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Wildfire Smoke Contamination Testing

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Wildfire

Uncontrolled fire in an area of vegetation

brush fire, bushfire, forest fire, desert fire, grass fire,

hill fire, peat fire, vegetation fire

Particulate components of the wildfire debris:

Char
main component

Ash
amount depending on temperature and duration of fire

Soot/Black carbon
Minimal

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Why testing?

Insurance Claims

Assessment of Contamination

Cleaning and Restoration

Current methods

AIHA Technical Guide for Wildfire Impact Investigations for the OEHS Professional (2018)

ASTM D 6602-13: Standard Practice for Sampling and Testing of Possible Carbon Black Fugitive Emissions or Other Environmental Particulate, or Both

(analytical methods)

Scope of Testing (Analytical)

Target:

Analysis of wildfire residues for presence of analytes of interest produced in a combustion event:

- char
- ash
- black carbon/soot

Result:

Information related to the extent of damage produced by the fire

Analytical results can be used for damage assessment, cleaning planning, and insurance claims

Definition of Analytes

Char

Material obtained by carbonization (chemical process of transformation of an organic substance by means of pyrolysis in a residue with carbon as the main elemental component)

char =particles larger than 1µm and may preserve the original cellular morphology of the material that was combusted. These particles can range up to several millimeter in size

(definition form ASTM D6602-13)

Definition of Analytes

Ash

Material obtained by carbonization

The main differences between ash and char:

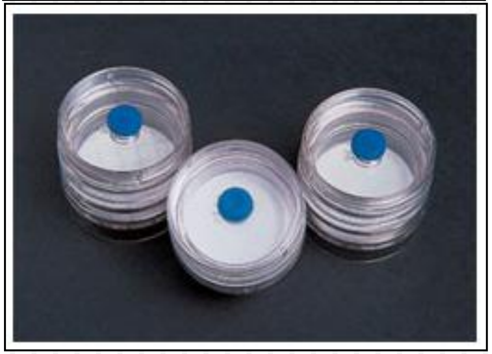
Ash may not preserve any of the original morphology of the precursor

It may have a higher concentration of inorganic components due to the complete consumption of some of the organic matrix.

Sampling Options

Air Sampling

NIOSH 5000: Carbon Black



Filter: (tared 5-µm PVC membrane)
Flow Rate : 1 to 2 L/min
VOL **-MIN:** 30 L @ 3.5 mg/m3
-MAX: 570 L

Alternative: NIOSH 0500/0600

Main difference: TEM analysis to ascertain presence of soot

Sampling Options

Air Sampling

Cassette: 0.45- to 1.2-µm MCE membrane, 25-mm
Flow Rate : 0.5 to 16 L/min
VOL **-MIN:** 400 L @ 0.1 particles/cc
-MAX: 1500-1800 L
(NIOSH 7400 sampling suggested)

Full ID for char and ash

Presumptive ID for soot; applicable for aggregates larger than 300 nm

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Sampling Options

Air Sampling

Air-O-Cell

Flow Rate : 15L/Min

VOL **-MIN:** 15 L

-MAX: 75 L

Full ID for char and ash

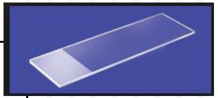
Presumptive ID for soot; applicable for aggregates larger than 300 nm

Sampling Options

Surface Sampling

Micro-vacuum

Tape Lift



Wipes

Sampling Options
Micro-vacuuming

Advantages	Disadvantages
- Efficient sampling method for collecting particles from porous and uneven surfaces with medium and heavy loading; - The samples represent bulk amount of particle material, often of many different sizes; - A variety of optical and electron microscopy methods can be used in the identification analysis; - The TEM confirmatory identification of aciniform soot, as indicated in ASTM D6602-13, can be applied using the drop-mount technique; - Chemical analysis of organic compounds associated with the fire deposits through bulk spectroscopy and/or chromatography (such as PAH's) can be applied; - Corrosivity analysis via pH measurement or anions scan by Ion Chromatography can be applied;	- Poor efficiency for collecting particles from relatively smooth non-porous surfaces with low loading; - It does not preserve the relative positions of the particles on the original surface and the population per unit area*; - Can induce damage to brittle particles such as char and ash**; *this is a limitation when the agglomerate size and the distribution over the collection surface is of interest **if proper sampling and sample preparation procedures are applied, the damage can be greatly minimized

Sampling Options
Tape Lifting

Advantages	Disadvantages
- Efficient sampling method for collecting particles from relatively smooth non-porous surfaces with typical monolayer loading; - It preserves the relative positions of the particles on the original surface and the population per unit area; - A variety of optical microscopy methods can be used in the identification analysis, with minimal preparation; - SEM/EDX methodology can be applied for comprehensive characterization of char and ash and presumptive identification of soot clusters.	- Poor efficiency for collecting on porous, uneven or heavily loaded surfaces, showing preferential sampling from the top layer particles; - Application of overpressure during sampling can obscure or damage the brittle particles of char and ash; - Limited sampling area; - Particles part of large agglomerations many not be correctly identified by applicable methods due to overlapping - The TEM confirmatory identification of aciniform soot cannot be applied; - Chemical analysis of organic compounds associated with the fire debris through spectroscopy and/or chromatography (such as PAH's) cannot be applied; - Corrosivity analysis via pH measurement or anions scan by Ion Chromatography cannot be applied.

