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**Air Quality During and After the 2025 Los Angeles,
California Fires and the Utility of Potassium as a
Fire Tracer**

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fires

Abstract

Wildland-urban interface fires are becoming more frequent, and their impacts on
adjacent urban centers are rising. In January 2025, the Eaton and Palisades fires
burned over 18,000 structures and 15,000 hectares of urban and wild lands and
blanketed parts of Southern California, USA in smoke and dust. Here we combine
hourly and multi-hour metals, particulate matter, and gas data from two sites with
meteorological and fire spatial extent data and several statistical methods to
understand the fire impacts on air quality. The primary receptor site, in
Huntington Park about 28 km from the Eaton fire, was intermittently directly
downwind. The smoke increased airborne lead concentrations by up to 250 times
its background, to about 0.2% of PM_{2.5} mass; arsenic, chlorine, bromine and copper

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25 were also highly elevated. Concentrations of elements associated with
26 resuspended soil began to rise when high winds started immediately prior to the
27 fire ignitions and decayed once the winds decreased. Potassium, often used as a
28 biomass burning tracer, was uncorrelated with smoke. It was strongly associated
29 with coarse particles, and its mass-normalized concentration fell within its normal
30 range during the fires, indicating potassium cannot be used as a fire tracer in this
31 context. Lead was elevated in smoke throughout the fire, thus its concentration
32 could not be used to determine urban versus wildland combustion within this
33 WUI fire event. There was no clear tracer of urban vs. wildland burning in the
34 smoke or coarse particles. Finally, we found little evidence of fire-associated
35 pollution after the fires were extinguished.

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37 **Introduction**

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39 A growing body of evidence shows that wildfire smoke and dust result in
40 increased incidence of adverse cardiovascular, birth, developmental and mental
41 health outcomes¹⁻³ and may be more toxic than typical urban air pollution.⁴⁻⁶ While
42 the impacts of wildland smoke on urban air quality have been the subject of
43 substantial study, until recently studies of urban fires have been focused at small
44 scales, such as burning individual household items, a test structure, or on

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45 occupational exposures of firefighters.^{3,5-9} In recent years, as large fires have
46 become more common in the 'Wildland-Urban-Interface' (WUI), a few studies
47 have begun to emerge describing the impacts of large fires that burn both
48 structures and wildlands.¹⁰⁻¹⁵ Structure and WUI fires are likely to be even more
49 toxic than wildland burning, due to the addition of metals, halogens and organics
50 that may be less common of wildfire smoke, although many questions remain^{16,17}.

51 Fires produce smoke consisting of gases and combustion particles (PM_{2.5}, particles
52 smaller than 2.5 µm in diameter), coarse particles (PM_{10-2.5}, between 2.5 and 10 µm
53 in diameter), and larger ash particles. Metals reported in wildland fire smoke
54 include potassium (K), manganese (Mn), zinc (Zn), chromium (Cr), titanium (Ti),
55 and to a lesser extent, arsenic (As), lead (Pb), and copper (Cu) depending on fuel
56 composition, geology, and combustion phase.^{12,15,18-21} Mobilization of metals from
57 soil and vegetation by wildfires is well established; previous studies have
58 attributed calcium (Ca), aluminum (Al), iron (Fe) and silicon (Si) as tracers for
59 mobilized soil in wildfire ash and coarse PM across multiple landscapes.^{12,18,19} K
60 has been considered to be a key tracer for smoke particles^{12,20,22-25} although some
61 studies have found it to have quite limited utility.²⁶

62 Several studies have reported that structure fires have different elemental profiles
63 from wildland fires. Li et al. (2023),⁹ investigated elemental emissions from several
64 watercraft and warehouse fires in Hong Kong. They found highly elevated
65 concentrations of Pb, Zn and Cu, in addition to Br and Cl. Significant levels of Pb,

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66 Cu, Zn and Cr were found in soil and indoor PM_{2.5} in burned areas left by the 2021
67 Marshall Fires in Colorado, which burned more than 1,000 structures.^{14,15} The 2017
68 California wildland fire season included some of the most destructive fires ever
69 recorded, including the Camp Fire, which burned 63,052 hectares of land and
70 18,804 structures, and several other fires that burned extensive wildlands. Much
71 higher Pb, Zn and Ca were found in PM_{2.5} from the Camp Fire compared to the
72 other fires.²⁷ Boaggio et al.¹² analyzed PM_{2.5} samples from several other California
73 WUI fires over a 13 year period and found that smoke from wildland fires
74 contained more magnesium (Mg), Mn, sodium (Na), and K, whereas fires that
75 burned more structures had elevated levels of Pb and Cu, in line with the
76 California Air Resources Board (CARB) report.¹²

77 Because of the unique characteristics of Southern California geography, large WUI
78 and wildfires often start during strong wind events originating in the high deserts
79 to the North, a configuration that blows smoke and dust directly over Southern
80 California's urbanized communities.²⁸⁻³¹ The winds, known as Santa Anas,
81 continue offshore, but pollution plumes sometimes recirculate over the urbanized
82 area in subsequent onshore breezes. In January 2025, the Los Angeles area
83 experienced a period of intense Santa Ana winds. The winter rains, which
84 normally start in late fall had not yet arrived, leading to extreme fire risk. Within
85 about eight hours on January 7th, two major fires ignited. The Eaton fire was
86 upwind of a large swath of Los Angeles. The Palisades fire, located on the western

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87 edge of the city adjacent to the Pacific Ocean, impacted the city's air quality less
88 because the smoke was largely blown offshore. The fires burned 5,674 and 9,489
89 hectares of wildlands and 10,488 and 7,810 structures respectively, and several
90 smaller or more distant fires also ignited in this period.

91 In 2022, the South Coast Air Quality Management District (AQMD) installed an
92 instrument to monitor hourly elements in PM_{10} in Huntington Park, about 28 km
93 south-southwest of the Eaton fire. This site is in an industrialized area expected to
94 have a relatively high urban 'background' of heavy metals and other pollutants.
95 The site also has a suite of instruments to characterize particulate matter mass,
96 black carbon, several gases, and meteorology. This station was often in the plume
97 of the Eaton fire or received recirculated air from the Eaton and Palisades fires.

98 Here we combine the hourly element data with several other data types and
99 models, including meteorological data, the Hybrid Single-particle Lagrangian
100 Integrated Trajectory model (HYSPLIT),^{32,33} elements from filters collected at the
101 University of California, Los Angeles (UCLA), and analysis of burn area and the
102 proportion of urban vs wildland burned as the fires progressed. We use positive
103 matrix factorization and other statistical tools to separate smoke from larger
104 particles. We investigate the degree to which elements were elevated compared to
105 typical urban conditions, the degree to which the smoke and dust impacted the air
106 quality in the area after burning ceased and the evidence that K is a useful tracer

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107 for urban or wildland fire emissions. We also look for separate signatures of urban
108 vs. wildland fires.

