Characterization of Wildfire Smoke Residues in Residential Properties

By Joe C. Spurgeon, PhD, Franco Seif, and Euginia Mirica, PhD

INTRODUCTION

The purpose of the study was to characterize the effects of selected parameters on the evaluation of wildfire smoke residues when evaluating their impact on structures, primarily residential properties but other structures as well. The study included wildfire smoke residue samples that were collected from houses that were potentially impacted by various wildfires in northern California. The parameters included the frequency with which a residue was detected, the distance of the site from the wildfire, the elapsed time between the inspection and the wildfire, the effect of sampling location in the structure, the effects of sampling method, and the numerical guideline for evaluating if a structure had been impacted by wildfire smoke residues.

Rationale for Sampling Method

In practice, wet wipes may perform better than tape lifts for sampling hard surfaces.[1] In addition, wet wipes may be the preferred residue sampling method within the industry.[2] About 80% of the wildfire smoke residue samples submitted to the EMSL facility in Cinnaminson, NJ were wipes, 10% were tape lifts, and 10% were micro-vacuum samples. At EMSL's Pasadena, CA facility, 70% of the samples were wipes, 25% were tape lifts, and 5% were micro-vacuums.

The wet-wipe sampling method offered several potential advantages for collecting wildfire smoke residues, especially since char was expected to be the dominant wildfire smoke residue.[1]

First, the method could be applied to both smooth and intricate hard surfaces, as well as heavily loaded surfaces. Second, the sample preparation step increased homogeneity of subsamples for analysis by optical microscopy, which reduced analytical

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SYNOPSIS

Wildfire smoke residues were evaluated in 343 northern California houses that were potentially impacted by one of 22 wildfires. A total of 1,715 wet-wipe samples were collected from five hard-surface sampling areas in each house, including exterior surfaces, attics, interior window sills, interior hard surfaces, and return air plenums.

The samples were analyzed for char, ash, and soot. Char was detected in 363 of the samples, ash was detected in 37 of the samples, and soot was detected in four of the samples. Char was the primary wildfire smoke residue based on the frequency of detection and was the most useful for evaluating the impact of wildfire smoke residues on structures.

Char concentrations on interior surfaces were primarily detected in four concentration ranges: <1%, 1%–2%, 3%–10%, and >10%. More than half (55%) of char concentrations on interior surfaces in impacted structures were 1%–2%, with an additional 28% exceeding 10%.

Char concentrations were less than 1% in all five sampling areas in 147 (43%) of the 343 houses and were 1% or more in at least one sampling area in 196 (57%). Defining sampled surfaces with a char concentration of 1% or more as having been impacted by wildfire smoke residues was a practical criterion, it was consistent with the laboratory LOQ, and it was a useful guideline for evaluating impact.

Houses closest to the wildfire were impacted by char to a greater extent than those farther from the wildfire. About 74% of exterior samples and 65% of interior samples with char concentrations of 1% or more were collected within one mile of the wildfire. Although peak concentrations decreased with distance from the wildfire in the range of 1–30 miles, the average concentrations did not vary substantially in the range of 6–50 miles.

The average char concentrations on exterior surfaces, interior window sills, and interior hard surfaces declined at small but relatively constant rates during the first 10 months. Therefore, the elapsed time between the wildfire and the inspection may need to be considered when evaluating initial conditions.

The char concentration measured for one sampling area was not a good indicator of the char concentrations measured at other sampling areas. There was at least a 3% difference in the average char concentration between the interior window sills and hard surfaces in 44% of the 143 houses that had a char concentration of 1% or more in both locations. These results suggested that the inspection and sampling strategies for evaluating the impact of smoke residues should include the concepts of "similar impact areas" and "similar restoration areas."

The wet-wipe sampling method was effective for sampling wildfire smoke residues, especially the dominant residue (char). The method could be applied to smooth and intricate hard surfaces, as well as heavily loaded surfaces. The sample preparation step increased the homogeneity of subsamples for analysis, which reduced analytical variability and dispersed obstructing debris particles.

The wet wipe method allowed composite samples to be collected, with each composite sample representing the result for three to five individual surfaces. Composite samples increased the probability of detecting wildfire smoke residues, resulted in a better characterization of the space that was sampled, and reduced sampling cost.

variability and dispersed obstructing debris particles. Third, it allowed composite samples to be collected, with each composite sample representing the result for 3–5 individual surfaces. Composite samples increased the probability of detecting wildfire smoke residues, resulted in a better characterization of the space that was sampled, and reduced sampling cost by allowing more surfaces to be sampled using fewer samples.