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Sampling Options
Wet Wiping

Advantages	Disadvantages
- Efficient sampling method for collecting particles from relatively smooth non-porous surfaces with low or heavy loading; - A variety of optical and electron microscopy methods can be used in the identification analysis; - The TEM confirmatory identification of aciniform soot, as indicated in ASTM D6602-13 can be applied using the drop-mount technique; - Particle dispersion techniques for breaking up the agglomerates may enable more accurate identification of individual grains, necessary when environmental interferences are suspected; - Chemical analysis of organic compounds associated with the fire deposits through bulk spectroscopy and/or chromatography (such as PAH's) can be applied; - Corrosivity analysis via pH measurement or anions scan by Ion Chromatography can be applied;	- Poor efficiency for collecting on porous and uneven surfaces; - It does not preserve the relative positions of the particles on the original surface and the population per unit area*; - Can induce damage to brittle particles such as char and ash; - There can be variance in what particles are successfully transferred from the wipe and therefore isolated for analysis. *this is a limitation when the agglomerate size and the distribution over the collection surface is of interest

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Sampling Options
Surface Sampling/Recommended Surfaces

Microvac:
Main living areas
Interior door frame
Corner of floors
Door tracks
Attic Areas

Wet Wipe:
TV's
Computer displays
Plastic surfaces
Furniture
Windows
Refrigerators

Tape Lift:
Main living areas
Interior door frame
Corner of floors
Door tracks
Attic Areas

AVOID PAINTED SURFACES

Choose sampling method based on surface and scope

Methods of Analysis Instrumentation

Light Microscopy

(Primary Method for Char and Ash; Secondary method for soot)

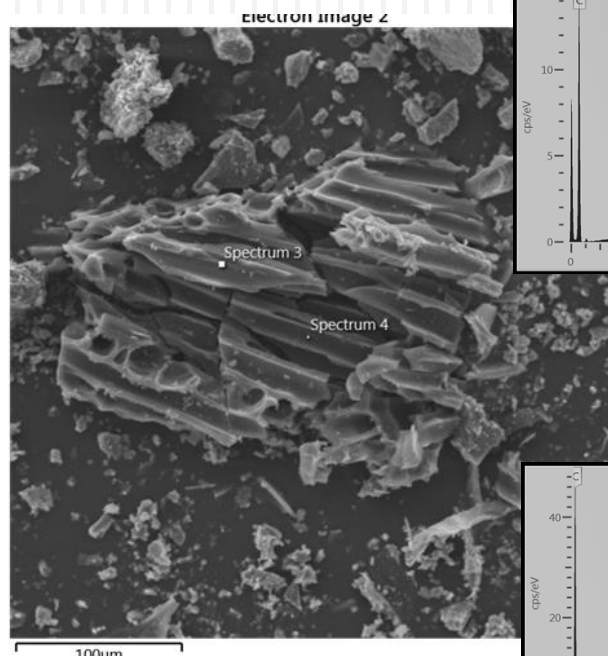
Scanning Electron Microscopy (SEM/EDX)

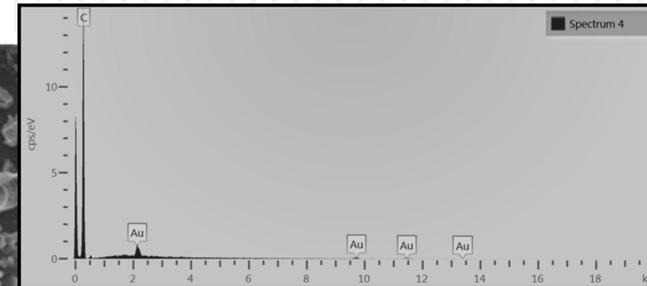
(Secondary Method for Char, Ash, and soot)

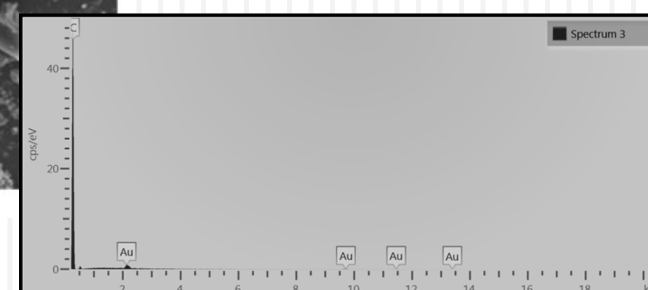
Transmission Electron Microscopy (TEM/EDX)

