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Much Ado About Fire

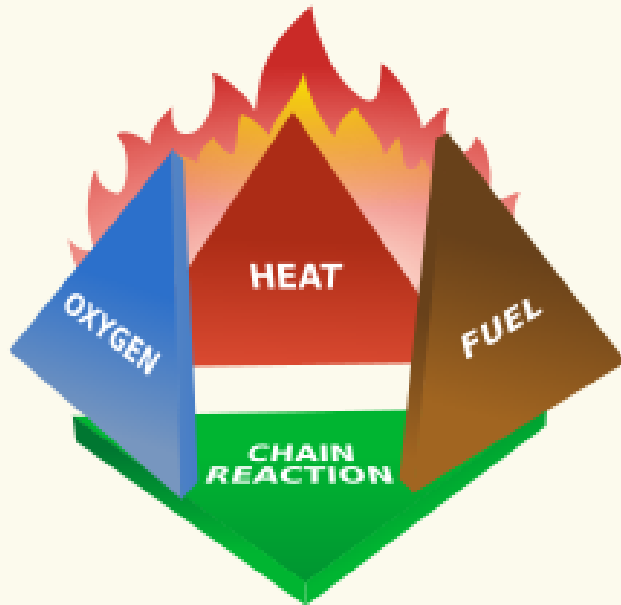




- ✓ *All About Fire*
- ✓ *Fire Residues*
- ✓ *Fire Source Identification*
- ✓ *Post-Remediation*
- ✓ *Wrap-Up*

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, CO₂, etc.)
Volatile Organics (VOCs)
Semi-Volatile Organics (SVOCs)

Complete

- Fuel (Hydrocarbons) + O₂ + Heat
→ CO₂ + H₂O
- Rare in most environmental fires

Incomplete

- Not enough O₂ 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

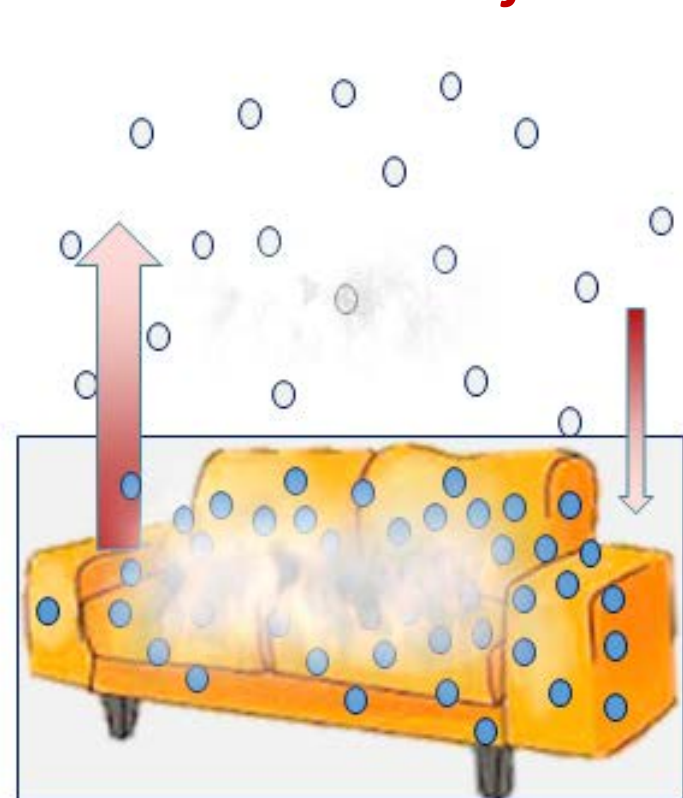
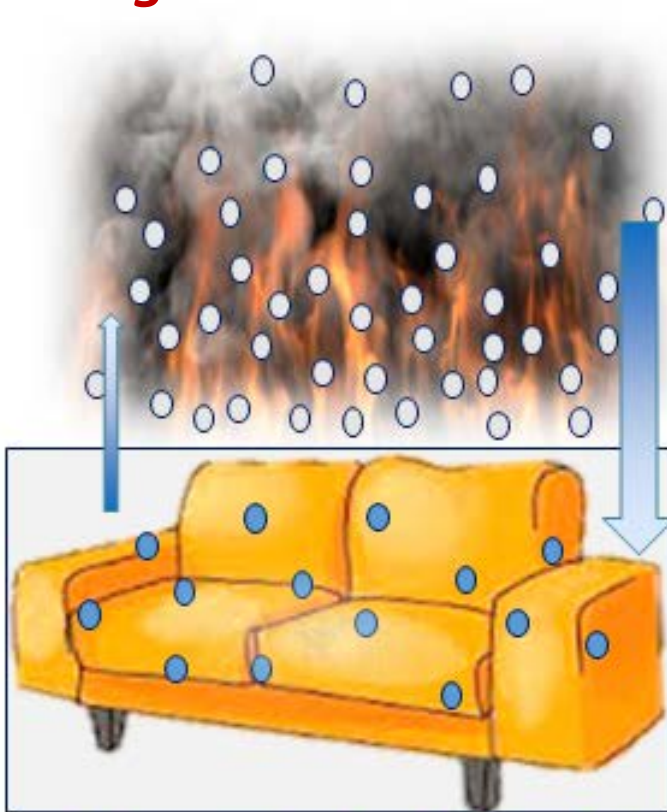
Mix of chemicals

