 (2025) and recent court rulings support a consistent, evidence-based standard of care.
- Mitigation strategies—high-efficiency filtration, portable & DIY cleaners, occupant protection—reduce health risks.
- Eurofins offers comprehensive testing and expertise to support insurers, restorers & policyholders.

## Questions?