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A thesis submitted in partial satisfaction of the

Requirements for the degree Master of Science

in Civil Engineering

by

Carmen Lizeth Fregoso Valdovinos

2025

ABSTRACT OF THE THESIS

Chromium (VI) Contamination in Residential Soils

After the 2025 Los Angeles Wildfires

by

Carmen Lizeth Fregoso Valdovinos

Master of Science in Civil Engineering

University of California, Los Angeles, 2025

Professor Sanjay Mohanty, Chair

Wildfires are increasing in frequency and severity across California, particularly in the wildland–urban interface, where they threaten not only structures but also environmental quality. Among the many toxic metals that can be generated during wildfires at wildland-urban interfaces, chromium is of concern because its hexavalent form [Cr(VI)] is soluble, mobile, and carcinogenic. This study aims to understand whether the 2025 Los Angeles wildfires have elevated Cr(VI)

concentrations in residential soil and whether the debris and topsoil removal within the ash footprints lowered the chromium (VI) concentration.

Soil samples were collected from burned homes, standing homes, and reference non-burned sites from two burned zones: Palisades Fire and Eaton Fire near Altadena. From burned properties, composite soil samples were collected from the area where debris and soil were scraped and from the surrounding perimeter area where soil was not remediated or removed. From standing homes, composite soil samples were collected from four locations: front yard, back yard, left side yard, right side yard. In some cases, two composite samples were collected, one from close to the standing home and one from far from the fence. Cr(VI) was extracted using phosphate buffer and analyzed using Inductively Coupled Plasma–Mass Spectrometry (ICP-MS). Data were analyzed in Python with nonparametric statistical tests to compare concentrations across site categories.

Median Cr(VI) concentrations in both Altadena (0.22 mg/kg) and Palisades (0.12 mg/kg) were below the US EPA residential soil screening level of 0.95 mg/kg for carcinogens with a risk factor of 1 in one million. However, soils from some properties exceeded the more stringent California residential screening level of 0.3 mg/kg. These exceedances were observed in standing-home perimeters, burned-home perimeters, and even in some scraped soils. The results confirm that wildfires may have contributed to increased levels of Cr(VI). While scraping overall lowered Cr(VI) level, it did not result in lowering the level below the California health screening level in all properties. In general, Altadena soils contained higher Cr (VI) than Palisades, reflecting differences in recovery, washing off of Cr(VI) during ensuing rainfall events after the fires, and legacy contamination. Particle-size analysis revealed that fine fractions (<75 μm) were enriched in Cr (VI), underscoring their mobility and potential for inhalation exposure.

Overall, this study demonstrates that Los Angeles wildfires elevated Cr (VI) levels in residential soils, which exceeded health-based thresholds under California guidelines in some properties. The debris removal or soil clean-up practices lowered the level, but they still left some properties with an elevated level of Cr (VI), which may pose a long-term health risk. These findings provide a scientific basis for targeted soil monitoring and site-specific remediation based on site history and terrain so that rebuilding efforts can protect public health in fire-impacted communities.

The thesis of Carmen L Fregoso Valdovinos is approved.

Jennifer Ayla Jay

Shaily Mahendra

Sanjay Mohanty, Committee Chair

University of California, Los Angeles

2025

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List of Acronyms

A	Away from home
ASCE	American Society of Civil Engineers
B	Back of the house
BH	Burned home
C	Close to home
CI	Confidence interval
Cr(III)	Trivalent Chromium
Cr(VI)	Hexavalent Chromium
EPA	Environmental Protection Agency
F	Front of house
ICP-MS	Inductively Coupled Plasma-Mass Spectrometry
L	Side left
MWU	Mann-Whitney U
N or n	Number of Samples
NB	Not burned
Ns	Not scraped
p	Probability value
R	Side right
Sc	Scraped
SH	Standing home
U	Mann–Whitney U test statistic
WUI	Wildland-Urban Interface

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I would like to begin by expressing my deepest gratitude to my advisor, Prof. Sanjay Mohanty, for his guidance, patience, and encouragement throughout this project. His mentorship was invaluable not only in shaping this thesis but also in helping me grow as a researcher. I am also thankful to my committee members for their support and feedback.