(Primary Method for soot)

Scanning Electron Microscopy Energy Dispersive X-Rays SEM/EDX







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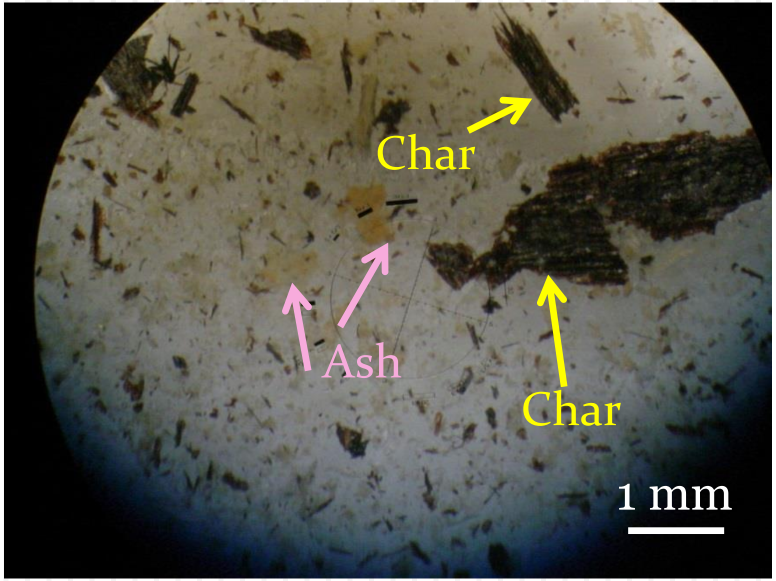
Light Microscopy

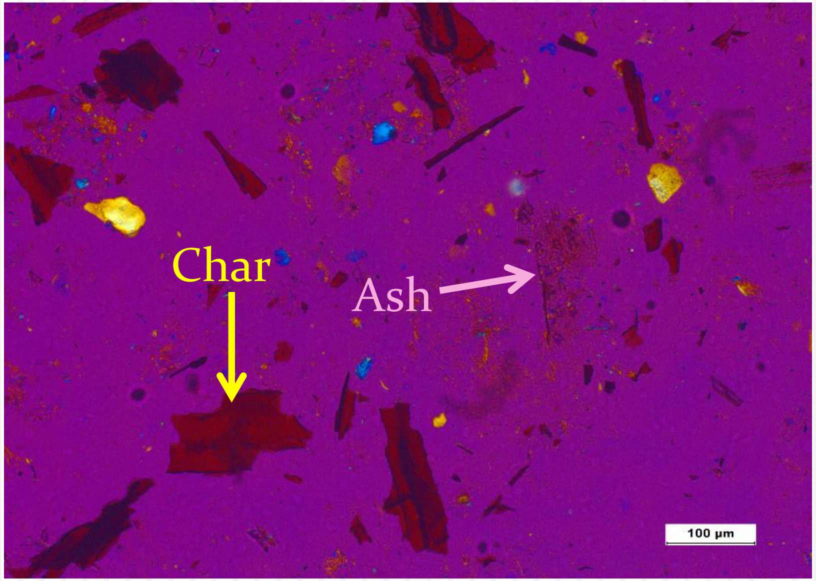


Reflected Light Microscopy (RLM)

Reflected light microscopy is primarily used to examine opaque particles:

metals, coal/coke, wood, slag, rock, plastics, alloys, composites, char

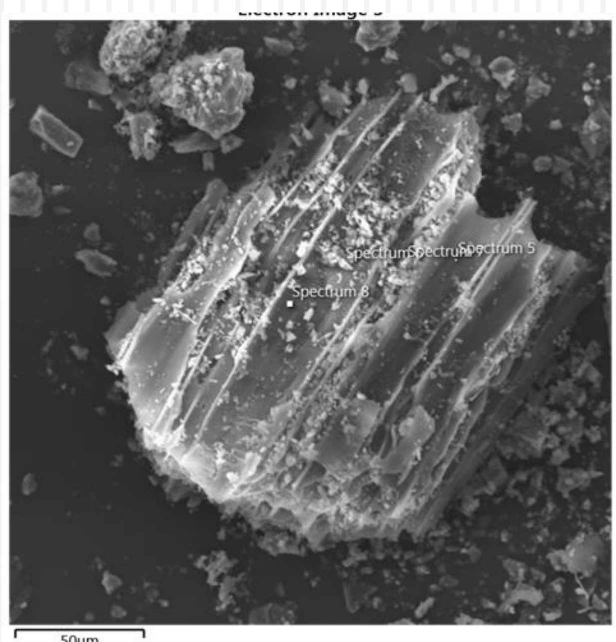
Light Microscopy



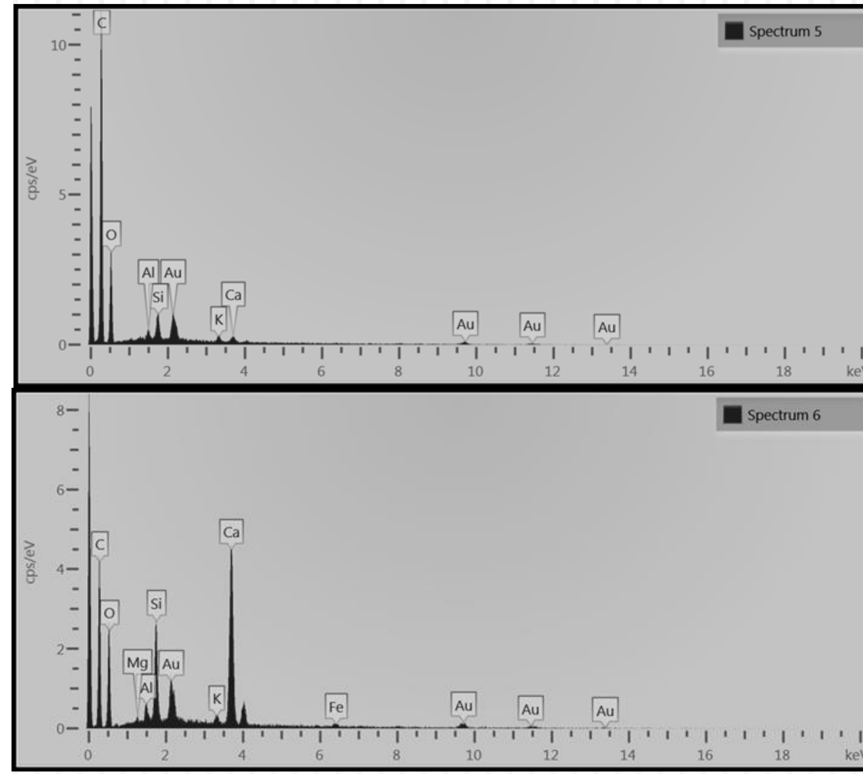
Polarized Light Microscopy (PLM)

Morphology, sign of elongation, birefringence, pleochroism, angle of extinction, and refractive index normally determined

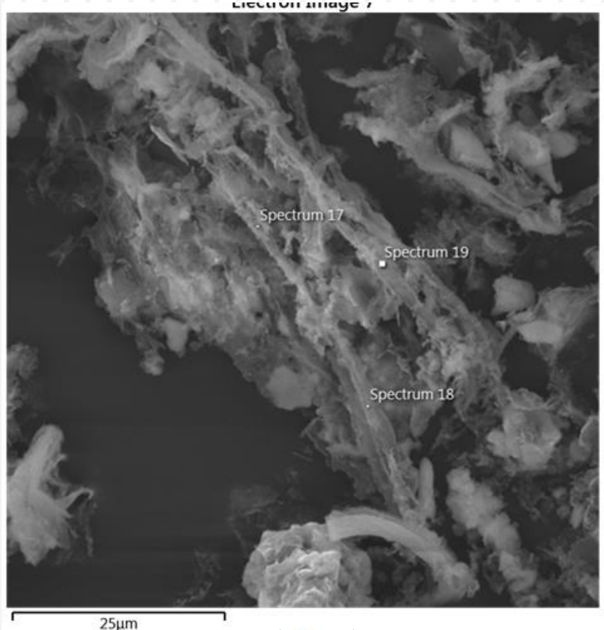
Scanning Electron Microscopy Energy Dispersive X-Rays SEM/EDX



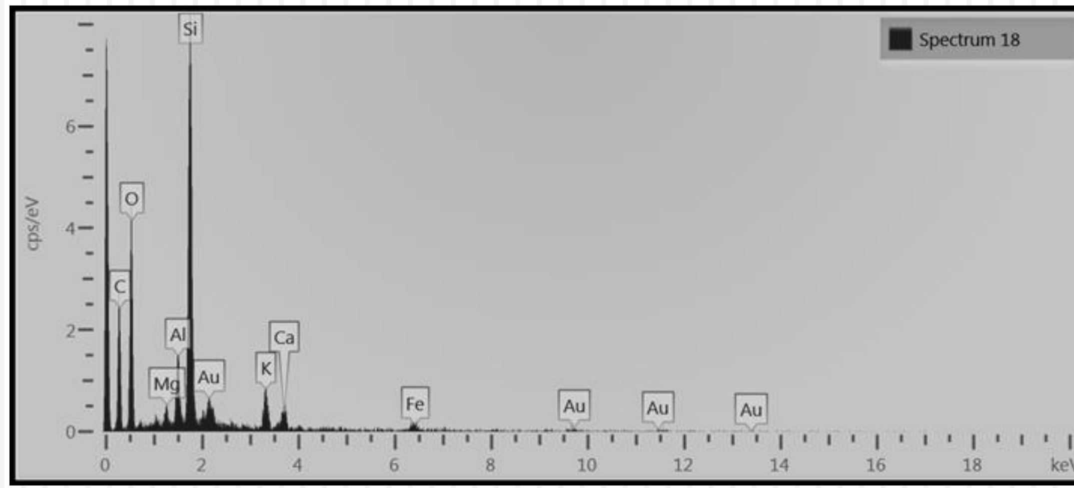
Wood char



Scanning Electron Microscopy Energy Dispersive X-Rays SEM/EDX



Wood ash



Determining Concentrations

Air Sample (NIOSH 5000)