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110 **Materials and Methods**

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112 **2.1 Fire Characteristics**

113 We determined the fire burned area of the Palisades and Eaton fires and estimated
114 the fraction of urban vs wildland fuel using twice daily, 375m resolution fire
115 detections from the Visible Infrared Imaging Radiometer Suite (VIIRS)
116 instruments on the NOAA-20, NOAA-21, and S-NPP satellites (NASA FIRMS)³⁴
117 using previously developed methods.^{35,36} VIIRS fire detections are hot-spot-based.
118 For each satellite overpass time, detections are aggregated into clusters of circular
119 polygons with diameters of 375 meters. Landcover data is based on the 40-class
120 Scott and Burgan fuel model, which tracks urban/developed land as a fuel class.³⁷
121 These data are available from LANDFIRE at 30m resolution. Total and urban fire
122 areas were computed as the product of the per-pixel (900m²) area with the total
123 number of LANDFIRE and LANDFIRE urban pixels, respectively intersecting the
124 polygon. Burned area and percentages were computed on a per-satellite overpass
125 basis and averaged to hourly resolution.

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126 2.2 Huntington Park AQMD Site Data

127 Several pollutants and meteorological data were retrieved from the AQMD site in
128 the community of Huntington Park, CA. This site measures hourly PM₁₀ elements
129 (ng/m³) (XAFS Sailbri Cooper Inc. Oregon, CA), BC (AE33, Aerosol USA Corp.),
130 PM_{2.5} and PM₁₀ (T640 Teledyne API); UFP (Environmental Particle Counter 3783,
131 TSI); H₂S and CH₄ (G2204, Picarro); NO, NO₂, and NO_x (T200, Teledyne) on an
132 hourly basis. Elements with averages greater than three times the uncertainty in a
133 particular time period were included in our analysis; others were excluded (see SI
134 Section S1.1, Tab. S1).

135 2.3 UCLA Sample Collection and Analysis

136 In addition to the AQMD dataset we collected six PM_{2.5} sample filters on acid
137 washed 47 mm Teflon filters (Cytiva) and a cyclone separator (URG-2000-30E-42-
138 2.5, URG) at 92 LPM. The field blank was handled the same way as samples except
139 air was pulled through it for only 30 seconds. Filters were weighed in a
140 temperature and humidity controlled room before and after sampling using a
141 microbalance (Sartorius ME-5). Prior to chemical measurements, filters were
142 analyzed for black and brown carbon using an optical transmissometer (OT-21,
143 Magee Scientific, Portland, USA) at 370 and 880 nm. A detailed description of data
144 processing and loading correction can be found in Kuang et al., (2017).³⁸ Total
145 concentrations for 26 elements were determined using Sector Field Inductively

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146 Coupled Plasma Mass Spectrometry (Thermo-Finnigan Element XR; see section
147 S1.2 for list of elements).³⁹

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149 **2.4 Local wind speed and direction data near the burn areas and back**
150 **trajectories.**

151 We used wind data from Huntington Park, and Eaton Canyon (SE215) [34.175, -
152 118.095], and Rubio Canyon (SE139) [34.200, -118.123] sites to characterize the
153 wind speed near the Eaton fire ignition site.⁴⁰ The latter two sites are 1.33 and 1.88
154 km from the ignition site of the Eaton fire, respectively (SI Fig. S1). SI Figure S2
155 shows Santa Ana wind periods which are consistent with the U.S. Forest Service
156 Santa Ana Wind Threat Index and red flag warning dashboard.⁴¹

157 Five hour air mass back trajectories were calculated with the NOAA Hybrid Single
158 Particle Lagrangian Integrated Trajectory (HYSPLIT) model for both the AQMD
159 and UCLA receptor sites to confirm that sampled air masses passed through the
160 active burn area.^{32,33} The NOAA High-Resolution Rapid Refresh (HRRR) 3-km
161 resolution archived data was chosen for its high resolution. To avoid surface
162 effects that can influence the model, the starting elevation was set to 250m.

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163 2.5 Statistical analyses

164 To analyze the AQMD dataset we used the Spearman rank correlations (r_s) using
165 the scipy.stats package in python and the U.S. EPA Positive Matrix Factorization
166 (EPA PMF 5.0) model.^{42,43} The EPA PMF model was run with a minimum of 100
167 hourly measurements in line with the recommended minimum sample size. For a
168 detailed description of PMF input parameters and quality checks see SI Section
169 S1.3.

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172 Results and Discussion

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174 3.1 Locations and Fire Progression

175 Figure 1a shows the locations of the Eaton [34.203, -118.088] (yellow) and Palisades
176 [34.070, -118.544] (red) ignition sites, along with the two receptor sites for this
177 study – Huntington Park [33.980, -118.217] (blue/purple) and UCLA [34.069, -
178 118.445] (blue/gold) – and the smoke plumes on January 10, 2025. Figure 1b shows
179 new burned areas and the proportion of urban lands burned compared to the total
180 burn area as a function of time for the Eaton fire. SI Figure S3 shows a similar plot

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181 for the Palisades fire. Most structures were consumed in the first two days of both
182 fires peaking at ~50% burn area contribution. However, since fuel loading in urban
183 areas is estimated to be larger than for vegetation areas, urban fire is estimated to
184 contribute more than 50% of the fuel in the earlier period.⁴⁴ While urban fire made
185 up a small fraction of the new burned area by the morning of January 9 and later,
186 fuel consumed contributions by urban vs vegetation depend highly on the
187 assumed duration of combustion (which is uncertain) with urban fire still having
188 the potential to contribute a large fraction for longer durations.⁴⁴

189 3.2 Metal concentrations during the wildfires

190 3.2.1 Huntington Park Site

191 Table 1 shows the time periods associated with each of the analyses below. From
192 the data prior to the fire, we selected the closest match to the post-fire period
193 (January 13 – 28, 2025) based on wind speed and direction, and avoiding major
194 holidays. During these periods winds were predominantly south/southwesterly,
195 from the coast (SI Fig. S4). While wind characteristics for our control period are
196 similar, it does not necessarily match other meteorological variables that impact
197 plume dilution, such as boundary layer height.

198 During the fires, the Huntington Park data show distinct patterns for fine smoke
199 ($PM_{2.5}$) and coarse ($PM_{10-2.5}$) particles (Fig. 2), with mass concentrations peaking at
200 as much as 20 times their respective urban backgrounds observed in late

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201 November-early December. PM_{2.5} has four distinct high peaks between Jan. 7 - 11,
202 while the coarse mode has only one high peak, followed by a few smaller peaks.
203 The Huntington Park site was in the Eaton fire plume for at least part of each day
204 from January 7 – 9 (SI Fig. S5). On the 10th, back trajectories included the near-
205 coastal area expected to contain lingering smoke from both the Eaton and
206 Palisades fires.

