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WEBINAR

Sampling and Characterizing Wildfire Smoke Residues

Presenters: **Joe Spurgeon, Ph.D.**
Franco Seif, PE



Joe C. Spurgeon, Ph.D. has a multidisciplinary doctorate degree in analytical chemistry and environmental health. He was a Certified Industrial Hygienist until 2012, has been working on residential and commercial IAQ investigations since 1993, and currently works as an expert witness in microbial IAQ and wildfire smoke contaminants. He has served as adjunct faculty and/or instructor in air pollution, introductive to fire science, asbestos abatement, and various courses in performing IAQ investigations.



Franco Seif is co-founder, president, and chief executive officer of Clark Seif Clark, Inc. (CSC). He has been working in the environmental and engineering industry for over three decades. He started his consulting career at Camp Dresser & McKee, Boston, in 1985. In 1987 he worked as an engineer at EPI, Center, a small industrial hygiene company in Santa Monica, California.

Webinar Presentation November 17, 2021

- **First CSC study**
 - Compare the relative performance of wet wipe and tape lift samples for evaluating the impact of surface char from wildfire smoke
 - **Franco Seif, PE**
- **Second CSC Study**
 - Characterize several factors that can affect the evaluation of wildfire smoke residues
 - **Joe Spurgeon, Ph.D.**

First Study*

- **Objective**
 - **Compare the relative performance of the wet wipe and tape lift sampling methods for evaluating impact**
- **Tape lift and wet wipe samples are two commonly used methods for sampling wildfire smoke residues**
- **Assumption: The choice of sampling method may affect the evaluation of the impact of wildfire smoke residues**

*Spurgeon J, Seif F, Mirika E; A comparison of the Wet Wipe and Tape Lift methods for Sampling Surface Char in Residential Properties Impacted by Wildfire Smoke; The Journal of Cleaning Science, Fall (16-24), 2021.

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Description

- **Compare the wet wipe and tape lift sampling methods for the collection of surface char by collecting side-by-side samples**
- **Compare the results for perimeter penetrations and interior surfaces by sampling**
 - **Perimeter locations (Interior Window Sills)**
 - **Interior locations (Interior Hard Surfaces)**

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Houses Sampled

- **48 houses were sampled in so. CA**
 - **Potentially impacted by one of five wildfires**
 - **Elapsed times between wildfire and inspection**
 - **90 – 120 days**
 - **Distances from wildfire to houses varied from**
 - **less than 1 mile to 15 miles**

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Sample Collection

- **Replicate (side-by-side) tape lift and wet wipe samples were collected in each house**
 - **Tape lifts – 2x4 in² BVDA tape**
 - **Wet wipe – 1x1 in² BD alcohol pads**
- **Individual samples were collected from 3-5 spots**
 - **Composited by the laboratory into 192 samples**
- **Interior window sills**
 - **48 tape lift and 48 wet wipe composite samples**
- **Interior hard surfaces**
 - **48 tape lift and 48 wet wipe composite samples**
 - **Tables, baseboards, floors, dressers, bed frames**

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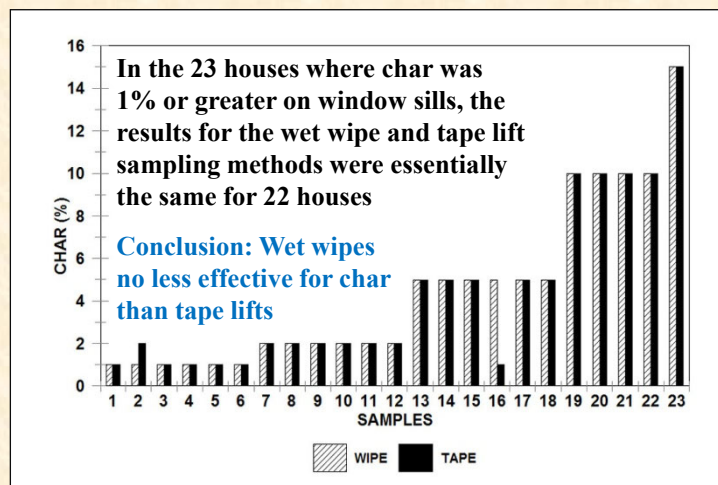
Sample Analysis