Gravimetric:

Concentration, C (mg/m3) in the air volume sampled, V (L):

$$C = \frac{(W_2 - W_1) - (B_2 - B_1)}{V} \cdot 10^3, \text{ mg/m}^3.$$

where:

W_1 = tare weight of filter before sampling (mg)

W_2 = post-sampling weight of sample-containing filter (mg)

B_1 = tare weight of blank filter (mg)

B_2 = post-sampling weight of blank filter (mg)

INTERFERENCES: The presence of any other particulate material in the air being sampled will be a positive interference since this is a gravimetric method.

Determining Concentrations

Air Sample (Particle Count)

Similar to NIOSH 7400 procedure (using PLM)

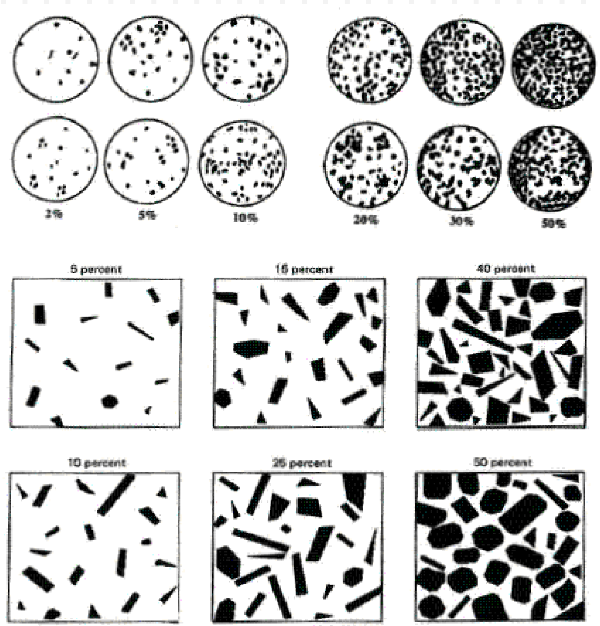
C= [# Particles/Field Area]*[Effective Filter Area/Volume]

Results expressed in #particles/volume of air

It does not take into consideration the particle size

Determining Concentrations

Bulk Sample /Visual Area Estimation
(EPA 600/R-93/116)



Comparison chart for visual area estimation
(after Terry and Chilingar, 1955)

Wildfire

Example of protocol for sampling:

Farmers Group of Companies: "Wildfire claims of damage from soot, char and ash; Protocol for Environmental Sampling of Residential Structures for Particulate Counts and Corrosivity by Certified Hygienist"

2-4 locations (2 samples/location)

Examples of locations

- Kitchen area (e.g. from an interior corner of a kitchen countertop or from rear of the countertop)
- Main living area, like family rooms, dining rooms and bathrooms (e.g. from top of interior door frame or window frame in room with main entrance to structure or room closest to main entrance of structure or from corners of floors)
- Bedrooms (e.g. from rear of a furniture top)
- Points of entry include window ledges, door sills, door tracks, etc.

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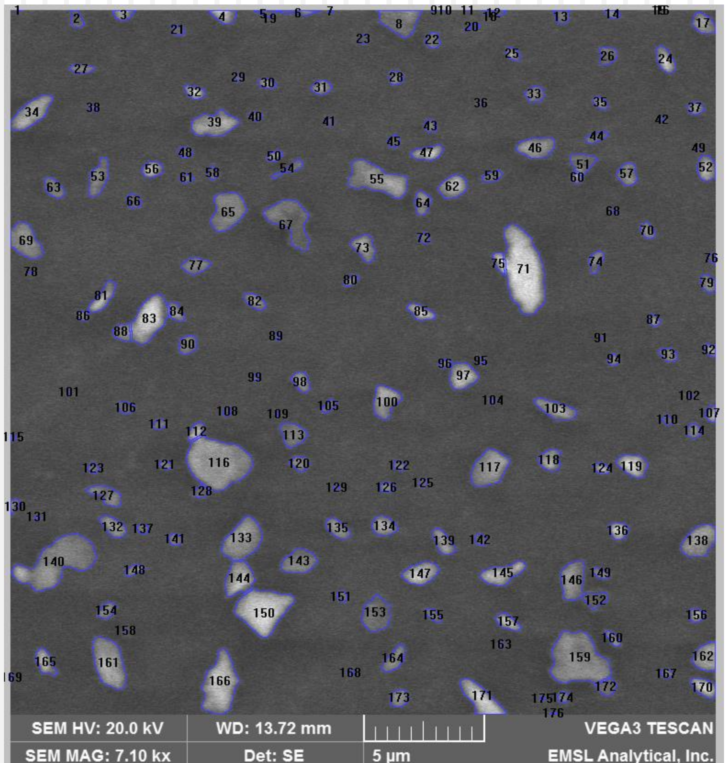
Determining Concentrations

Surface Sampling/ Particle Count



Results expressed as:

# of particles per surface area

% derived from particle count

It does not take into consideration the particle size.