207 Figure 2 also shows time series for Pb, As, chlorine (Cl), Ca, Ti, Fe and K. Like
208 PM_{2.5}, Pb, Cl and As also have four peaks (Fig. 2), as do bromine (Br), sulfur (S), Cu,
209 Zn and BC (SI Figs. S6–S9). Pb, Cl and As exceeded their average urban
210 background concentrations by about 250, 30 and about 20 times, respectively (SI
211 Fig. S7-S8). The Pb content in the particles (e.g., its mass-normalized concentration)
212 was also highly elevated (Fig. 2k), approaching 2% of PM_{2.5} mass, a factor of 10
213 higher than its background. While a handful of other elements (Ca, Al, Si, K,
214 rubidium (Rb) and Zn) had mass-normalized concentrations that exceeded their
215 respective backgrounds during the fires, these elements exhibited many other
216 peaks that were the same or larger at other non-fire times (SI Figs S10-S12).

217 In contrast to PM_{2.5}, the coarse particles started to increase several hours before
218 ignition of the Eaton fire, coincident with the onset of strong Santa Ana winds, and
219 they increased further shortly after ignition (Fig. 2). PM₁₀, Ca, Ti, Fe and K (Fig. 2),
220 Al, Si, Cr, Mn, nickel (Ni), strontium (Sr), and barium (Ba) (SI Figs. S8 and S9) all

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221 have similar time series. Peak concentrations for Ca and K were about 30 times and
222 Ti and Fe about 15 times their background levels.

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224 3.2.2 UCLA PM_{2.5}

225 We collected six PM_{2.5} filter samples plus a blank on the roof of the Mathematical
226 Science Building (32m above ground level) at UCLA, from January 7 – 14, 2025.
227 Filters were analyzed for mass, black and brown carbon and total concentrations of
228 26 elements. Four filters (#2-5) were partially impacted by the fires based on back
229 trajectories (SI Fig. S13) and chemical composition, and all except #2 was collected
230 after the fire fronts had moved primarily to wildlands (Figs 1, SI S3 and S13). Filter
231 #2 was partially downwind of the small Sunset fire [34.110, -188.353], which
232 burned vegetation surrounded by urbanized areas; all were likely impacted by one
233 or both of the Eaton and Palisades fires. At the UCLA site highly elevated (by more
234 than a factor of 10) volume-normalized concentrations of Pb, Zn, Cu, As, Ni, BC, S,
235 and tin (Sn) were observed in the fire-impacted samples #2-4, especially on January
236 9th (Filter #3, Fig. 3). K, Ba, phosphorous (P), zirconium (Zr) and Cr were elevated
237 by less than a factor of 10.

238 The only elements that had appreciably elevated mass-normalized concentrations
239 in the fire-impacted samples were Pb and Cu; Pb was about 0.6% of PM_{2.5} at its
240 peak, exceeding Al and Fe. In contrast, Al, Fe, Ca, Mg, Ti, Mn, Ba, Sr, vanadium

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241 (V), Zn and Cr each contributed markedly less to $PM_{2.5}$ mass during the fires than
242 to the samples with little or no fire impact. BC, K, S, Sn, As and Ni were fairly
243 constant across all samples. Filter #5 appears to be more like the non-fire samples;
244 it is unclear if that is because it is mostly typical urban $PM_{2.5}$ or another reason,
245 such as smoke originating from areas far from the urban edge. This indicates that
246 while fire emissions overwhelmed urban sources of particulate pollution, the fire-
247 related $PM_{2.5}$ particles were comprised of smaller amounts of many elements but
248 higher amounts of a few metals: Pb, Cu and to a lesser degree, Zn compared to
249 non-fire particles.

250 3.3 Source apportionment for the Huntington Park site

251 The background periods (Tab. 1) were best fit with 3-factor solutions: a mixed
252 marine source and two urban sources (SI Fig. 14). Note that our 'sources' derived
253 from PMF in different periods and named the same way are similar, but not
254 identical. The Huntington Park site is about 20 km from the coast and winds are
255 predominantly onshore. The mixed marine source has high loadings of Cl, Br, and
256 S and $PM_{2.5}$ and 10 - 25% of many other elements, including about 15% of the K.
257 The urban dust factor has 60 – 80% of the Si, K, Ca, Ti, Mn, and Fe, along with NO
258 H_2S , As, and Sr, and 20 – 30% of Cr and Pb. The second urban factor has high
259 loadings of NO, BC, Pb, and Cr. Br, Cu, and Zn, elements associated with brake
260 and tire wear⁴⁵ are fairly evenly split between these two factors.

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261 During the fire (January 7 – 11), data were best resolved with a four-factor solution
262 (Fig. 4). The ‘smoke’ factor is characterized by high loadings of Cl, Pb, Br, Zn, As,
263 Cu, BC and PM_{2.5} and agrees with earlier structure fire smoke measurements.^{9,12,27}
264 Pb, As, and Cu have been associated with emissions from burning common
265 building materials such as copper wiring and piping, pressure-treated wood and
266 lead-based paint, and persist in the urban environment over decades.^{9,12,46}
267 Halogens in PM_{2.5} have been linked to burning plastics, including polyvinyl
268 chloride (PVC), and brominated flame retardants, which are widely used in
269 construction, household goods, and insulation.⁹ The smoke factor has four distinct
270 peaks (Fig. 4e) closely matching the smoke-associated elements (Fig. 2), and
271 includes about 17% of the K. Contributions from this factor were minimal after
272 midday, January 10. The fire-crustal factor contains ~70% of the elements Si, Ca,
273 Ti, Fe, Sr, K and PM_{10-2.5}. This factor is dominant during the initial phase of the fire
274 coincident with the high wind period (Figs 2 and 4), after which it decays away.
275 The remaining two profiles are similar to the mixed urban profiles observed before
276 the fires (SI Fig. S14), although one of them contains more S and Cl than the urban
277 factors in the pre-fire period, suggesting marine influence in this factor.

278 The period immediately after the fire, from January 12 – 18 was best fit with a four-
279 factor solution (SI Fig. S15). This solution splits the crustal elements, with one
280 factor containing 75% of the Pb, 45-60% of the K, Ca, Ti, Ca, Ti, Mn, Sr, around 30%
281 of the Cu, As, Ba and Zn. The other crustal factor contains zero Pb and 20-40% of

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most all other elements except S, Cl and Br. The other two factors are similar to the mixed transportation and mixed marine factors observed during the background period. PM concentrations were much lower than during the fire and in the normal range (SI Fig. S6), but Pb moved from being strongly associated with the mixed transportation factor before the fires (and the smoke factor during the fires) to the crustal factor (SI Figs. S15-S20).