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On a personal note, I would like to thank my mother, who has worked tirelessly to make my dreams a reality, and whose love and warm meals were always there on the hardest days—this achievement belongs to her just as much as it does to me. I am also grateful for the friendship of Ruth Choquin, Luis Marin, Josue Escobar, and Shaelyn Rowen, who were my emotional anchors during my time at UCLA.

To all who stood by me in this journey—whether in the lab, the classroom, or beyond—I offer my sincerest gratitude.

Gracias….

1 Introduction

Wildfires are occurring with increasing frequency and severity across the globe, a trend strongly tied to climate change (Jech et al. 2024; Lopez et al. 2023). Rising temperatures, prolonged droughts, and shifts in vegetation patterns create landscapes that are hotter and drier, making them more prone to ignition and sustaining larger, more destructive fires (Jech et al. 2024). Unlike historical fires that were confined mainly to wilderness areas, many modern events occur in the wildland–urban interface, where they destroy homes, businesses, and infrastructure while simultaneously releasing pollutants into the environment (Lopez et al. 2024; Jech et al. 2024). In January 2025, Los Angeles experienced firestorms unlike any in its history. The Eaton and Palisades fires swept through neighborhoods in Altadena and the Pacific Palisades, burning nearly 40,000 acres and destroying more than 16,000 homes, schools, and businesses (Greene 2025). Beyond the immediate devastation, wildfires generate a wide range of hazardous pollutants, including particulate matter, polycyclic aromatic hydrocarbons, and toxic metals such as lead, arsenic, and chromium (Wolf et al. 2008; Lopez et al. 2023; Jech et al. 2024). Because these metals do not degrade and can persist in soils long after a fire, it is critical to examine post-wildfire soils to determine whether toxic concentrations have formed and to assess the long-term risks they pose to surrounding communities (Lopez et al. 2023; Wolf et al. 2008).

Among the many toxic metals released during wildfires, chromium is of particular concern because its hexavalent form [Cr(VI)] is highly soluble, mobile, and carcinogenic (Wolf et al. 2008; Thery et al. 2024). Recent work has shown that fire can substantially elevate Cr(VI) in soils and ash, especially on metal-rich geologies and at higher fire severities (Lopez et al., 2023). Chromium derives from both natural soils, where it predominantly occurs as trivalent Cr(III), often

substituting structurally into Fe(III) oxides, and from urban materials burned in wildland–urban interface (WUI) fires (Burton et al., 2019; Lopez et al., 2023). Under typical conditions, Cr(III) is comparatively insoluble and far less hazardous, whereas Cr(VI) poses a serious health risk (Burton et al. 2019; Wolf et al. 2008). High wildfire temperatures accelerate otherwise sluggish Cr(III) oxidation by oxygen. Formation of Cr(VI) is thermodynamically favored in hot, alkaline ash and has been observed from ~500–900 °C in combustion experiments (Pavichev et al. 2008; Burton et al. 2019). Heating studies further show large conversions of Cr(III) to Cr(VI) in Cr-substituted iron oxides and soils at wildfire-relevant temperatures, with exchangeable fractions indicating high mobility (Burton et al. 2019; Thery et al. 2024). Given the variability in burn intensity, fuel types, and building materials in urban fires, systematic measurement of chromium speciation in post-fire soils is essential to assess contamination and protect public health (Lopez et al. 2023; Magliozzi et al. 2024).

Many studies have examined the formation of Cr(VI) in soil after wildfire (Table 1). Chromium behavior in soils is highly dependent on environmental and mineralogical conditions, which control whether it remains in the relatively stable trivalent form [Cr(III)] or is transformed into the more toxic hexavalent form [Cr (VI)]. Iron-bearing minerals play a central role, as Cr (III) commonly substitutes into Fe (III) oxides such as goethite and hematite; when these oxides are exposed to heating during fire, structural changes can release Cr and enhance its oxidation (Burton et al. 2019; Botsou et al. 2023). Geological setting further influences chromium levels: ultramafic and serpentine soils are naturally enriched in Cr, making them particularly vulnerable to elevated Cr(VI) generation during fires (Lopez et al. 2023; Botsou et al. 2023). Fire severity also dictates outcomes, with higher temperatures and longer burn durations driving greater proportions of

Cr(III) to Cr(VI) (Thery et al. 2024). Beyond mineralogy and temperature, post-fire soil chemistry can stabilize Cr(VI); for instance, alkaline ash environments favor its persistence in soluble and mobile forms (Wolf et al. 2008). Together, these factors, including iron oxide content, geological substrate, fire severity, and post-fire soil chemistry, determine the concentration and mobility of chromium across burned landscapes, underscoring the complexity of assessing risk after wildfires.