- 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

After Fire



Adsorption by Material

Takes Hours

Emission from Material

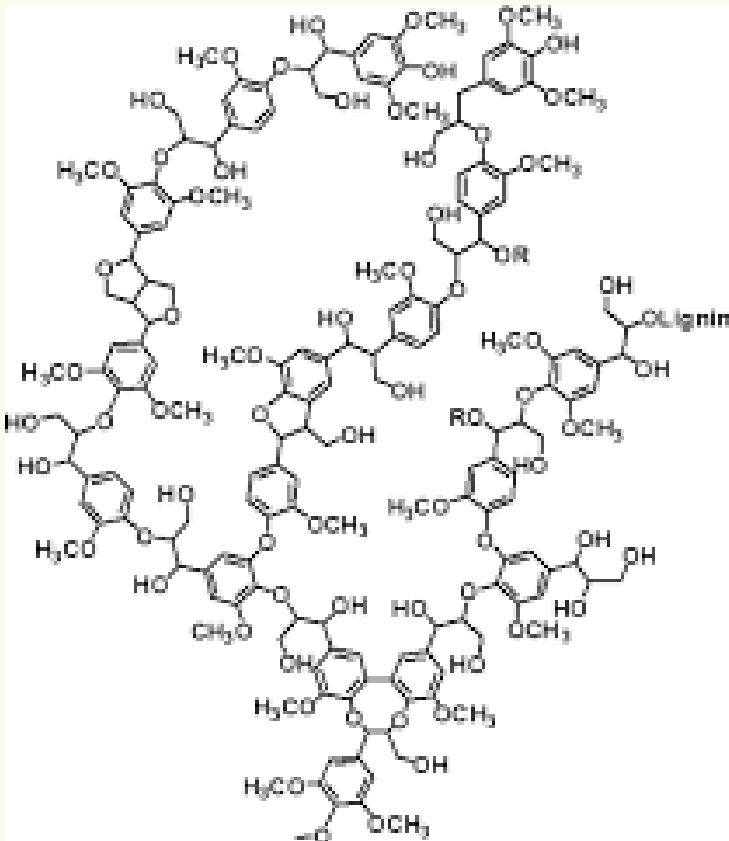
Takes Months or Years

Where's That Coming From?