The next post-fire periods (January 19 – 23 and 24 – 28) were best fit with three-factor profiles (SI Figs. S16-S17) that are similar to the pre-fire period. However, Pb remains primarily associated with the crustal-dominated factor rather than the mixed transportation factor prior to the fires. This pattern persists at least through late February, the last time we were able to investigate (Fig. S18-20). This could potentially be due to resuspension of lead-enriched smoke particles deposited on the soil. During this period however, in absolute terms, the airborne Pb concentration was lower than in the fall prior to the fires and often below the limit of detection (SI Tab. S2, Fig. S9).

3.4 Correlation Analyses for Smoke Peaks and other Shorter Periods

To explore shorter duration events, we calculated Spearman's r correlation heat maps (Tab. 1, Fig. 5, SI Figs. S21-28). During the background period most elements as well as BC, methane and NO_x were strongly correlated with $\text{PM}_{10-2.5}$ and in most cases, with one another (SI Fig. S21). In contrast, the elements associated with

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302 mixed marine PMF factor, S, Cl, and Br, correlate with $PM_{2.5}$. All other pollutants
303 except $PM_{10-2.5}$ have insignificant or weakly negative correlations with $PM_{2.5}$.

304 Strong winds, a proximate cause of the massive fires, began about 9 hours before
305 the Eaton Fire ignited. HYSPLIT back trajectories (SI Fig. S5) for this period
306 confirm direct transport from the Eaton Fire area to Huntington Park, although
307 pollutants may also originate from other areas along the trajectory. During this
308 period, correlations between the crustal elements Al, Si, Ca, Ti, Mn, Fe, K and Sr
309 and $PM_{10-2.5}$ tightened ($r > 0.96$) (SI Fig S22). Because of the distance from the fire to
310 Huntington Park, substantial amounts of $PM_{10-2.5}$ from the fires might be expected
311 to reach the site during high winds present at the beginning stages of the fires
312 when transport times were under a few hours, but less so later.

313 SI Figures S23 – S25 show the correlation heat maps for smoke peaks 1, 3, 4, and the
314 last days of the Eaton and Palisades fires, respectively. During peak 1, winds,
315 $PM_{10-2.5}$ and $PM_{2.5}$ were both high and correlated, so essentially all elements are
316 correlated with one another. During peaks 3 and 4 burning was primarily in
317 wildland areas and back trajectories were partially from a fire area (SI Fig. S5).
318 $PM_{2.5}$ was more elevated than $PM_{10-2.5}$ and winds were low, so the latter likely had
319 more contributions from local sources. These peaks are less distinct but mostly
320 separate $PM_{2.5}$ and $PM_{10-2.5}$ clusters compared to smoke peak 2 (see Fig. 5). The
321 crustal elements are less tightly correlated; K correlates with $PM_{2.5}$ in peak 3 and
322 with $PM_{10-2.5}$ in peak 4 (SI Fig. S25). Comparing the four smoke peaks, the first two

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of which took place when a large fraction of the burning was in urban areas and the last two in wildlands does not reveal a clear chemical signature of wildland vs. urban burning.

Figure 5 shows the correlation heat map for smoke peak 2 from 9:00 – 18:00, January 8, when the ratio of urban to wildland area burned was highest (Fig. 1b). At this time, $PM_{10-2.5}$ and $PM_{2.5}$ were negatively correlated, allowing the smoke and coarse particles to be cleanly separated. The smoke components, $PM_{2.5}$, Cl, Br, S, Pb, Cu, Zn, As, BC are all tightly correlated. UFP are correlated with the crustal elements, but also with methane and NO_x ; because the fires were 28 km from the site and UFP coagulate rapidly, elevated UFP from the fires are not expected. Al, Si, Ca, Ti, Mn, Fe and Sr and $PM_{10-2.5}$ correlate with one another ($0.88 < r < 0.99$) more tightly than during the non-fire reference period ($0.73 < r < 0.94$). This is consistent with several studies that report enhanced dust emissions in wildfire plumes,^{28,31} although especially because winds had died down there was likely less contribution of the fires to $PM_{10-2.5}$. However, similar to in the UCLA $PM_{2.5}$ samples, the (mass-normalized) $PM_{10-2.5}$ content of several elements, including Cr, Ni, Ba, S and Se drop during the fires, and K and Cl have many higher peak concentrations during non-fire periods (SI Figs. S11, S12, Tab. S2), suggesting higher content of these elements in particles from local soil and industrial sources than from the fires.

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343 For the last days of the fires (Jan. 10-12) and during the post-fire periods the
344 correlation matrices (SI Figs S26-28) are similar to Nov.-Dec. pre-fire period (SI Fig.
345 S21); most pollutants correlate with one another and there is a more or less clear
346 marine-related cluster.

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349 Discussion

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351 4.1 Potassium as a marker for fire emissions

352 The elemental data collected at both the UCLA and Huntington Park sites are not
353 consistent with the idea that K is a useful indicator of either structure or wildland
354 burning for either $PM_{2.5}$ or $PM_{10-2.5}$ particles in the Los Angeles area. During the
355 fires, the PMF analysis places 63% of the K with the coarse particles and divides the
356 remaining K fairly evenly among the smoke and urban factors. The K content in
357 the particles rose and was tightly correlated with crustal elements and $PM_{10-2.5}$
358 during the high wind period before the Eaton fire ignited (Figs. 2, 4, SI Fig. S22). It
359 continued to cluster primarily with crustal elements throughout the fire period
360 except briefly during smoke peak 3 (Fig. 5, SI Figs. S23 – S25). Further, there were
361 several other non-fire periods in the fall and spring during which particles had

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362 higher K content (SI Fig. S11). At the UCLA site, the mass-normalized $PM_{2.5}$ K
363 concentration was largely unchanged for fire and non-fire samples (Fig. 3).
364 Potassium hovers around 1-2% of both PM_{10} and $PM_{2.5}$ at the two sites (Fig. 3, SI
365 Figs. S11 and S14). Rodenas et al.⁴⁷ reported 1 – 7% K content in particles from a
366 biomass burning in a laboratory setting; in the absence of fires, K content in the
367 particles at the two sites already falls within this range. Taken together our results
368 suggest that while the burning particles do contain significant K—unlike many
369 crustal elements, K does not decline in the UCLA smoke $PM_{2.5}$ samples—, the
370 enhancement is not enough for the element to be a useful burning tracer in this
371 area, in line with the result found for the area around Beijing.^{26,48}

372 4.2 Persistence of fire-related particulate pollution after the fires were 373 extinguished

374 In the absolute concentration data (SI Tab. S2), there is no evidence that PM
375 concentrations nor fire-related elements were elevated after the fires. PM
376 concentrations were not elevated outside their normal ranges even during the first
377 few days after the fires (SI Fig. S6). Pb, the element most elevated compared to non-
378 fire periods, had lower average concentrations in the spring following the fires
379 than it did in the fall prior. The PMF analysis did however move Pb to be
380 associated with the $PM_{10-2.5}$ and the crustal elements rather than the mixed
381 transportation source, a pattern that persisted at least into February (SI Figs S18-

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20). This may suggest resuspension of lead-enriched PM_{2.5} particles that deposited on the soil.¹⁹ However, this crustal factor contributes little to PM mass (less than 2%), with the exception of a few brief spikes. Thereafter, the contribution returns to background levels (SI Figs. S14 –S20). Further, because resuspension of deposited particles would not cease when active burning stopped, the lack of elevated PM and fire-related elements after the fires (SI Tab. S2; SI Fig. S6) is inconsistent with resuspension as a major contributor to element levels during the fire in our data.