The objective of this study is to evaluate how the 2025 Los Angeles wildfires have altered chromium (VI) occurrence in soils at the wildland–urban interface. The study will test the hypothesis that soil heating during the wildfire could oxidize Cr (III) to Cr (VI) in surface soils, but that the extent of this transformation in the soil will depend on site history and distance from the burned properties. The soil samples were collected from two fire-affected regions with distinct terrain (slope) and geological conditions to examine if these factors affect Cr (VI) concentration. Collectively, the study aims to understand when and where Cr (VI) may be elevated after wildfire and quantify the effectiveness of soil scraping as a mitigation measure to lower Cr (VI) exposure. This work provides insight into the environmental risks associated with chromium mobilization following wildfires and supports strategies for post-fire soil monitoring and community protection.

Table 1. Summary of previously reported studies that examine chromium (VI) fate in soil with and without wildfires.

Study Type	Media	Wildfire	Variable Tested	Effect on pollutant	References
Lab	● Synthetic Fe oxides: Ferrihydrite, goethite, and hematite ● Ferrosol-type soil	Wildland	● Temperature (200–800 °C) ● Mineral type (ferrihydrite, goethite, hematite) ● Soil heating (Ferrosol-type)	● Cr(III) oxidized → Cr(VI) ● Ferrihydrite & hematite: ~50% conversion at 200–400 °C ● Goethite: ~100% at ~800 °C ● Soil: up to 35% of total Cr oxidized; 31–42% exchangeable	(Burton et al. 2019)
Lab	● Synthetic Cr(III)-Fe(III) (oxy)hydroxides	Wildland	● Temperature: (200–800 °C) ● Cr–Fe ratio: 0.1–0.9	● Cr(III) oxidized → Cr(VI) ● Up to ~40% converted at 200–400 °C ● 17–70% of Cr(VI) exchangeable (mobile)	(Burton et al. 2019)
Field	● Soils (residential & nonresidential) ● Inside & outside Marshall Fire perimeter	Wildland Urban Interface	● Burn status (inside vs. outside fire perimeter) ● Land use (residential vs. nonresidential)	● Increased heavy metals in residential areas ● No PAH increase ● Levels below concern thresholds	(Jech et al. 2024)
Lab	Cr-rich soils: ● Ferralsols ● Cambisols ● Vertisols ● Regosols	Wildland	● Temperature (≥400 °C) ● Soil type (Ferralsols, Cambisols, Vertisols, Regosols) ● Initial Cr speciation	● Partial oxidation of Cr(III) → Cr(VI) from 400 °C ● Mobility depends on initial Cr speciation	(They et al. 2024)

Study Type	Media	Wildfire	Variable Tested	Effect on pollutant	References
Field	• Soils (metal-rich, e.g., serpentinite) • Ash and particulates from California wildfires	Wildfire	• Geology: Serpentinite soils and Metal-rich soils • Fire severity • Post-fire persistence	• Cr(III) oxidized → Cr(VI) in soils/ash • Cr(VI) in ash: 327–13,100 µg/kg • High levels persisted up to 10 months post-fire • Mobilized in wind-dispersible particulates	(Lopez et al. 2023)
Review	• Soil organic matter (SOM), • Metals(As, Cr, etc.) • Pyrogenic organic matter	Wildfire	• Effects of wildfire on SOM chemistry • Metal redox cycling: As, Cr • Ecosystem processes	• ISOM solubility increased; +32% N-containing molecules • PAHs doubled • Toxic metals formed (As(III), Cr(VI))	(Lopez et al. 2024)
Field + Lab	• Soil and ash samples (residential & wildland, Southern California fires) • Leachates (DI water, simulated lung fluid)	Wildfire	• Sample type (residential vs. wildland soils/ash) • Leaching solution (DI water vs. simulated lung fluid) • pH conditions (alkaline vs. neutral)	• Cr(III) oxidized → Cr(VI) • Cr(VI) stabilized in high pH leachates • Cr(VI) is dominant in water & lung fluid extracts	(Wolf et al. 2008)
Lab + Pilot field context	• Cr-rich Ferralsols (New Caledonia) • Suspended particulate matter in catchments	Wildland	• Temperature (200–400+ °C) • Mineralogy (Fe-oxide/silicate ratio) • Catchment location (top vs. slope/base)	• Cr(III) oxidized → Cr(VI) at 200–400 °C • Mobility controlled by Fe-oxide/silicate ratio • Risk of freshwater Cr(VI) pollution confirmed	(Thery et al. 2023)