A previous comparison of replicate wet-wipe and tape lift samples indicated that wet-wipe sampling was an effective method for evaluating the impact of wildfire smoke residues.[2] One limitation of that study was that both the replicate wet-wipe and tape lift samples were composite samples collected from 3–5 surfaces. Although this is not a recommended practice, the samples were collected as part of a limited add-on research study. Extra care was used to visually inspect both the surface of the tape and the sampled areas after each sample. This was done to check for overloading and to ensure visible debris was picked up by the sticky tape. When the tape visibly approached an overloaded condition, the hygienist was instructed to stop using it. This resulted in the sampling of a range of 3–5 surfaces in each composite sample.

The results indicated there was no difference in the collection, sample preparation, or analytical efficiencies between replicate wet-wipe and tape lift samples for interior window sills. However, wet-wipes did perform better on interior hard surfaces. This may have been due to three factors: 1) the advantages of averaging composite samples, 2) the advantages of homogenization during sample preparation by the laboratory as per EPA's VAE method (EPA/600/R-93/116), and 3) interior hard surfaces varied in contour and roughness compared to smooth, flat window sills.

METHODS

Sample Collection

A total of 343 houses in northern California that were potentially impacted by one of 22 wildfires were sampled for char, ash, and soot using the wet-wipe sampling method. The wildfires occurred during a four-year period from 2017 through 2020. A total of 1,715 wet-wipe samples were collected from five hard-surface sampling locations in each house. The five "similar sampling areas" included exposed exterior surfaces, attic surfaces, interior window sills, interior hard surfaces, and return plenum surfaces. Field inspections and sample collection were performed by trained, experienced industrial hygienists.

Wet-wipe samples were collected using foil-sealed Beckton Dickinson alcohol pads containing 70% isopropyl alcohol and measuring 1×1 square inch. A pad was used to wipe approximately 8 square inches of the hard surface. The pad was then placed into a clean 4×4 square inch Ziplok plastic sample bag, sealed, and labeled. This process was repeated on 3–5 hard surfaces inside each property, using a clean pad for each surface. The individual samples were then combined by the laboratory for analysis to provide a composite sample, with the area sampled varying from 24–40 square inches depending on the number of surfaces sampled.

Laboratory Analysis

The wet-wipe samples were shipped to EMSL Laboratories in Cinnaminson, NJ, typically the day after they were collected, where they were composited and analyzed. The samples were analyzed by stereomicroscopy, epi-reflected light microscopy, polarized light microscopy, TEM/EDX, and SEM/EDX.[2] A minimum wildfire smoke residue concentration of 1% was defined as the Limit of Quantitation (LOQ).

The PLM technique was used for the identification of char and ash, the screening and presumptive analysis of soot clusters, and the reporting of char on a relative area percentage basis using the Visual Area Estimation (VAE) method (EPA/600/R-93/116). A sample in which a smoke residue was detected at a concentration of 1% or greater was defined as being positive and houses in which positive samples were detected were considered to have been impacted by a wildfire smoke residue.

RESULTS AND DISCUSSION

Detection of Wildfire Smoke Residues

Char was detected at a concentration of 1% or more in 196 (57%) of the 343 houses, ash was detected at a concentration of 1% or more in 8.8% of the houses, and soot was detected in 1.2% of the houses. Char was detected in 363 (21.1%) of the 1,715 samples, ash was detected in 37 (2.2%) of the samples, and soot was detected in four (0.2%) of the samples.

Char was the primary wildfire smoke residue based on frequency of detection, in this study as well as in two previous studies.[2, 3] The frequencies of detection for ash and soot in this study were too low for those wildfire smoke residues to be useful for evaluating impact. Since char was the only wildfire smoke residue detected with sufficient frequency to be useful for evaluating the impact of wildfire smoke residues, evaluations were based on the concentrations of char detected on interior and exterior surfaces.

LOCATION	CHAR	ASH	SOOT
Window Sills	40%	2.6 %	0.6 %
Exterior Surfaces	39%	5.8 %	0.6 %
Interior Surfaces	14%	1.2 %	
Attic Surfaces	9%	1.2 %	
HVAC Returns	4%		

Table 1. Percentage of similar sampling areas impacted by wildfire smoke residues in the 343 houses.