- Analysis by EMSL Laboratories
 - Composited, sonicated, filtered, then analyzed
 - Samples examined by stereo-microscopy, reflected light microscopy, TEM/EDX, and SEM/EDX
 - Soot and ash were not detected in any sample
 - Laboratory confirmed this result was not unusual or specific to the wet wipe method
 - Char analysis by polarized light microscopy (PLM) and concentration (%-char) reported using the Visual Area Estimation method
- Comparison of methods based on %-char

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Perimeter Window Sills

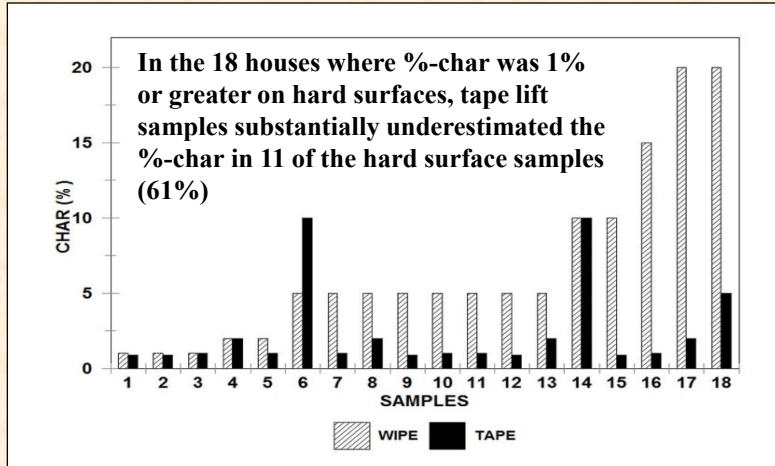
Was the interior exposed to a wildfire smoke residues?



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Interior Hard Surfaces

What was the impact of the wildfire plume?



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Wet Wipe v Tape Lift

	Windows	Windows	Interiors	Interiors
CHAR	Wipe	Tape	Wipe	Tape
<1%	25	25	30	34
1%	6	6	3	6
2%	6	7	2	5
5%	6	5	8	1
10%	4	4	2	2
>10%	1	1	3	0

Results:

Wet Wipes => Fewer with <1%, more with higher %-char

Tape Lifts => More with <1%, more with lower %-char

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Interior Hard Surfaces

- Char was detected at less than 1%
 - In 63% of wet wipe and 71% of tape lift samples
 - **Conclusion: Background char was “less than 1%”**
- In samples with a %-char of 1% or greater
 - 72% of wet wipes had a %-char of 5% or greater
 - 61% of tape lifts had a %-char of 1% or 2%
- **Conclusion: The wet wipe sampling method detected higher levels of char, and in a higher percentage of houses**
- **Conclusion: The wet wipe method performed better for the purpose of evaluating the impact of wildfire smoke residues on interior hard surfaces**

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Choice of Sampling Method

- Different methods for different objectives
 - Could sample interior window sills using either tape lifts or wet wipes if the objective is to evaluate
 - The structure was exposed to a wildfire plume
 - The interior was exposed to wildfire residues
 - Would sample interior hard surfaces using wet wipes if the objective is to
 - Evaluate the impact of wildfire smoke residues
- **Conclusion: The wet wipe sampling method was no less effective than the tape lift method for detecting char, and may have had advantages for evaluating the impact of char**

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Second Study

Characterization of Wildfire Smoke Residues

Joe Spurgeon

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Objective

- Lot's of industry experience and knowledge, but difficult to find published documentation of that knowledge
- Objective
 - Characterize the factors that can affect the evaluation of the impact of wildfire smoke residues
 - Frequency of residue detection
 - Distance from the wildfire
 - Elapsed time since the wildfire
 - Effect of sampling location
 - Background concentration of char

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Sample Collection

2,058 wet wipe samples were collected for

- Char, Ash and Soot
 - Composites of 3-5 individual samples
- Samples were collected from 343 houses affected by 22 wildfires over a four year period (2017-2020)
- Sampling locations included
 - Exterior surfaces
 - Interior hard surfaces
 - Attic surfaces
 - Air return plenums
 - Interior window sills
 - Clothing