Wildfire

Primarily biomass

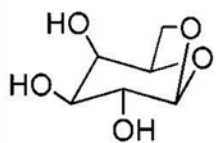
woods, shrubs/plants, grasses



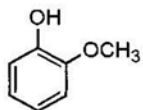
Lignin

Complex polymer
Cell walls of plants

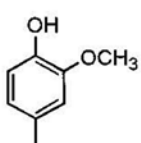
Wood Combustion



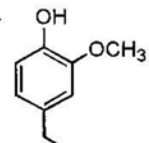
Levoglucosan



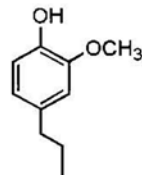
Guaiacol



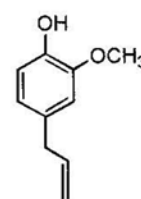
Methylguaiacol



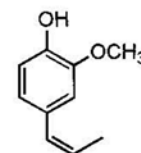
Ethylguaiacol



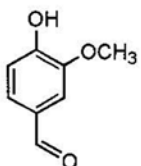
Propylguaiacol



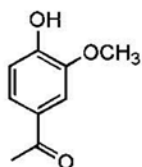
Eugenol



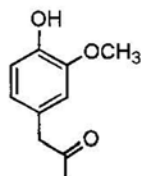
cis-Isoeugenol



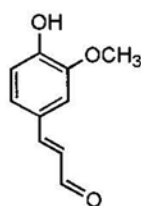
Vanillin



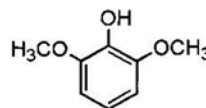
Acetovanillone



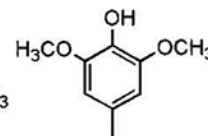
Guaiacyl acetone



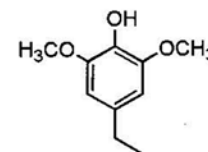
Coniferyl aldehyde



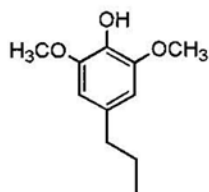
Syringol



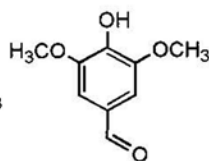
Methylsyringol



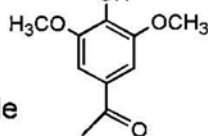
Ethylsyringol



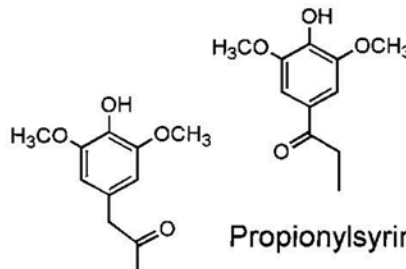
Propylsyringol



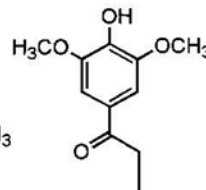
Syringaldehyde



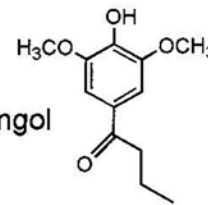
Acetosyringone



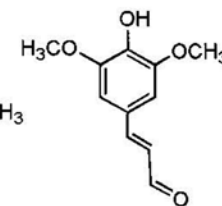
Syringyl acetone



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

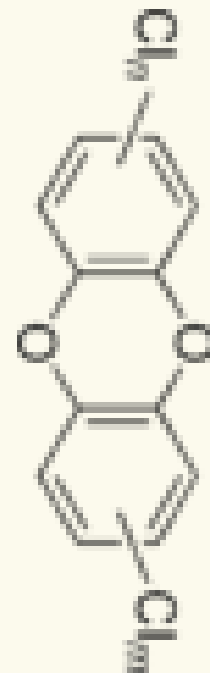
Highly toxic

- 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



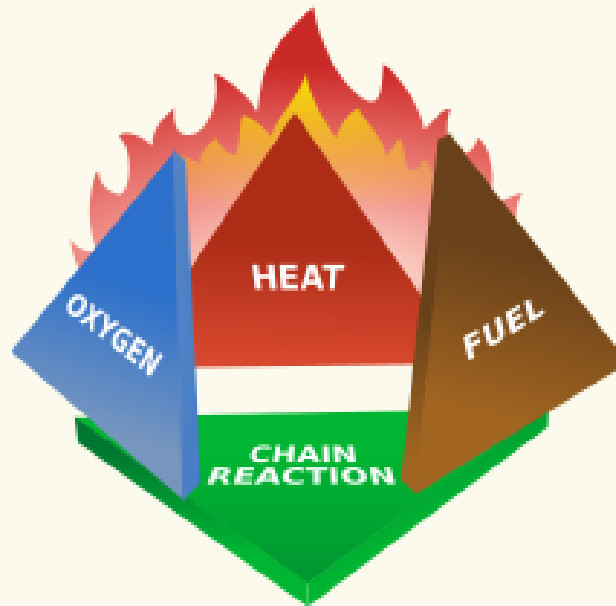
Air Purifiers

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, CO₂, 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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