Sampling Locations

The percentages of sampling locations impacted by char, ash, or soot concentrations of 1% or more in the 343 houses were listed in Table 1 for each of the five similar sampling areas. Freasor example, char was detected on exterior surfaces in 39% of the houses and on attic surfaces in 9% of the houses. For interior surfaces, char concentrations of 1% or more were detected in 40% of interior window sill samples but in only 14% of interior hard surface samples. A char concentration of 1% or more was detected 2.8 times more frequently on interior window sills compared to interior hard surfaces, suggesting that interior window sills were a good sampling location for evaluating exposure of the structure to wildfire smoke residues.

Table 2 describes the percentage of samples in each of the five ranges of char concentrations for four of the five similar sampling areas in this study. The samples were collected in the 196 houses in which a char concentration of 1% or more was detected. Char concentrations on exterior and attic surfaces were concentrated primarily in the higher concentration ranges. About 97% of the char concentrations were 3% or more, and approximately 60% of the exterior and attic samples had a char concentration exceeding 10%.

Char concentrations in the interior window sill and hard surface samples were concentrated at the lower char concentrations, with a secondary grouping at the highest concentration. About 55% of the interior surface samples had a char concentration of 1%–2%, and about 28% had a char concentration exceeding 10%. While 97% of the char concentrations were 3% or more in the exterior and attic samples, about 55% of the interior surface samples had a char concentration of less than 3%.

In a previous study of 64 houses by Ward, the char concentrations for wet-wipe samples were less than 1% in 14 houses (22%), it was 1%–2% in 37 houses (58%), 2%–5% in 10 houses (15%), and greater that 5% in three houses (5%).[3] Both Ward's study and the current study suggest that 50%–60% of impacted structures may be expected to have an average char concentration of 1%–2% for interior samples.

CHAR	Exteriors	Attics	Window Sills	Interiors
SAMPLES	132	31	136	49
1%	0.8%	0%	28%	29%
2%	0%	3%	28%	26%
3%–5%	19%	26%	14%	12%
>5%–10%	18%	13%	0.7%	0%
>10%	61%	58%	29%	27%

Table 2. Percentages of samples in each concentration range of char by sampling location for 196 residue-impacted houses.

Distance from Wildfire

The distances of the houses from the subject wildfire varied from less than a mile to a maximum of 150 miles, with 92% of the houses located within 30 miles of the wildfire. The houses closest to the wildfire were impacted by char to a greater extent than those farther from the wildfire. The majority of samples with 1% or more of char were collected within one mile of the wildfire, as illustrated in Figure 1. The percentage of samples collected at a distance of one mile or less were 63% and 67% for interior locations and 74% for attic and exterior surfaces. An additional 9%–16% of samples were collected within 1–2 miles, depending on the sample area in Figure 1, with a similar range of percentages collected at 3–5 miles.

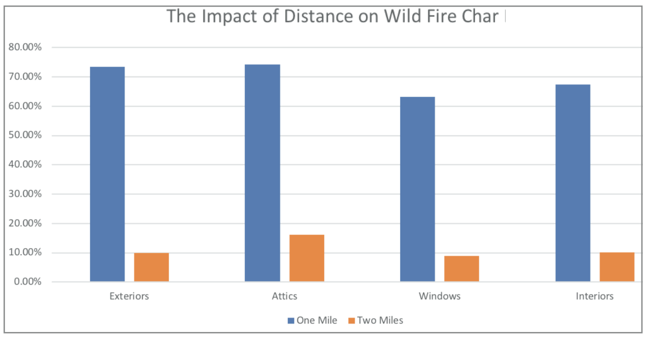

Figure 1. Percentage of samples with a char concentration of 1% or more collected within two miles of the wildfire by a similar sampling area.

The average concentration of char generally decreased with distance from the wildfire, as illustrated in Table 3. Exterior concentrations were about 2–4 times the average interior concentration for each similar sampling area. An increase in the average char concentration at the greater distances was due to a small number of elevated values for a limited number of total samples.

Miles	Exteriors	Attics	Window Sills	Interior Surfaces
1	26.5%	19.9%	10.6%	12.8%
2	20.0%	24.0%	5.4%	8.0%
3–5	3.6%	3.0%	3.6%	6.1%
6–150	9.2%	7.5%	2.9%	11.0%

Table 3. Average percent char by distance from the wildfire and by similar sampling area for 343 samples.