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Sampling Location Wildfire Smoke Residues

Percentage of samples positive (=> 1%)
for residues in the 343 Houses

LOCATION	CHAR	ASH	SOOT
SAMPLES (Positive)	368	37	4
SAMPLES (%)	17.9%	1.8%	0.2%
Window Sills	39.7 %	2.6 %	0.6 %
Exterior Surfaces	38.5 %	5.8 %	0.6 %
Interior Surfaces	14.3 %	1.2 %	
Attic Surfaces	9.0 %	1.2 %	
Return Plenums	4.4 %		
Clothing	1.5 %		

Char was detected on interior surfaces in 43% of the 343 houses

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Primary Smoke Residue

- **Conclusion: Char was the only residue that was useful for evaluating the impact of wildfire smoke residues**
 - Neither Ash nor Soot were considered useful due to their low frequency of detection
- **Paying for the analysis of Ash and Soot was not a good use of resources in these two studies**
- **Following discussions based on %-Char**

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Sampling Location Variation of %-Char

Positive percentages based on
343 samples per sampling location

%-CHAR	Exteriors	Attics	Window Sills	Interiors
<1%	61.5%	91.0%	60.4%	85.7%
1%	0.3%	0.0%	11.1%	4.1%
2%	0%	0.3%	11.1%	3.8%
3% - 5%	7.3%	2.2%	5.6%	1.7%
>5% - 10%	6.9%	1.1%	0.3%	0%
>10%	23.5%	5.4%	11.7%	3.8%

Conclusions:

- **60%-90% of samples were less than 1% char**
- **Four apparent ranges of %-char for interior samples**
 - <1%, 1%-2%, 3%-10%, >10%

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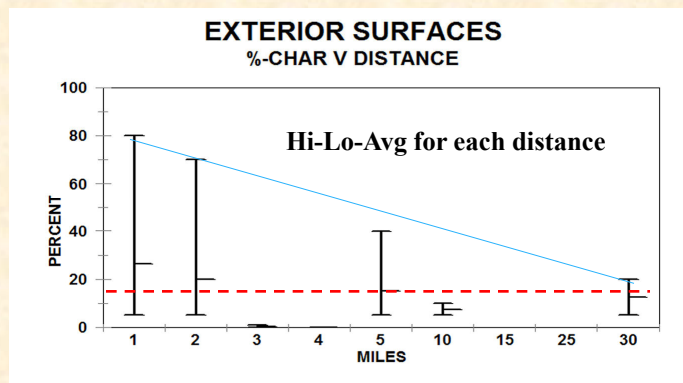
Sampling Location Average %-Char

LOCATION	AVG %-CHAR	SAMPLES
Exterior Surfaces	23.2%	132
Attic Surfaces	19.6%	31
Interior Hard Surfaces	11.7%	49
Interior Window Sills	8.0%	136
Return Plenums	4.9%	15
Clothing	3.8%	5

Conclusion: Average %-char on exterior and attic surfaces was about twice that on interior surfaces (20% v 10%)

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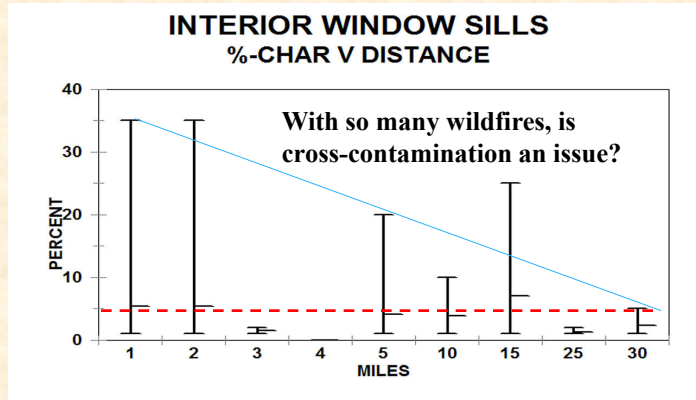
Effect of Distance



Conclusion: No association between average %-char and distance from the wildfire for exterior surfaces