Several previous WUI fire observations have found elevated structure-related elements such as Cu, Pb, Sn, Sb, As, Zn and Cr in ash and dust in near-fire zones.^{14, 15,49,50} For example after the 2021 Marshall fire, where sampled dust in smoke impacted homes carried elevated metals such as Pb, Cu, Cr, and Zn that persisted indoors for weeks and were resuspended by household activities like vacuuming and running the fan.^{14,15} However, most resuspended particulate matter mass is in a size range that would not be expected to travel long distances and impact communities 10s of kms away. Taken together with the observation that the coarse PM crustal elements were only high during high wind periods, these patterns indicate that fire-related pollution did not persist appreciably in the broader Los Angeles area after the fires and that the enrichments we report primarily reflect active burning.

4.3 Comparison with Air Quality Standards

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The US Environmental Protection Agency National Ambient Air Quality Standard (NAAQS) for Pb is 150 ng/m³ in total suspended particles, as a rolling three-month average.⁵¹ The US also has occupational exposure limits, but they are much higher. At the Huntington Park site, PM₁₀ Pb averaged about 2.1 ng/m³ during the pre-fire baseline (Nov 27–Dec 11, 2024), then rose to about 108 ng/m³ during the active fire period (Jan 7–12, 2025). Over a 3 month period from January to March 2025, the average was about 10.2 ng/m³, well below the NAAQS, although these are PM₁₀-based measurements rather than the TSP basis on which the NAAQS is defined.

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4.4 Comparison with other WUI fires

Data for elements in smoke from WUI fires is very limited. The most relevant smoke study is of the Camp Fire, a large fire in Northern California. This fire, like the combined Eaton and Palisades fires consumed about 18,000 structures, but about 10 times as much wildland. Boaggio et al.¹² reported that Pb concentrations on days impacted by smoke from the Camp fire were more than 40 times higher than background at a monitoring station roughly 200 km away.¹² Our data show Pb concentrations at its height reaching above 250 times the background; over the entire fire period it averaged 65 times higher (Fig. 2, SI Fig. S9). Larger enrichment is expected for the closer proximity of our receptor sites (20 – 40 km), but other factors may also play roles, particularly the makeup of the structures and the local

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422 geology. Boaggio et al.¹² also observed consistently elevated Cu, Mn and As in
423 smoke from WUI fires, but did not indicate by how much. Cu and As are also
424 associated with smoke in our samples, but Mn is associated with the coarse mode
425 particles (SI Fig. S8–9).

426 Kelly et al.²¹ measured elements in smoke 7 – 30 km offshore from the 2017 Thomas
427 fire which burned about 1060 structures and 114,000 hectares of land in coastal
428 southern California north of Los Angeles. While this has been considered a WUI
429 fire, the ratio of structures to wildland area burned is small compared to the Los
430 Angeles fires; further, measurements were performed on day 10 of the fire, when
431 primarily wild lands were burning. Both their volume and mass-normalized metal
432 concentrations were at the low end or below the ranges of the annual averages for
433 the Huntington Park site and the non-fire samples at UCLA, but well above
434 reference values over the Pacific Ocean.²¹

435 Boaggio et al.¹² suggested the ratio of (Pb + Cu)/K ratio as an indicator of structure
436 fire burning. This ratio is shown in SI Figs. S29 and S30 for the UCLA and AQMD
437 Huntington Park datasets, which ranged from 0.02 - 0.35 (six samples) and 0.02 -
438 0.46 (Jan 1 - Mar 30, 2025), respectively. The peak values exceeded the maximum
439 Camp Fire value of 0.11.¹² The highest UCLA values occurred between January 8
440 and 10, at the height of structure burning (Figs. 1b, 3d, 3e, SI S3). This ratio was also
441 high during the fires at the Huntington Park site. However, in the three month
442 dataset there were multiple other peaks that were similar or higher than the peak

443 fire values. While this ratio may have utility as an indicator of WUI fire smoke, it
444 should be used with caution.

445 **4.5 Markers of urban vs. wildland fires**

446 Many elements expected to be enhanced in urban fire smoke are clearly evident,
447 including Pb, As, Cu, Zn, Cl, and Br in the initial smoke peaks when urban burning
448 was high (Fig. 2). Yet once the newly active urban burn area became low, these
449 elements remained high in the smoke, with only slightly weaker cross-correlations
450 (SI Figs. S24–S25). The Pb content of the particles when only about 10% of the
451 burning area was urban (smoke peak 4) was essentially the same as when about
452 50% of the burning area was urban (smoke peaks 1 and 2, Fig. 2k). If Pb originated
453 solely from burning structures, its mass-normalized concentration should have
454 declined as the burned area shifted toward vegetation; instead, it persisted,
455 indicating that Pb does not cleanly distinguish urban from wildland burning.

456 Several explanations are possible, including the persistence of high-Pb particles in
457 the air from earlier days of the fires, the potential for long combustion times in
458 urban fires (see Section 3.1), and the accumulation of Pb in (burning) soils adjacent
459 to the urban area. Pb emission factors from natural fuels are generally low,⁵² but
460 prior work has reported elevated soil Pb in urban areas including the Los Angeles
461 area, attributed to legacy leaded gasoline, lead-based paint, and industrial
462 emissions,^{53–56} however it is not clear how far into the surrounding wildlands this

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463 contamination reaches. Lead and related elements are clearly indicative of a WUI
464 fire, however within a single fire event these elements do not support
465 differentiation of structure vs. wildland burning.

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468 Conclusions

469 In this study we investigate the composition of smoke transported tens of
470 kilometers from the large WUI fires that took place in 2025 in the Los Angeles
471 California area. We found elements associated with resuspended soils were
472 elevated prior to fire ignition, coincident with high winds, and then decayed as
473 winds subsided. Potassium, commonly used as a biomass burning tracer, was
474 uncorrelated with smoke $PM_{2.5}$ particles and was instead associated with coarse
475 particles, indicating that K is not a reliable fire tracer in this geographical context.
476 Lead and several other elements were highly elevated in the smoke and remained
477 high even after the burning transitioned from urban to wildland areas. Fire-
478 associated pollution was only detectable for approximately six days following the
479 event and remained at background levels in the months that followed.