% char= [#char particles/#total particles]*100

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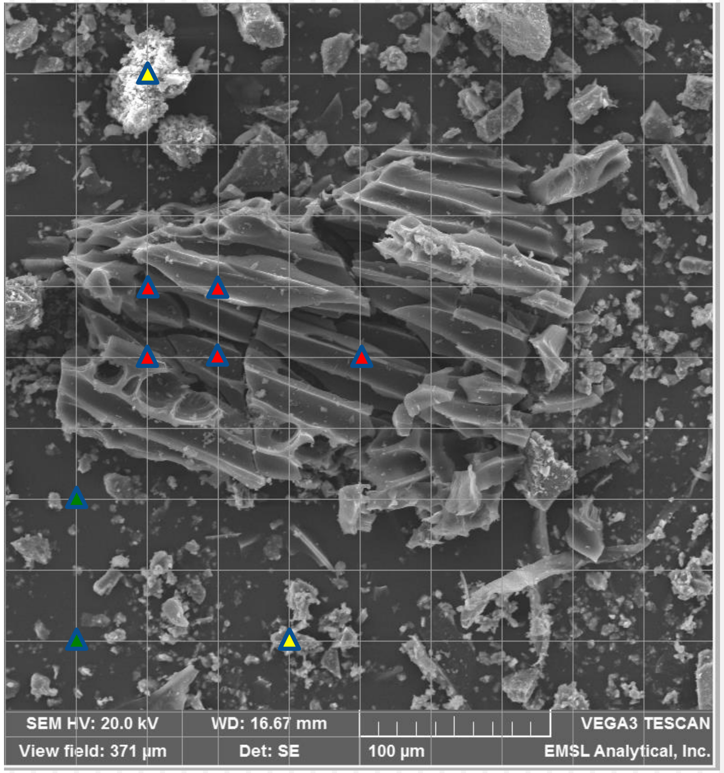
Determining Concentrations

Surface Sampling/ Point Count



EPA 600/R-93/116

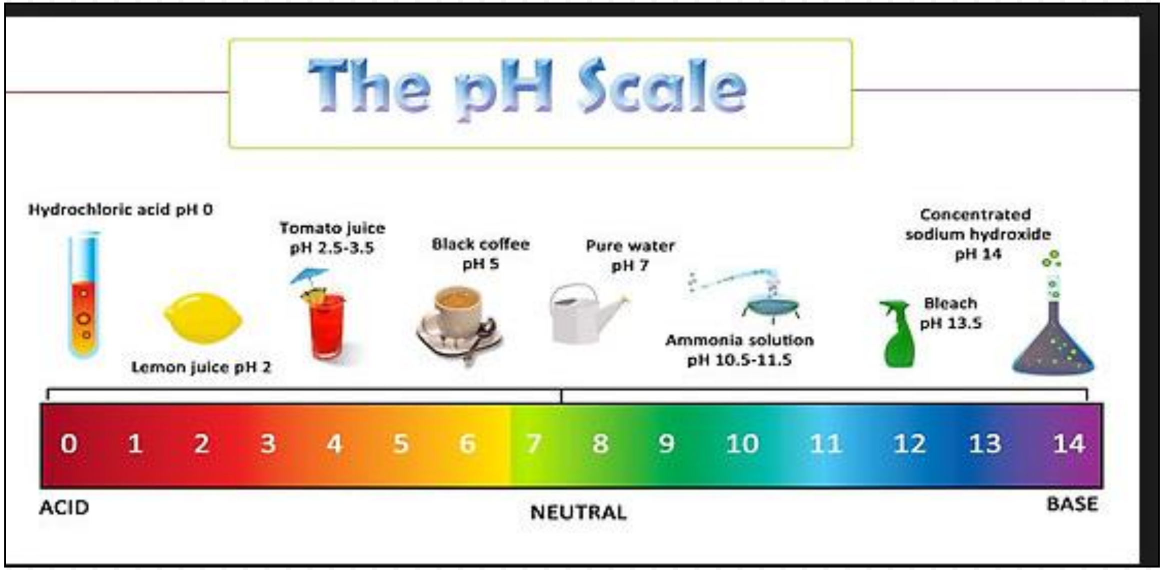
Results expressed as:

% derived from point particle count

It **does** take into consideration the particle size

% char= [#char points/#total particle points]*100

Corrosivity of the wildfire debris



ASTM D4972-13: Standard method for pH of soils

EPA SW-846-Test method 9045D: Soil and waste pH

Alternative: Anions/Ion Chromatography

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Emissions

1993 EPA Report

A Summary of the Emissions Characterization and Noncancer Respiratory Effects of Wood Smoke, EPA-453/R-93-036

(see next page for results)

Emissions

Table 2. Chemical Composition of Wood Smoke

Species[1]	g/kg wood[2]	Physical State[3]	Reference
Carbon Monoxide	80-370	V	4,5
Methane	14-25	V	5
VOCs (C_2-C_7)	7-27	V	5
Aldehydes	0.6-5.4	V	4,6
Formaldehyde	0.1-0.7	V	4,6
Acrolein	0.02-0.1	V	6
Propionaldehyde	0.1-0.3	V	4,6
Butryaldehyde	0.01-1.7	V	4,6
Acetaldehyde	0.03-0.6	V	4,6
Furfural	0.2-1.6	V	7,8
Substituted Furans	0.15-1.7	V	7,8
Benzene	0.6-4.0	V	5
Alkyl Benzenes	1-6	V	9
Toluene	0.15-1.0	V	9
Acetic Acid	1.8-2.4	V	7
Formic Acid	0.06-0.08	V	7
Nitrogen Oxides (NO,NO_2)	0.2-0.9	V	4,5
Sulfur Dioxide	0.16-0.24	V	4
Methyl chloride	0.01-0.04		10
Napthalene	0.24-1.6	V	9
Substituted Napthalenes	0.3-2.1	V/P	9
Oxygenated Monoaromatics	1 - 7	V/P	9
Guaiacol (and derivatives)	0.4-1.6	V/P	11
Phenol (and derivatives)	0.2-0.8	V/P	11
Syringol (and derivatives)	0.7-2.7	V/P	11
Catechol (and derivatives)	0.2-0.8	V/P	11
Total Particle Mass	7-30	P	5
Particulate Organic Carbon	2-20	P	12
Oxygenated PAHs	0.15-1	V/P	9
PAHs			
Fluorene	$4x10^{-5}$ - $1.7x10^{-2}$	V/P	13
Phenanthrene	$2x10^{-5}$ - $3.4x10^{-2}$	V/P	13
Anthracene	$5x10^{-5}$ - $2.1x10^{-2}$	V/P	13
Methylanthracenes	$7x10^{-5}$ - $8x10^{-3}$	V/P	13
Fluoranthene	$7x10^{-4}$ - $4.2x10^{-2}$	V/P	13
Pyrene	$8x10^{-4}$ - $3.1x10^{-2}$	V/P	13
Benzo(a)anthracene	$4x10^{-4}$ - $2x10^{-3}$	V/P	13
Chrysene	$5x10^{-4}$ - $1x10^{-2}$	V/P	13
Benzofluoranthenes	$6x10^{-4}$ - $5x10^{-3}$	V/P	13
Benzo(e)pyrene	$2x10^{-4}$ - $4x10^{-3}$	V/P	13
Benzo(a)pyrene	$3x10^{-4}$ - $5x10^{-3}$	V/P	13
Perylene	$5x10^{-5}$ - $3x10^{-3}$	V/P	13
Ideno(1,2,3-cd)pyrene	$2x10^{-4}$ - $1.3x10^{-2}$	V/P	13
Benz(ghi)perylene	$3x10^{-5}$ - $1.1x10^{-2}$	V/P	13
Coronene	$8x10^{-4}$ - $3x10^{-3}$	V/P	13
Dibenzo(a,h)pyrene	$3x10^{-4}$ - $1x10^{-3}$	V/P	13
Retene	$7x10^{-3}$ - $3x10^{-2}$	V/P	14
Dibenz(a,h)anthracene	$2x10^{-5}$ - $2x10^{-3}$	V/P	13
Trace Elements			
Na	$3x10^{-3}$ - $1.8x10^{-2}$	P	15
Mg	$2x10^{-4}$ - $3x10^{-3}$	P	15
Al	$1x10^{-4}$ - $2.4x10^{-2}$	P	15
Si	$3x10^{-4}$ - $3.1x10^{-2}$	P	15
S	$1x10^{-3}$ - $2.9x10^{-2}$	P	15
Cl	$7x10^{-4}$ - $2.1x10^{-1}$	P	15
K	$3x10^{-3}$ - $8.6x10^{-2}$	P	15
Ca	$9x10^{-4}$ - $1.8x10^{-2}$	P	15
Ti	$4x10^{-5}$ - $3x10^{-3}$	P	15
V	$2x10^{-5}$ - $4x10^{-3}$	P	15
Cr	$2x10^{-5}$ - $3x10^{-3}$	P	15
Mn	$7x10^{-5}$ - $4x10^{-3}$	P	15
Fe	$3x10^{-4}$ - $5x10^{-3}$	P	15
Ni	$1x10^{-6}$ - $1x10^{-3}$	P	15
Cu	$2x10^{-4}$ - $9x10^{-4}$	P	15
Zn	$7x10^{-4}$ - $8x10^{-3}$	P	15
Br	$7x10^{-5}$ - $9x10^{-4}$	P	15
Pb	$1x10^{-4}$ - $3x10^{-3}$	P	15
Particulate Elemental Carbon	0.3 - 5	P	16
Normal alkanes (C_{24}-C_{30})	$1x10^{-3}$ - $6x10^{-3}$	P	17
Cyclic di-and triterpenoids			
Dehydroabietic acid	0.01 - 0.05	P	18
Isopimaric acid	0.02 - 0.10	P	18
Lupenone	$2x10^{-3}$ - $8x10^{-3}$	P	18
Friedelin	$4x10^{-6}$ - $2x10^{-5}$	P	18
Chlorinated dioxins	$1x10^{-5}$ - $4x10^{-5}$	P	19
Particulate Acidity	$7x10^{-3}$ - $7x10^{-2}$	P	20