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Effect of Distance



Conclusion: No association between average %-char and distance from the wildfire for interior window sills

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Effect of Distance

The Detection of char by distance from the wildfire

%-CHAR	Exteriors	Attics	Windows	Interiors
Samples	132	31	136	49
One Mile	73.5%	74.2%	63.2%	67.3%
Two Miles	9.9%	16.1%	8.8%	10.2%
Cumulative %	83.4%	90.3%	72.0%	77.5%

75% of interior char and 83% of exterior char samples detected within two miles of the wildfire

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Elapsed Time Effect on Ash

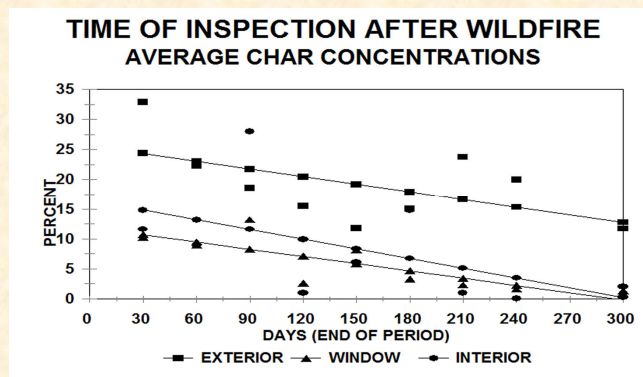
Exterior Surfaces			Window Sills	
DAYS	ASH	%	ASH	CUM %
30	10	48%	3	33.3%
60	11	52%	4	44.4%
90			2	22.2%

- Ash was only detected in the first 90 days
- Char continued to be detected over time, from 9 days through 1,270 days

Conclusion: Char could be used to evaluate impact in 100% of inspections over a 3 ½ year period; Ash in 11% of inspections over a 90 day period.

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Elapsed Time Effect on Char



Data were variable, but in general %-char decreased at different rates on different surfaces during the first 300 days

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Elapsed Time Effect on Char

- %-char decreased at:
- 1.1% / month on interior window sills [Light cleaning]
- 1.3% / month on exterior surfaces [Weathering effects]
- 1.7% / month on interior hard surfaces [Occupant activities]
- Actual numbers can be variable, but order-of-magnitude estimates
- **Conclusion: Elapsed time between wildfire and inspection should be considered when estimating original conditions**

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Composite Samples

LOCATIONS	HOUSES	PERCENT
1 / 6	95	28%
2 / 6	58	17%
3 / 6	30	9%
4 / 6	13	4%
5 / 6	3	1%

- Char was only detected in 1 of 6 sampling locations in 28% of houses; and in 1 - 2 locations in 45% of houses
- Sampling multiple locations increased the chance of detecting char

Conclusion: Composite samples were useful. They allowed 3-5 locations to be sampled per composite cost-effectively

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Background %-Char

- No consensus guidelines for background concentrations of wildfire smoke residues, HOWEVER
- The background char was less than 1% in 63% of the 48 houses and in 42% of the 343 houses for wet wipe samples
- The houses included in these studies were selected from houses potentially exposed to wildfire plumes
 - So background concentrations of char were expected to be higher than in the general housing stock, not lower
- Therefore: “Less than 1% char” was a rational definition for background char in these two studies

2011 Wildfire Study*

- 64 houses potentially exposed to a 2011 wildfire
- Distances from the wildfire were 6-60 miles
- Elapsed times were 3-8 months
- Wet wipe sampling method
 - 1” BD alcohol pad
 - 3 samples collected per house on interior surfaces
 - Average %-char was reported for each house
 - Composited samples after analysis (Research Study)

* Ward T (2014) “Evaluating the Use of Indoor Residential Wet Wipe Samples Following a Wildfire”; *Intermountain Journal of Sciences*; 20(1), 1-3

Summary of 2011 Study

- Ash was not reported in any of the 64 houses, similar to the two studies of 48 and 343 houses
- Not a strong correlation between distance from the wildfire and %-char, similar to our two studies
- %-char was less than 1% in 22% of the 64 houses compared to 42% in the later 343 house study
- Composite samples – Sample results are typically averaged (composited) either before or after analysis

