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**Much Ado About Fire**



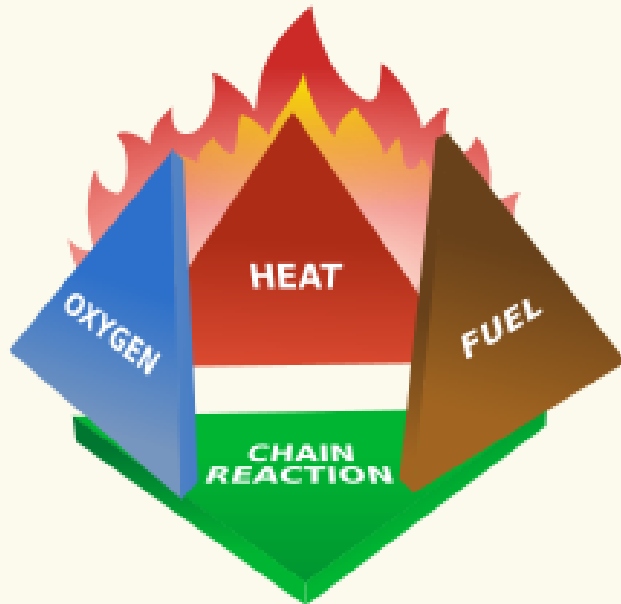




- ✓ *All About Fire*
- ✓ *Fire Residues*
- ✓ *Fire Source Identification*
- ✓ *Post-Remediation*
- ✓ *Wrap-Up*

# All About Fire ...

# What is Fire?



*Rapid oxidation process  
involving  
fuel, heat, and oxygen  
that releases heat, light,  
and various reaction  
products*

## Particulate

Soot  
Char  
Ash

## Gases

Inorganic Gases (CO, CO<sub>2</sub>, etc.)  
Volatile Organics (VOCs)  
Semi-Volatile Organics (SVOCs)

## Complete

- Fuel (Hydrocarbons) + O<sub>2</sub> + Heat  
→ CO<sub>2</sub> + H<sub>2</sub>O
- Rare in most environmental fires

## Incomplete

- Not enough O<sub>2</sub> to completely oxidize hydrocarbons
- Produces a variety of chemical compounds in various stages of oxidation
  - furans, phenols, carbonyls, aldehydes, ketones, esters, acids, etc.
- Common in most environmental fires



# Types

# Fire Residues



# Particulate

## 3 Types

- Soot: fine carbonaceous material produced during incomplete combustion; aciniform structure
- Char: larger, mostly carbonaceous irregular fragments of burned material
- Ash: larger, decarbonized (mostly inorganic) remaining residue of cellulose material; typically mineral salts, carbonates, and oxides or metal/non-combustible compounds and oxides



# Particulate Effects



- Particulate coats the surfaces and gets ground into the materials
- Can also be corrosive and cause extensive damage if left too long
- Primarily surface concern

# Chemical

## Hundreds of chemicals

- Many chemical classes
  - Inorganics, hydrocarbons (alkanes, alkenes, cyclic), aromatics, aldehydes, furans, phenols, esters, acids, PAHs, etc.
- Large volatility range
  - Permanent gases → VOCs → SVOCs → solids

*Must use unique indicators or “fingerprint” as surrogate to represent all chemicals*

## Newer Fire

- Mixture
  - Different types
  - Different volatilities (high to low)
- Strongest odor and health effects

## Older Fire

- Mixture
  - Fewer types (most reactive gone)
  - Mostly low volatility (heavier chemical compounds)
- Less odor but still potential health effects