[1] Some species are grouped into general classes as indicated by italics
[2] To estimate the weight percentage in the exhaust, divide the g/kg value by 80. This assumes that there are 7.3 kg combustion air per kg of wood. Major species not listed here include carbon dioxide and water vapor (about 12 and 7 weight percent respectively under the assumed conditions).
[3] At ambient conditions; V = vapor, P = particulate, and V/P = vapor and/or particulate (i.e., semi-volatile).
[4] DeAngelis (1980)
[5] OMNI (1988)
[6] Lipari (1984), values for fireplaces
[7] Edye et al (1991). smoldering conditions; other substituted furans include 2-furanmethanol, 2 acetylfuran, 5-methyl-2furaldehyde, and benzofuran
[8] Value estimated for pine from Edye et al (1991) from reported yield relative to guaiacol, from guaiacol values of Hawthorne (1989) and assuming particulate organic carbon is 50% of total particle mass
[9] Steiber et al (1992), values computed assuming a range of 3-20 g of total extractable, speciated mass per kg wood
10 Khalil (1983)
[11] Hawthorne (1989), values for syringol for hardwood fuel; see also Hawthorne (1988)
[12] Core (1989), DeAngelis (1980), Kalman and Larson (1987)
[13] From one or more of the following studies: Cooke (1981), Truesdale (1984), Alfheim et al (1984), Zeedijk (1986), Core (1989), Kalman and Larson (1987); assuming a range of 7 to 30 grams of particulate mass per kg wood when values were reported in grams per gram of particulate mass. Similar assumptions apply to references 14,15 and references 17-19
[14] Core (1989), Kalman and Larson (1987)
[15] Watson (1979), Core (1989), Kalman and Larson (1987)
[16] Rau (1989), Core (1989)
[17] Core (1989)
[18] Standley and Simoneit (1990); Dehydroabietic acid values for pine smoke, lupenone and isopimaric acid values for alder smoke, and friedelin values for oak soot.
[19] Nestrick and Lamparski (1982), from particulate condensed on flue pipes; includes TCDDs, HCDDs, H_7CDDs and OCDDS
[20] Burnet et al (1986); one gram of acid = one equivalent of acid needed to reach a pH of 5.6 in extract solution

Metals Analysis/Trace Elements

Na	Si	K	V	Fe	Zn
Mg	S	Ca	Cr	Ni	Br
Al	Cl	Ti	Mn	Cu	Pb

Add As, Hg, Cd for heavy metals panel

Semi-Volatiles Compounds (GC-MS)

VOC's (C_2-C_7)	PAH's
Aldehydes	Alkanes (C_{24}-C_{30})
Dioxin and Furans	Terpenoids

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Data Interpretation

No recognized numerical values or generally accepted consensus regarding the concentrations associated with contamination or damage

Damage= alteration resulting in impairment or loss of function, appearance, utility or value

Presence/Absence- radical approach

Particle count:

OSHA 1910.1000 Table Z-3: Inert/Nuisance Dust: 15 mmpcf = 5 mg/m3

Conversion factors - mppcf × 35.3 = million particles per cubic meter = particles per c.c.

VAE method: LOQ = 1%

Health Effects

Components of wildfire smoke:

-Heavy metals

-PAH's

-Dioxin

-Furans

Many of these components are regulated as carcinogens

-Upper respiratory system irritations

-Inflammatory responses

-Asthma triggers

-Changes in lung functions

-Immune system suppression

Cleaning/Remediation

Goal: return the property to a pre-fire condition

Cleaning of surfaces:

- Dry sponge
- Damp wiping
- Vacuuming with HEPA

Ventilation the building by opening windows, installing fans

Verify cleaning with spot sampling

Thank You!

Contact:

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