Peak char concentrations on exterior surfaces tended to decrease with distance from the wildfire in the range of 1–30 miles. Peak char concentrations were over 70% at 1–2 miles, 40% at 5 miles, and 20% at 30 miles. However, average char concentrations at various distances were in a relatively narrow range and were poorly correlated with distance. Peak char concentrations on interior window sills also decreased with distance. The range of char concentrations for interior window sill samples varied from a low of 1% to a high of about 35%.

Elapsed Time Since Wildfire

Changes in the initial conditions can occur as the elapsed time between the wildfire and the inspection increases, making it more difficult to evaluate the initial impact of wildfire smoke residues. The elapsed time between the wildfire and the date of the inspection varied from a minimum of nine days to a maximum of 1,270 days (3.5 years). About 77% of the inspections occurred within the first 180 days, with 16% of inspections occurring within 30 days, 29% within 30–90 days, and 32% within 90–180 days.

The average char concentration decreased on exterior surfaces, interior window sills, and interior hard surfaces during the first ten months. The rates at which the average char concentration decreased per 30-day period were 1.7% on interior hard surfaces, 1.3% on exterior surfaces, and 1.1% on interior window sills. Although these rates were variable and should be viewed as approximations, they provided an order-of-magnitude estimate for the removal rates for surface char. The results suggested that the elapsed time between the wildfire and the inspection should be considered as a potentially biasing factor when estimating initial conditions.

The loss of char over time may have been due to several factors. The average concentration of char decreased at the highest rate on interior hard surfaces. Hard surfaces were presumably subject to frequent occupant activities such as cleaning and disturbance, as well as increased physical degradation due to contact. The exterior samples were collected from unprotected surfaces that were subject to losses due to wind and weather, UV radiation, physical degradation, and physical removal. However, the decrease in char concentration on interior window sills was similar to the rate on exterior surfaces. The interior window sills may have been disturbed less frequently than interior hard surfaces, and were protected from weathering effects. This similarity in rates suggests physical degradation may have been primarily responsible for the loss of char during this period of time.

This result could lead to the false conclusion that since the visible char particles "disappear" over time, cleaning and restoration are not required. However, conservation of mass should be expected. Presumably, the larger char particles degrade into smaller particles over time, which would be expected to be in the inhalable and respirable size ranges (1–10 microns); exposure to the lower respiratory tract would likely increase as the char particles physically degrade. Since char consists of both elemental and organic carbon, besides the effects of PM2.5 and PM10, it can also contain irritant and carcinogenic compounds.[4, 5, 6] Therefore, this scenario suggests that cleaning and restoration should occur as soon as possible after the wildfire.

Cleaning and Restoration

The primary objectives of sampling and evaluating wildfire smoke residues are to 1) identify those structures that have been impacted by the residues, and 2) determine a scope of work for the cleaning and restoration of the impacted properties. The characterization of char concentrations in this study was based on a relatively large sample of 343 houses. A previous study of 48 houses compared replicate wet-wipe and tape-lift samples for interior window sills and interior hard surfaces—sampling areas that were also included in the current study.[2] When the results of these two studies are considered together, several factors that can affect the clean/restore decision can be evaluated. These factors include the primary wildfire smoke residue, the concentration of a wildfire smoke residue that indicates a structure has been impacted and should be subject to cleaning/restoration, and the impact of the sampling method on the clean/restore decision.

There are no consensus guidelines for the concentrations of wildfire smoke residues that can be used to identify houses that have been impacted by those residues.[1] However, the selection of the concentration of a smoke residue as a minimum criterion for assessing impact determines which structures may be defined as having been impacted by wildfire smoke residues, and which houses should be subject to cleaning/restoration. The concentrations of wildfire smoke residues used to assess impact are typically based on professional judgment (for example, "1% or more" or "3% or more"). Using a char concentration of "1% or more" for wet-wipe samples was a practical definition for assessing the impact for the 343 houses included in this study.

A char concentration of 1% or more was consistent with the Limit of Quantitation (LOQ) used by the laboratory to report samples positive for char. In addition, the char concentration was less than 1% in all six sampling areas in 147 (43%) of the 343 houses. Two smaller studies of 64 and 48 houses using wet-wipe samples to collect char found the char concentration was less than 1% in 63% and 22% of the wet-wipe samples, respectively.[2, 3] The average for the three studies was 43%, which was considered to be a reasonable percentage of houses; therefore 1% char was considered to be a reasonable numerical guideline for evaluating impact.