# Post-Fire Age

# Smoky Odor

Persistent and irritating

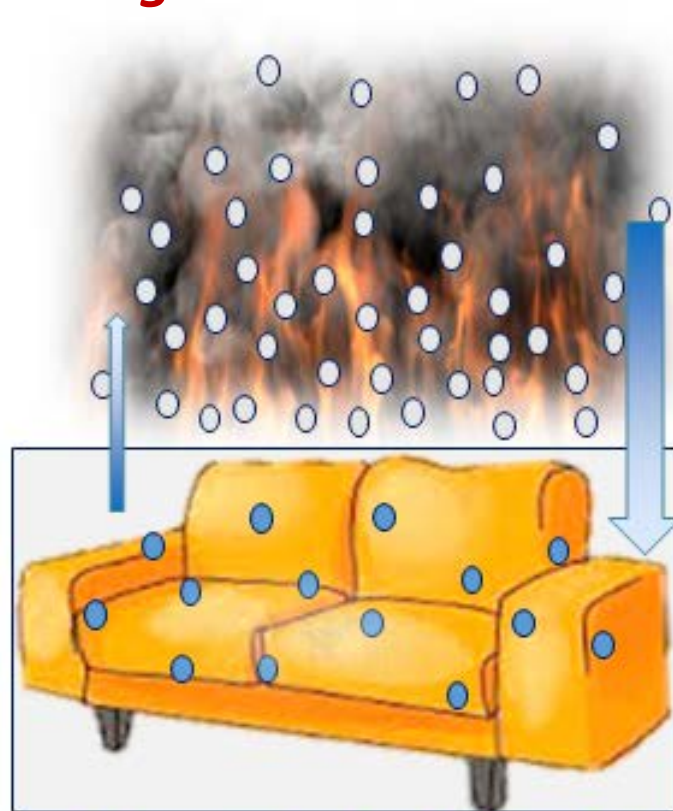
Mix of chemicals

- Guaicols (methoxy phenols)
- Syringols (dimethoxy phenols)
- Cresols (methyl phenols)
- Creosol (methoxy cresol or methoxy methyl phenol)
- Aldehydes
- Pyrans and Furans
- PAHs