480 The persistence of Pb concentrations even after the majority of urban burning had
481 occurred, the lack of an elemental signature of urban vs. wildland fires, and the

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482 lack of an association between potassium and smoke highlights the complexity of
483 WUI emissions. Better understanding of the area's soils and their emissions as they
484 are pyrolyzed could help unravel the causes of both Pb and K behavior. As WUI
485 fires become more common and intense, our results should caution researchers
486 against assuming K is useful as a wildfire tracer in the Los Angeles area and
487 potentially other locations and reassure Angelenos that the fires have not
488 degraded air quality across greater Los Angeles over the long term.

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491 **Supporting Information**

492 The supplementary information includes site locations, metal selection criteria, and wind
493 data; VIIRS imagery for the Palisades Fire; HYSPLIT back-trajectories for each site; mass-
494 and volume-normalized particulate matter, black carbon, and metals data for the full
495 study period at the AQMD site; background and post-fire results from positive matrix
496 factorization (PMF) and Spearman rank correlation analyses; a summary of
497 concentrations for select metals across analysis periods; and lead-to-potassium and
498 copper-to-potassium ratios used to identify urban burning at each site.

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508 **Author Contributions**

509 CB, KC, LT Formal Analysis; CB, KC Investigation; CB, KC, SP, LT, PS Methodology;
510 KC, CB, LT Data Curation; CB, KC, LT Visualization; CB, SP, KC, LT Writing -Original
511 Draft; SP, CB, KC, PS Writing- Review and Editing; SP Conceptualization and Funding
512 Acquisition.

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741 **Figures and Tables**

742 **Table 1.** Time periods selected based on the wind data retrieved at the Eaton
743 Fire start.

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Time Period	Analysis	Start	End	Huntington Park wind speed (m/s) avg. $\pm$ st. dev.	Comments
Pre-fire	PMF	11/28/24 00:30	12/4/24 23:00	0.98 ± 0.68	Background period split into two periods for better fit.
		12/5/24 00:30	12/9/24 23:00	0.79 ± 0.45	
	Heat map	11/27/24 00:30	12/12/24 23:00	0.95 ± 0.62	Background period.
		1/7/25 8:00	1/7/25 18:00	2.17 ± 1.27	Brief period of Santa Ana winds immediately before ignition.
Fire Smoke peak 1 Smoke peak 2 Smoke peak 3 Smoke peak 4	PMF	1/7/25 18:00	1/11/25 23:00	1.09 ± 0.93	Eaton fire ignition at 18:18.
	Heat map Fig. 2 color: Green Yellow Pink Orange	1/7/25 22:00	1/8/25 7:00	2.04 ± 0.93	High winds at Huntington Park, urban fire.
		1/8/25 9:00	1/8/25 18:00	0.87 ± 0.28	Winds die down, urban fire.
		1/9/25 1:00	1/9/25 11:00	0.79 ± 0.20	Shift from urban to wildland fire.
		1/9/25 21:00	1/10/25 11:00	0.58 ± 0.15	Wildland burning continues for both Palisades and Eaton fires.
		1/10/25 12:00	1/12/25 12:00	0.87 ± 0.44	Wildland fires continue.
Post-fire	PMF*	1/12/25 00:30	1/18/25 23:00	0.95 ± 0.51	For post-fire analysis, PMF is split into seven periods to capture separate high wind periods for two months post-fire, and to ensure that enough data entries are used for each period.
		1/19/25 00:30	1/23/25 23:00	1.01 ± 0.54	
		1/24/25 00:30	1/28/25 23:00	1.31 ± 0.64	
		1/29/25 00:30	2/5/25 12:00	1.00 ± 0.59	
		2/5/25 13:00	2/12/25 23:00	1.19 ± 0.61 1.15 ± 0.72	

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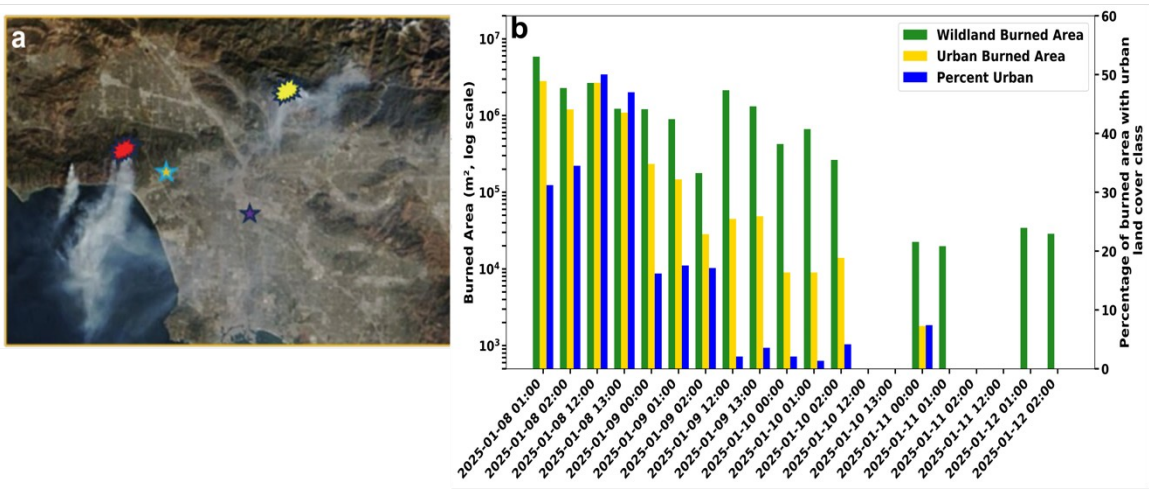
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		2/13/25 00:30	2/20/25 23:00		
	Heat maps	1/12/25 13:00	1/19/25 23:00	0.95 ± 0.53 1.19 ± 0.65	First week after fires.
		1/20/25 00:30	1/28/25 23:00		

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748 **Figure 1.** (a) Satellite map of the Palisades (red) and Eaton (yellow) fire
749 smoke plumes, the Huntington Park (purple) and UCLA (blue/gold)
750 site on January 10, 2025, at approximately 10 AM.⁵⁷ (b) Bar plot of
751 new burn area of wildland (green) and urban (yellow) areas (left axis,
752 log scale) and percentage of total burned area (blue) classified as
753 urban (right axis, linear scale) for each satellite overpass for the
754 Eaton fire.