Both the selection of the sampling method and the minimum residue concentration for evaluating impact can affect the proportion of houses evaluated as requiring cleaning or restoration. For example, the results in Table 2 and in Ward's study indicated that 50%–60% of char concentrations on interior surfaces may be expected to be 1%-2%. If it were presumed that samples collected from interior surfaces, as compared to the exterior or attic surfaces, would be more relevant for evaluating the impact of wildfire smoke residues on interior spaces when preparing a restoration work plan, then pre-selecting a minimum residue concentration of 3% for evaluating impact, for example, would exclude over half of the potentially impacted houses from cleaning or restoration. In comparison, pre-selecting a minimum residue concentration of 1% for evaluating impact would not exclude any of the potentially impacted houses from cleaning or restoration.

A previous study of 48 houses, although limited in size, compared the tape lift and wet-wipe methods for collecting char samples from interior window sills and interior hard surfaces.[2] Eighteen of the 48 houses included in that study had a char concentration of 1% or more on the interior surfaces. These data were used in Table 4 to compare the percentages of those 18 houses that would have been subject to restoration assuming the indicated sampling method and minimum residue concentration of char for assessing impact had been selected in the study.

For example, selecting the wet-wipe sampling method and defining a minimum char concentration for assessing impact as "1% or more" would have identified 100% of the 18 houses as being impacted by wildfire smoke residues. In comparison, selecting the tape lift sampling method and defining a minimum char concentration for assessing impact as "3% or more" would have identified 17% of the 18 houses as being impacted by wildfire smoke residues.

Minimum Char	Wet Wipe	Tape Lift	Difference
1% or More	100%	94%	6%
3% or More	72%	17%	76%
Difference	28%	82%	NA

Table 4. Effect of sampling method and minimum char concentration for evaluating impact on the percentages of 18 houses subject to restoration.

The percentages of the 18 houses in Table 4 illustrate the effects of selecting a sampling method and minimum char concentration for assessing the impact on the decision to clean/restore a structure. Table 4 suggests that these two parameters can have meaningful effects on whether or not a structure will be evaluated as having been impacted by wildfire smoke residues and subject to cleaning and restoration.

The largest difference in the evaluation of impact in Table 4 occurred between using 1% or 3% as the minimum char concentration for evaluating impact. There was only a 6% difference in the evaluation of impact between the wet-wipe and tape lift sampling methods when a char concentration of 1% or more was used to assess impact. However, this difference increased to 76% when the criterion used to evaluate impact was changed to 3% or more.

Composite Samples

The wet-wipe sampling method allowed composite samples to be collected, with each composite sample representing the result for 3 – 5 individual surfaces.[7] Using composites to sample multiple surfaces increased the probability of detecting wildfire smoke residues, better characterized the spaces that were sampled, and reduced costs. However, composite samples should only be collected within a single "similar sampling area." I.e., all individual samples in a composite sample should be collected from interior window sills, interior hard surfaces, etc.

Char was only detected in one of the six similar sampling area in 96 (49%) of the 196 houses in which a char concentration of 1% or more was detected, and that one sample represented 3–5 surfaces. This result emphasized the need to sample as many surfaces as possible in order to detect the presence of wildfire smoke residues. The more surfaces that are sampled, the greater the probability that a surface contaminant may be detected; and the more representative the results will be. Therefore, the sampling plan should maximize the number of similar sampling areas, and the number of surfaces that can be sampled within each sampling area. However, because of cost limitations, this typically requires a balance between the collection of individual samples and the use of composite samples.

The advantages of collecting individual samples include the ability to perform statistical tests, greater detail in the data, and the ability to detect patterns and gradients in the results. If these factors are important to the sampling plan, then individual samples should be collected. But these advantages may not actually be utilized in the typical wildfire inspection. The disadvantages are that collecting individual samples either limits the number of surfaces that can be sampled, or requires larger sample sizes to be collected at an increased cost. Collecting composite samples within each similar sampling area is a recognized method for sampling a larger number of surfaces at a reasonable cost. Collecting a composite sample is equivalent to collecting individual samples and then averaging the sample results after they have been analyzed.[3]

Extrapolation of Results

The average concentrations of char differed between the similar sampling areas. The concentration measured for one sampling area was not a reliable predictor of the concentration for another sampling area. For example, sampling the interior window sill of a house did not provide very much information as to what the sample result would be for the interior hard surfaces. Char was not detected on the exterior surfaces of 61 houses in which char was detected on interior window sills. In these 61 houses, a char concentration of 1% was detected on 26 window sills; 2% char on 18; and 3%–30% on 10 window sills.