# Persistence of Smoky Odor

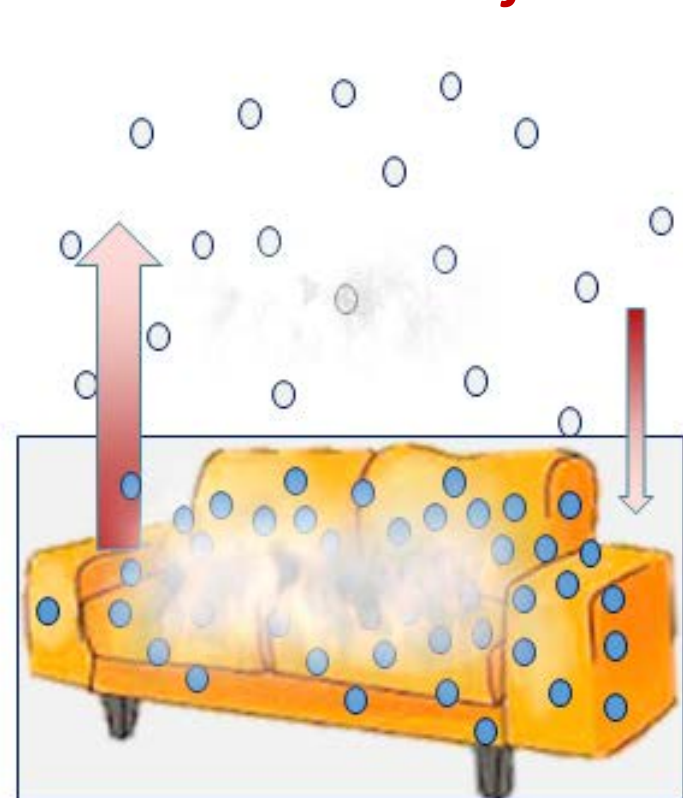
*During Fire*



**Adsorption by Material**

*Takes Hours*

*After Fire*



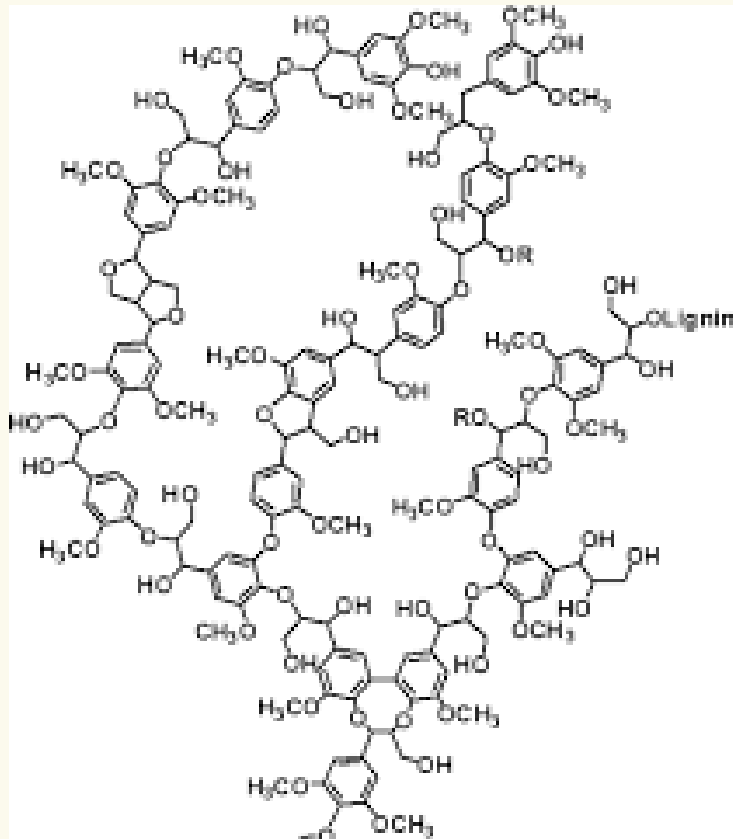
**Emission from Material**

*Takes Months or Years*

# Where's That Coming From?

# Wildfire

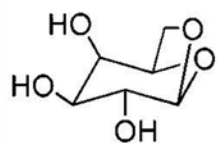
Primarily biomass  
woods, shrubs/plants, grasses



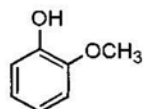
## Lignin

Complex polymer  
Cell walls of plants

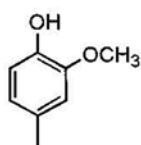
# Wood Combustion



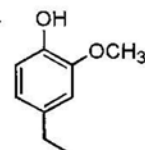
Levoglucosan



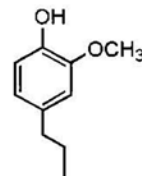
Guaiacol



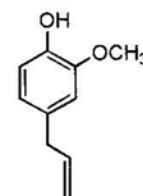
Methylguaiacol



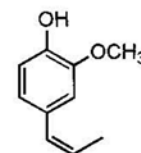
Ethylguaiacol



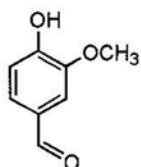
Propylguaiacol



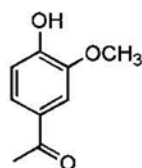
Eugenol



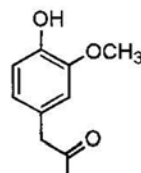
cis-Isoeugenol



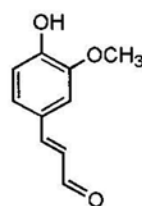
Vanillin



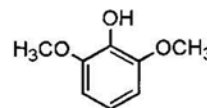
Acetovanillone



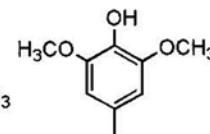
Guaiacyl acetone



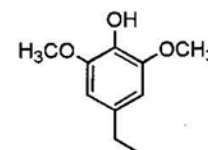
Coniferyl aldehyde



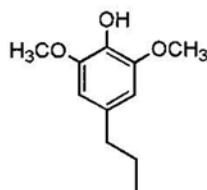
Syringol



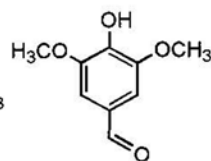
Methylsyringol



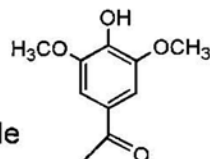
Ethylsyringol



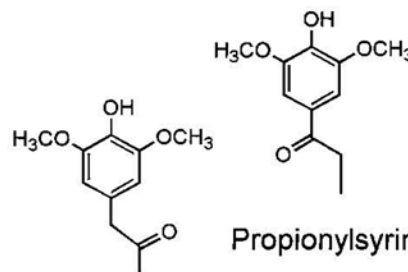
Propylsyringol



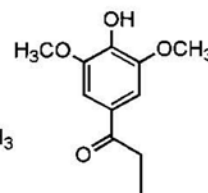
Syringaldehyde



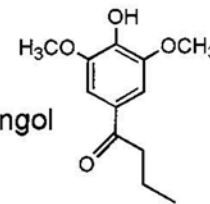
Acetosyringone



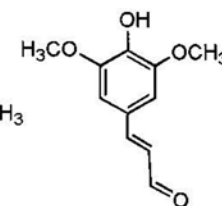
Syringyl acetone



Propionylsyringol



Butyrylsyringol



Sinapyl aldehyde

Schauer et al., Env Sci Tech, 2001

# Indoor or Structural Fire

## → Building materials

Drywall, building insulation, electrical wiring, flooring, roofing, structural supports, coatings and paints, etc.

## → Building contents

Clothing and other textiles, furniture, plastics, rubber, electrical components, appliances, etc.