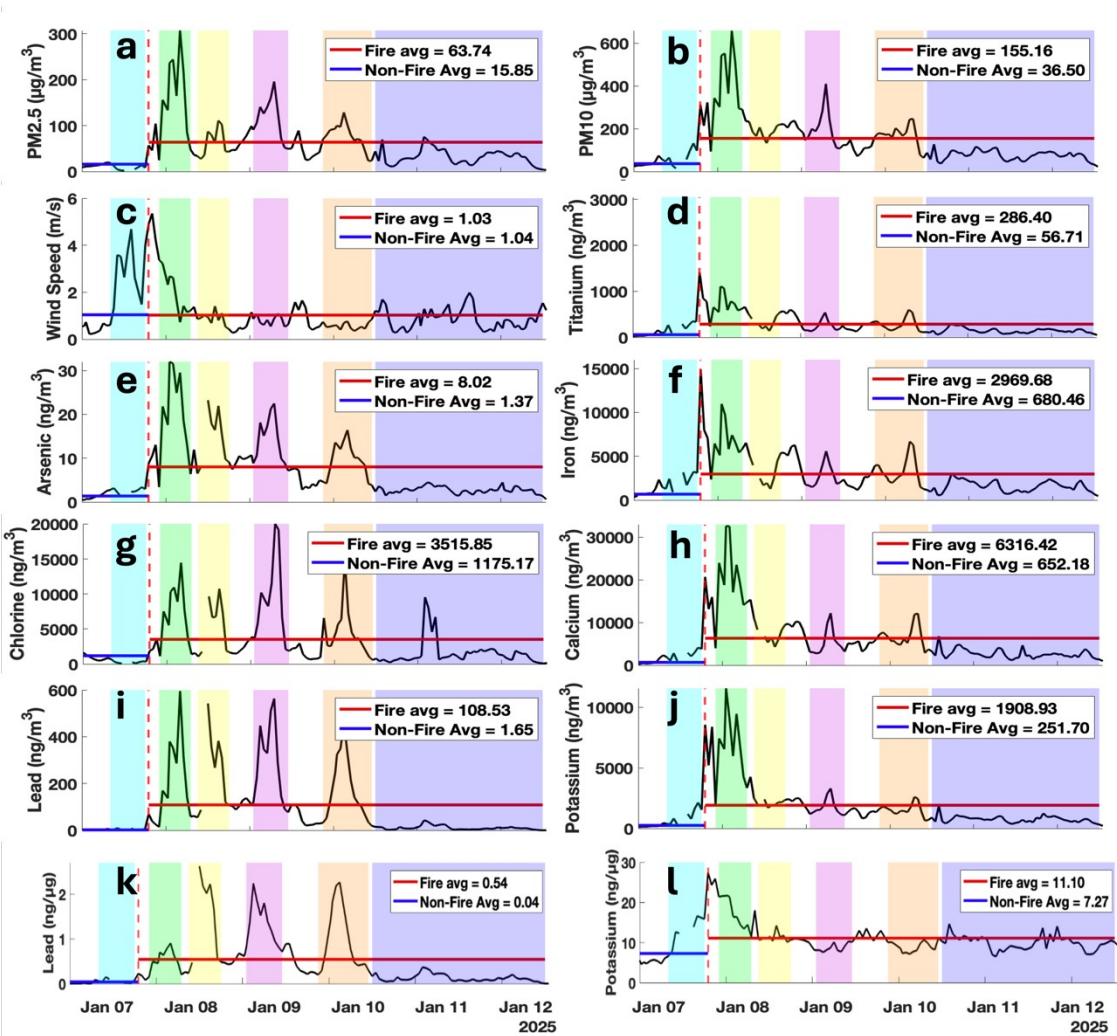
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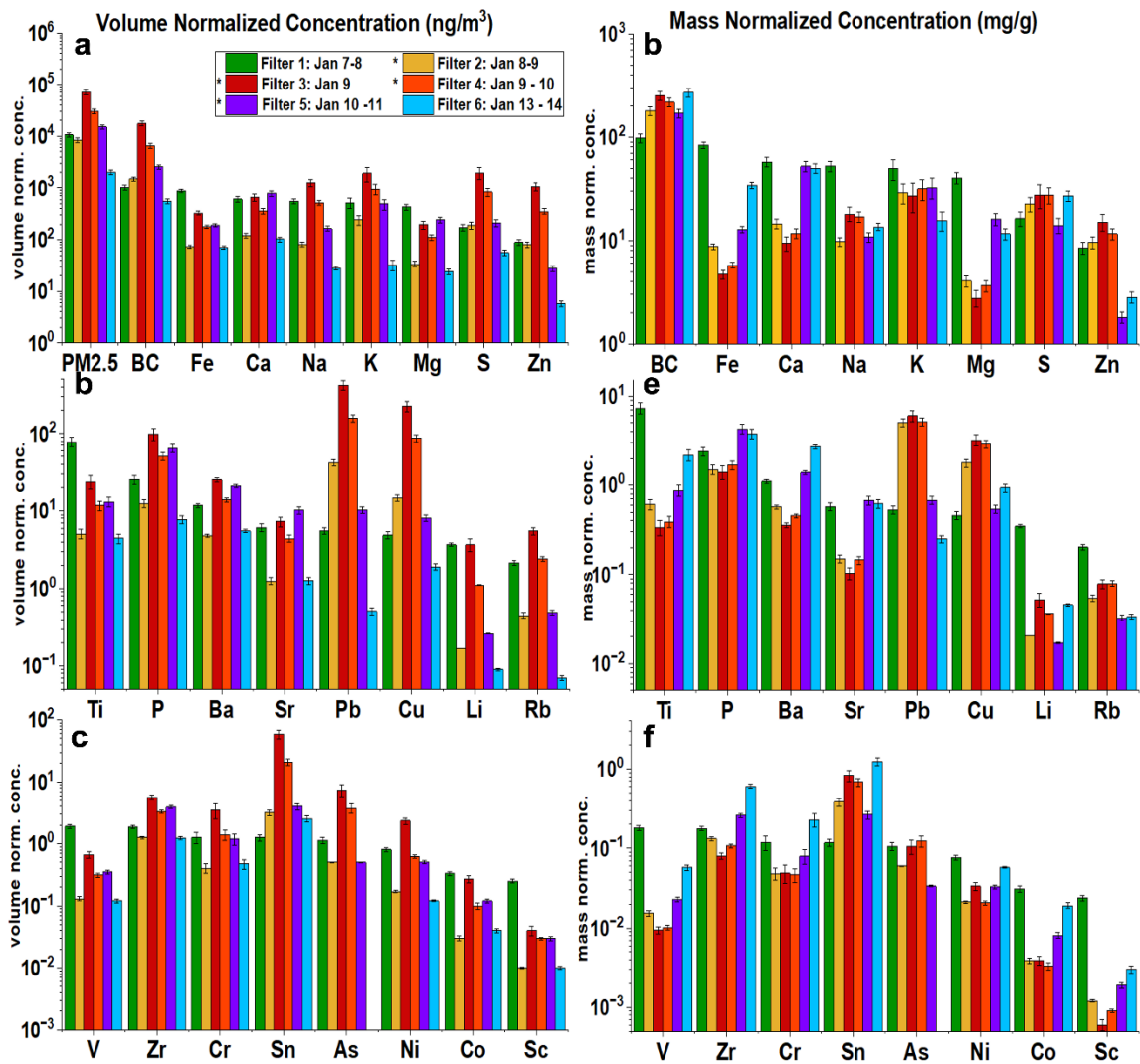
Figure 2. Time series of Huntington Park of (a) PM_{2.5} and (e, g, i) three smoke-associated elements ; (b) PM₁₀ and (d, f, h, j) four associated crustal elements; and wind (c) during the high-wind pre-fire period (blue), smoke peaks 1-4 (green, yellow, pink, and orange) and the last days of the fires (purple). Panels (d-j) are volume normalized; k and l are mass-normalized. Fire period average from January 7 - 12 is marked with a red line, and the non-fire average including data from November 2024 - March 2025, but excluding the fire period, is marked by the blue line.