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SAMPLING LOCATIONS

Use of Conditional Areas* in Wildfire Inspections as Part of an Inspection and Sampling Strategy

*Residue Impact Areas

Developed by British Occupational Health & Safety in the 1950's
Commonly used in Environmental Sciences and Industrial Hygiene

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IICRC* Standard S520 for Mold

*Institute of Inspection Cleaning and Restoration Certification

- **Condition 1**
 - Unaffected areas, normal conditions
- **Condition 2**
 - Areas affected by settled mold spores
- **Condition 3**
 - Areas subject to mold growth
- **Is the same concept - Residue Impact Areas (RIA) useful (necessary?) for wildfire inspections?**

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343 Houses Exterior v Interior

61 houses with less than 1% char
in Exterior Surface samples

Essentially no char detected on 61 exterior surfaces,
but char was detected in

- 54 interior window sill samples
- 13 interior hard surface samples

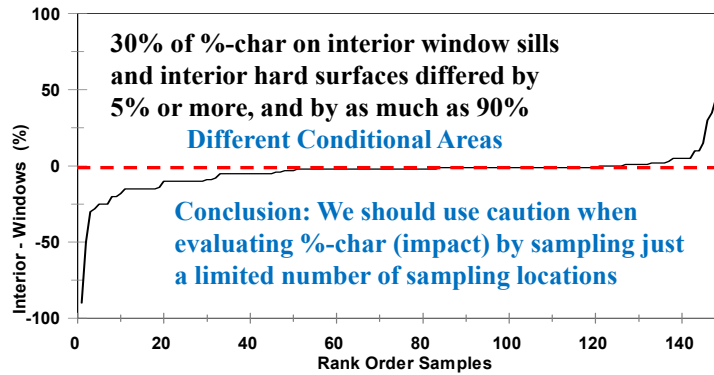
Conclusion: Little association of %-char between exterior & interior sampling locations – separate Conditional Areas

%-CHAR	<1%	1%-2%	3%-5%	>5%
Interior Windows	12%	72%	12%	5%
Interior Surfaces	79%	15%	2%	5%

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343 Houses

INTERIOR WINDOWS SILLS - HARD SURFACES DIFFERENCES IN %-CHAR



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Differences: Interior Surfaces

Difference in %-char between
interior window sills and hard surfaces

DIFFERENCE (%)	SAMPLES	SAMPLES (%)
1%	43	30.0%
2%	37	25.9%
3%	4	2.8%
5%	19	13.3%
10%	14	9.8%
15%	10	7.0%
>15%	16	11%

Conclusion: We should use caution when evaluating %-char (residue impact) by sampling just a limited number of sampling locations [41% with 5% or greater difference]

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Sampling Locations as Conditional Areas

- 149 houses in which char was detected on interior window sills or interior hard surfaces
- Could we predict %-char

On Surface	By Sampling	R-Value
Hard Surfaces	Window Sills	0.23
Attic Surfaces	Window Sills	0.17
Exterior Surfaces	Window Sills	0.37
Exterior Surfaces	Attic Surfaces	0.21

Could maybe do this if $r = 0.9$ or higher

IMPORTANT RESULT !!

- **Conclusion:** Could not use %-char from one sampling location to evaluate the impact of char for other sampling locations
 - Six sampling locations were each separate Conditional Areas
 - Each sampling location was an independent Residue Impact Areas

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Sampling Transportation Accidents

US Air Flight 1549 [2009]



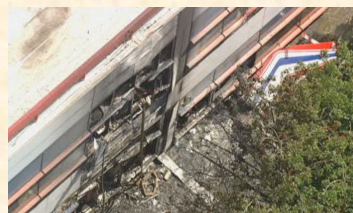
Continental Flight 3407 [2009]



Amtrak, Fallon, NV [2011]



Raytheon, El Segundo, CA [2011]



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Items and Materials Tested in Transportation Fires

- Luggage
- Clothing
- Shoes & Belts
- Coats & Furs
- Electronics
- Jewelry
- Toys
- Hard plastics
- Soft plastics
- Synthetic fabrics
- Natural fabrics
- Wood
- Paper & Cardboard
- Glass & Metal