The lack of association between the detection of char on interior window sills and interior hard surfaces was described in Table 5. A char concentration of 1% or more was detected on both interior window sills and interior hard surfaces in 143 houses. For example, 43 of the paired char concentrations only differed by 1%. However, the paired char concentrations on interior window sills and hard surfaces differed by 3% or more in 63 of the 143 houses, and the differences in the paired char concentrations in 16 of the houses ranged from 25%–90%.

These results were consistent with a previous study in which char concentrations were compared on interior window sills and interior hard surfaces for 18 wet-wipe samples in 48 houses.[2] In that study, 45% of the properties that had been impacted by wildfire smoke residues had substantially different average char concentrations in these two sampling area.

DIFFERENCE (%)	SAMPLES	SAMPLES (%)
1%	43	30%
2%	37	26%
3%	4	3%
5%	19	13%
10%	14	10%
15%	10	7%
25% – 90%	16	11%

Table 5. Percentage of houses with the indicated difference in char concentrations between the interior window sill and interior hard surface samples in 143 houses.

The results in Table 5 suggested differences in char concentrations between interior window sills and interior hard surfaces may be common. Since these two locations may be used to evaluate the impact of wildfire smoke residues, the results suggested caution should be used when extrapolating char concentrations between sampling areas to evaluate impact.

The differences in char concentrations were compared for a broader selection of sampling areas in Table 6. The coefficients of correlation (r-value) for the differences in char concentrations were calculated for the four pairs of similar sampling locations in Table 6. The low correlations between the four sampling areas, with three of the four r-values essentially 0.2, reinforced the conclusion that char concentrations from one sampling area should be used with caution to estimate char concentrations for other sampling areas.[8]

LOCATION 1	LOCATION 2	R-VALUE
Window Sills	Hard Surfaces	0.23
Window Sills	Attic Surfaces	0.17
Window Sills	Exterior Surfaces	0.37
Attic Surfaces	Exterior Surfaces	0.21

Table 6. Coefficients of Correlation between the char concentrations were measured for similar sampling areas.

CONCLUSIONS

- The wet-wipe sampling method was an effective method for sampling wildfire smoke residues, especially char. The method could be applied to both smooth and intricate hard surfaces, as well as heavily loaded surfaces. The sample preparation step increased the homogeneity of subsamples for analysis, which reduced analytical variability and dispersed obstructing debris particles.

- The wet wipe sampling method allowed composite samples to be collected, with each composite sample representing the result for 3 – 5 individual surfaces. Composite samples increased the probability of detecting wildfire smoke residues, resulted in a better characterization of the space that was sampled, and reduced sampling cost by allowing more surfaces to be sampled using fewer samples.
- Char was the primary wildfire smoke residue based on the frequency of detection and was most useful in evaluating both exposure of the structures and the impact of wildfire smoke residues. The frequencies of detection for ash and soot were too low to be useful for assessing impact.
- Each of the five similar sampling areas was an independent similar impact area; caution should be used when extrapolating char concentrations between sampling areas to evaluate impact.
- Houses closest to the wildfire were impacted by char to a greater extent than those farther from the wildfire. About 65% of the interior surface samples with a char concentration of 1% or more were collected within one mile of the wildfire. About 74% of the exterior surface samples were collected within one mile of the wildfire.
- The results of the study suggested that more than half (55%) of char concentrations on interior surfaces may be expected to be less than 3%. Therefore, using a char concentration of "1% or more" for wet-wipe samples as the minimum char concentration for assessing impact was reasonable for the houses included in this study, and was consistent with the laboratory LOQ.
- The results of the study suggested that the char concentration measured for one of the five sampling areas should not be used to evaluate the impact of char for other sampling areas. Each similar sampling location should be evaluated independently. Char concentrations on interior surfaces were primarily detected in four concentration ranges:
- <1%, 1%-2%, 3%-10%, and >10%.

LIMITATIONS

This was a relatively large study, but just one study. Additional studies should be performed to validate these results and to examine these and other factors that may affect evaluation and assessment strategies for wildfire smoke residues.

The wildfire smoke residue samples were collected using the wet-wipe sampling method. Generalizing the results and conclusions of this study to other sampling methods should be done with caution.

The replicated study in reference 2 comparing the wet-wipe and tape lift sampling methods for evaluating char concentrations was based on limited sample size.

The inspections and sample collection were performed by an environmental company. The objectives, the extent of residue impact characterization, and the distribution of elapsed times may have been different if the inspections had been performed by a restoration contractor, independent environmental professional, or another party. JCS

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