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770 **Figure 3.** Bar plots of elements collected on filters at the UCLA
771 receptor site (log scale) for (a-c) volume-normalized filter collected
772 from Jan 7-8 (jade), Jan 8-9 (yellow orange), Jan 9 (maroon), Jan 9-10
773 (red), Jan 10-11 (orchid), and Jan 13-14 (sky blue), as well as (d-f)
774 mass-normalized (filter collected from Jan. 7 - 8 (green), Jan. 8 - 9
775 (yellow), Jan. 9 (brick red), Jan 9-10 (orange), Jan 10-11 (purple), and
776 Jan 13-14 (blue) All of the samples except the first and last had at
777 least some back trajectories that intersected an area that was
778 burning, although the majority of back trajectories for samples 2 and
779 5 were not from a burn area, *indicates filters sampled with at least
780 some back trajectories leading to active fires; (see text). Data for Al,
781 Mn and W were omitted for clarity; these metals had nearly identical
782 patterns as Fe, Ti/Sr and Co respectively.

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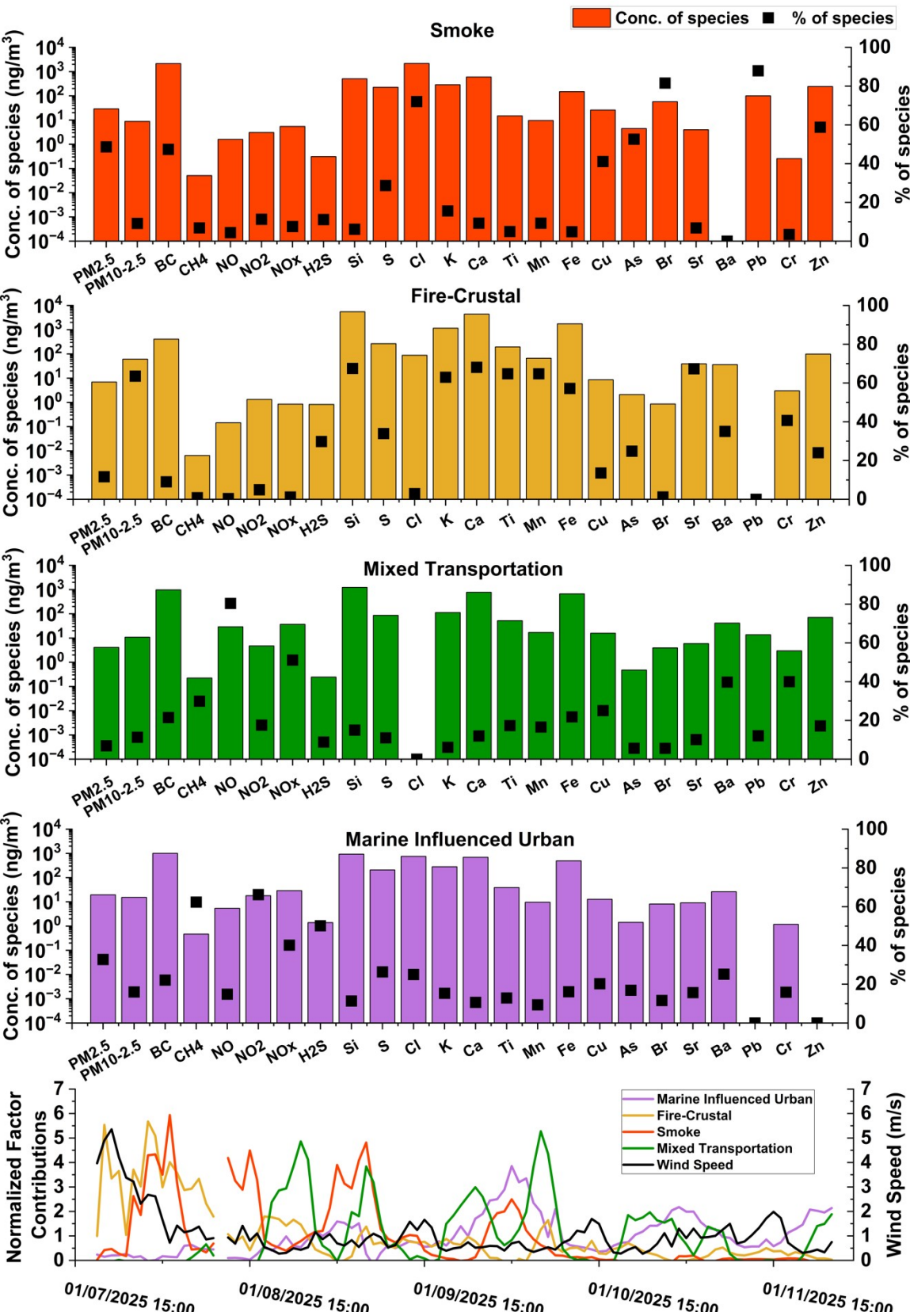
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785 **Figure 4.** PMF results for January 7 – 11, 2025 showing the four-factor
786 source profiles fine smoke particles (red), fire- and wind-related
787 coarse ‘dust’ (orange), mixed vehicular exhaust, brake, and tire wear
788 (green), mixed urban (blue), and corresponding temporally resolved
789 factor contributions and windspeed for the Huntington Park site.
790 PM_{2.5} and PM_{10-2.5} are in µg/m³, gases are in ppm or ppb, BC and
791 elements are in ng/m³. The ‘normalized factor contributions’ in the
792 lower panel show temporal variations in the contribution of each
793 factor relative to itself over time. The black squares in the upper
794 panels show the contributions of each factor to PM_{2.5}, PM_{10-2.5} etc. in
795 absolute terms.

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Figure 5. Correlation heatmap showing Spearman's r values ($p < 0.05$) for 9:00 – 18:00 on January 8 for the Huntington Park site (smoke peak 2). Pink and green indicate positive and negative correlations respectively, and intensity the strength of the

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802 correlation. $PM_{2.5}$ and $PM_{10-2.5}$ are in $\mu g/m^3$, metals are in ng/m^3 , CH_4
803 in ppm and other gases are in ppb.

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