Similar items as in a house fire

Fire Zones Are Conditional Areas

Fire Zones = Conditional Areas = Residue Impact Areas

Items Tested	Control Zone	Water Zone	Smoke Zone	Burn Zone
FIRE ZONE	1	2	3	4
Area, Room, Box, Item*				

*Aircraft or Office

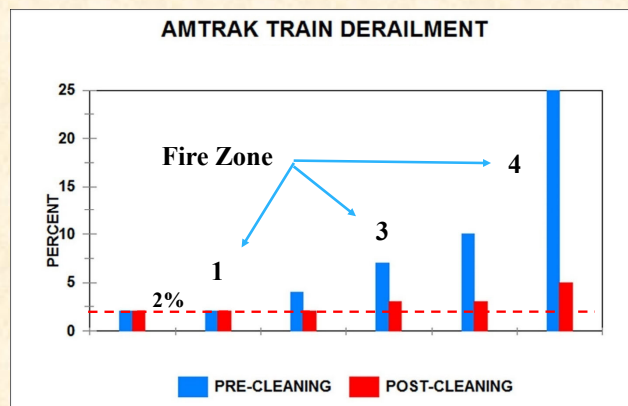
Conclusion: Using Conditional Areas in fire sampling is not a “new concept”. I used Conditional Areas for sampling transportation fires in 2009.

Combustion Particulate PCM Cassette Samples

- 6 pieces of luggage (Amtrak)
 - Closed-face 25 mm cassette
 - 0.8 um MCE filter
- % Char and Opaque [soot-like] particulate
 - Direct PLM and SEM/TEM Analysis



Six Suitcases: Percent Soot



Conclusion: Fire Zones (Conditional Areas) were associated with restorability, and return to initial condition

Wildfire Smoke Residues Alternative Wipe Samples

- Quartz fiber filters for sample collection
- Lab analysis using Mod EGA/TOR Method
 - Report as Total Carbon, Organic Carbon, Elemental Carbon
 - Can also reported as %-Char and %-Soot
 - Cost range of \$70-\$125 per sample



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Wildfire Smoke Residues Evaluation

- Ward (2011) concluded
 - “The wet wipe sampling method was useful for qualitatively assessing wildfire smoke impacts in indoor environments.”
 - Also applies to the tape lift method
- Microscopy method itself not sufficiently sensitive or accurate
 - For example, difference between 3% & 5% char
 - Lab reported 1%, 2%, 5%, 10%, 15%, 20%

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Sensitivity and Accuracy

Total Carbon (TC) using the NIOSH 5040/TOR Methods

- Differences in traffic levels between the Control Houses?
- Control, Restored, and Unrestored houses in three ranges
- Comparison of TC and Tape Lifts

HOUSE	CONDITION	TC	Char*
Control	Residential (Light Traffic)	424	
Control	(US 1 Coast Highway Traffic)	760	
1	Walls painted (owner)	1,040	7%
2	Cleaned (owner)	2,080	5%
3	Cleaned (professional)	2,430	27%
4	Remodeled (owner)	2,800	8%
5	Contents (steam cleaned)	3,070	20%
6	Not restored	5,688	14%

*Char sampled by tape lift (PLM)

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Ranges of %-Char for 199 Impacted Houses

%-CHAR	Exteriors	Attics	Window Sills	Interiors
SAMPLES	132	31	136	49
1%	0.8%	0%	28%	28.6%
2%	0%	3%	28%	26.5%
3% - 5%	19%	26%	14%	12%
>5% - 10%	18%	13%	0.7%	0%
>10%	61%	58%	29.4%	26.5%
Range >10%	15% - 80%	15% - 60%	15% - 90%	15% - 99%

Average %-Char for Interior Spaces

%-CHAR	<1%	1%-2%	3%-10%	>10%
HOUSES	42%	56%	13%	28%
RIA *	1	2	3	4

*RIA: Residue Impact Areas; same concept as the (2009) Fire Zones

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Using Residue Impact Areas in Wildfire Inspections