# Wood & Plant Based Materials

- Cresols
- Creosol
- Guaicols
- Syringols
- Acetol
- Vanillin
- Benzene
- Phenol
- Benzaldehyde
- Naphthalene

# Plastics

- Phthalates
- Bibenzyl
- Styrene
- Biphenyl

# Electrical Insulation

- Phenylethyne
- Methyl Styrenes
- Indane
- Indene
- Methyl Indenes
- Phthalic anhydride
- Chloro naphthalenes
- 2-ethenyl naphthalene
- biphenylene
- Benzene
- Styrene
- Benzaldehyde
- Biphenyl
- Acenaphthylene

# Dioxins & Furans

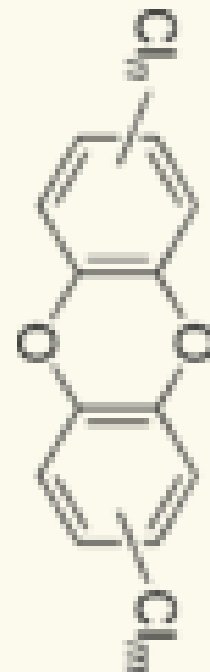
Highly toxic

- Polychlorinated dibenzo-p-dioxins (PCDDs)
- Polychlorinated dibenzofurans (PCDFs)
- Polychlorinated/polybrominated biphenyls (PCBs/PBBs)

Persistent Organic Pollutants (POPs)

Toxic Equivalency (TEQ) – 0.7 pg/kg/day

- 50 lb = 22.7 kg = 15.9 pg/day = 0.02 ng/day
- 150 lb ~ 68 kg = 47.6 pg/day = 0.05 ng/day
- 250 lb ~ 113.4 kg = 79.4 pg/day = 0.8 ng/day



# Post-Remediation





# New Materials

- High initial VOCs → High off gassing
- Packaged
- Interaction with existing contaminants



# Paints & Coatings

- Paint, stain, varnish, sealer, wax, etc.
  - Complex chemical mixtures
  - Large surface area
- Low or No-VOC
  - Does not mean no “chemicals”
- Additives
  - Viscosity
  - Fungicide
  - Fragrance



# Adhesives, Glues, & Cements

- Very high VOCs
- Strong odors
- Toluene
- Xylenes
- Solvents



# Cleaning Solutions & Solvents

- Powerful (potentially harmful) carrier/base
- Active ingredients
- Additives
- Non-porous surfaces
- Porous materials



# Air Purifiers

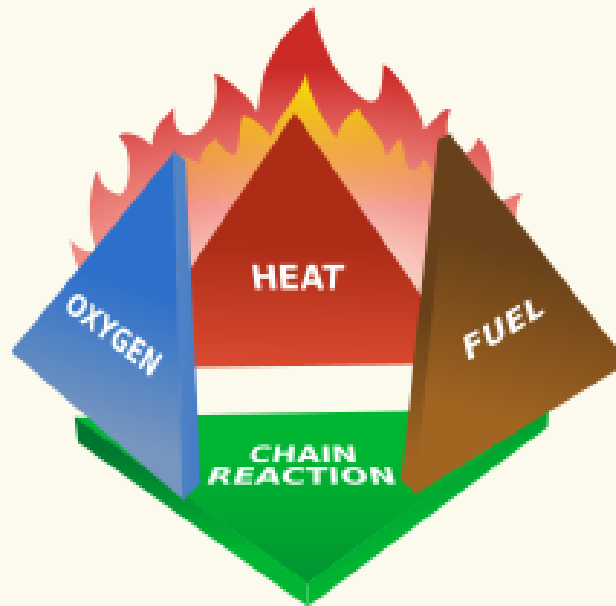
Filter (Carbon-based)

Oxidation

- Chemical reaction – converts to different form
- Not selective – affects all chemicals
- Intermediate chemical forms



# Fire Chemistry



## Particulate

Soot  
Char  
Ash

## Gases

Inorganic Gases (CO, CO<sub>2</sub>, etc.)  
Volatile Organics (VOCs)  
Semi-Volatile Organics (SVOCs)

# Fire Residues

- Particulate
  - Soot
  - Char
  - Ash
- Chemical
  - Complex mixture
  - Range of volatilities

*Must use unique indicators or “fingerprint” as surrogate to represent all chemicals*

# Fire Source Identification

## General

- Benzene
- Cresols
- Naphthalene
- Biphenyl
- Benzaldehyde
- Dibenzofuran
- Phenol

## Specific

- Styrene
- Indane
- Indene
- Methyl Styrenes
- Bibenzyl
- Phthalates

# Post-Remediation

- New materials
- Paints and coatings
- Adhesives and glues
- Cleaning solutions and solvents
- Air purifiers and filters

# Questions

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