- **Using RIA as part of an inspection and sampling strategy**
 - Encourage the Inspector to define and use RIA
 - Encourage inspection of each RIA
 - Each RIA should be sampled if resources permit
 - Use caution if estimating impact by sampling a limited number of RIA
 - Compositing samples should only be collected within each RIA
 - All 3-5 samples from interior window sills, for example

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Wildfire Inspections Residue Impact Areas (RIA)

- **Conditional Areas may be defined differently in the inspection and restoration phases**
- **Inspections and Restorations have different objectives**
 - Sample interior window sills and hard surfaces
 - Restore living rooms and dining rooms
- **Objective of using Conditional Areas**
 - Link the inspection results to the Restoration Work Plan
 - Allocate resources more efficiently, and where needed most (by area rather than structure)
- **Results for each RIA can be summarized to define**
 - Similar Restoration Areas in the Restoration Work Plan

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Wildfire Restorations Similar Restoration Areas (SRA)

CRITERIA FOR DEFINING SRA

- **Visual Inspection**
- **Incident History**
- **Occupant Interview**
- **Odor Detection**
- **Visual Wipe Tests**
- **Sample Results (RIA)**

SIMILAR RESTORATION AREAS (Defined by Inspector)

- **By Area**
- **By Room**
- **By Floor**
- **By System**

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Wildfire Restorations Similar Restoration Areas (SRA)

RIA

- **Window sill, Hard Surfaces**
- **Carpet**
- **Soft surfaces**
- **Return plenum, Supply**

SRA

- **Living Room, First floor**
- **Carpets, Carpet in LR**
- **Soft surfaces**
- **Air delivery system**

Conditional Areas:

- **RIA defined for the Inspector in the Inspection Phase**
- **SRA defined for the Restoration Contractor in the Restoration Work Plan**

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Wildfire Restorations Similar Restoration Areas

% Char*	SRA	IMPACT	Restoration Work Plan
< 1%	1	None	Background; Control Area
1% - 2%	2	Low	Wiping, HEPA-Vac
3% - 10%	3	Moderate	Restoration Methods
>10%	4	Heavy	Aggressive, Systems, Occupants

*Other criteria, as well:

**In this study,
Sampling Locations
were defined as
Residue Impact Areas**

- Visual Inspection
- Incident History
- Occupant Interview
- Odor Detection
- Visual Wipe Tests
- Sample Results

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PRESENTATION SUMMARY

- **The wet wipe sampling method detected higher levels of char, and in a higher percentage of houses compared to the tape lift method**
 - **The wet wipe sampling method resulted in a higher evaluation of the impact of char in 88% of the smoke-impacted houses**
- **Collecting composite samples was a reasonable methodology for sampling a large number of surfaces at a reasonable cost**
 - **Samples, or sample results, are typically composited for assessment either prior to, or following, analysis**

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PRESENTATION SUMMARY

- Char was the only wildfire smoke residue that was useful for evaluating impact since Ash and Soot were not detected with sufficient frequency to be useful
- 63% of the 48 houses and 42% of the 343 houses had a %-char of “less than 1%”, which was a reasonable definition of background concentration in the two studies
- The concept of Conditional Areas was useful, even necessary, for properly evaluating the impact of wildfire smoke residues in the inspection of the 343 houses
 - %-char was not correlated between sampling locations, and each sampling location was an independent Conditional Area

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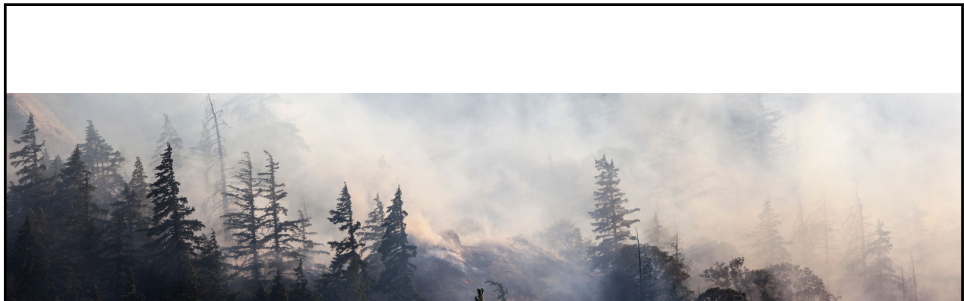


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