Study Type	Media	Wildfire	Variable Tested	Effect on pollutant	References
Field	● Surface water (baseflow & stormflow) ● Watersheds (burned vs. unburned, urban vs. wildland) ● Ash & debris runoff	Wildland Urban Interface	● Burn status (Burned vs. Unburned) ● Stormflow vs. baseflow ● Particulate size fraction ○ 0.22–1.2 µm	● Metals ↑ up to 200× pre-fire ● Exceeded EPA criteria by up to 16× ● Persisted ~5 months post-fire ● Mostly particulate-bound, some colloidal (Al, Cr, Fe, Pb)	(Magliozzi et al. 2024)
Lab	● EP/TCLP extracts ● groundwater	Analytical Method	● Dissolved Cr(VI) via colorimetric analysis	● Measurement method only (no effect on pollutant)	(Botsou et al. 2021)
Lab + Field	● Ultramafic rocks ● Serpentine soils**,** Lab-heated and Fire-impacted	Wildland	● Temperature (600 °C, 1 h lab heating) ● Soil type (ultramafic/serpentine) Comparison (unheated vs. fire-impacted soils)	● Cr(VI) increased 2–41× after 600 °C heating ● 33–52% of Cr(VI) water-soluble ● Field soils showed smaller increases than lab	(Wolf et al. 2010)
Lab + Field	● Soils & ashes from multiple California wildfires (2007–2009) ● Leachates (DI water, simulated lung fluid)	Wildfire	● Burn setting (residential vs. wildland) ● Leaching medium (DI water vs. lung fluid) ● Storage/preservation conditions	● Cr(III) oxidized → Cr(VI). ● Higher Cr(VI) in residential ash/soil ● Elevated metals (As, Pb, Sb, Cu, Zn) exceeded EPA ● Leachates are highly alkaline (pH 10–12)	(Pavichev et al. 2008)

Study Type	Media	Wildfire	Variable Tested	Effect on pollutant	References
Lab + Field	• Grass (Hyperthelia dissoluta) • Vegetation ash • Topsoil (0–3 cm) from bushfire areas	Wildland	• Temperature (500–900 °C lab heating) • Sample type (grass vs. ash vs. soil) • Atmospheric oxygen + alkaline conditions	• Cr(VI) % increased with temperature (2.5% → 58.1%) • Soil Cr(VI) rose 6× post-fire (0.3 → 1.8 µg/g) • Condensation from flames/ash added Cr to the soil	(EPA 1992)

2 Materials and Methods

2.1 Sampling locations

Soil samples were collected from two wildfire burn zones in Los Angeles County: the Palisades Fire (23,448 acres) and the Eaton Fire (34,021 acres) ("California Department of Forestry and Fire Protection | CAL FIRE." 2025). Both sites are located in the wildland–urban interface and represent contrasting post-fire settings. Steep coastal canyon slopes characterize the Palisades site, while the Altadena (Eaton Fire) site is located in the foothills of the San Gabriel Mountains on relatively lower slopes.

Figure 1. Incident perimeter map of the Palisades, as provided by CAL FIRE (California Department of Forestry and Fire Protection, 2025)

Samples were collected from both burned homes and standing homes within each fire zone. Composite soil samples from burned homes consists of two groups: scraped soils, where the top

~6 inches of soil within the visible ash perimeter had been removed during cleanup, and not scraped soils, representing surface soil that remained untouched during cleanup or debris removal efforts following the wildfire. Composite soil samples from standing homes were divided into four groups: front yard, backyard, right side, and left side. Additional soils were collected based on proximity to the home, classified as close (immediately adjacent to the structure) or away (near the fence of the house towards the sidewalk or street). For control, soils were also collected from residences outside of the burned zones (Simi Valley, Thousand Oaks, Somis, and LA), which served as non-burned reference sites.

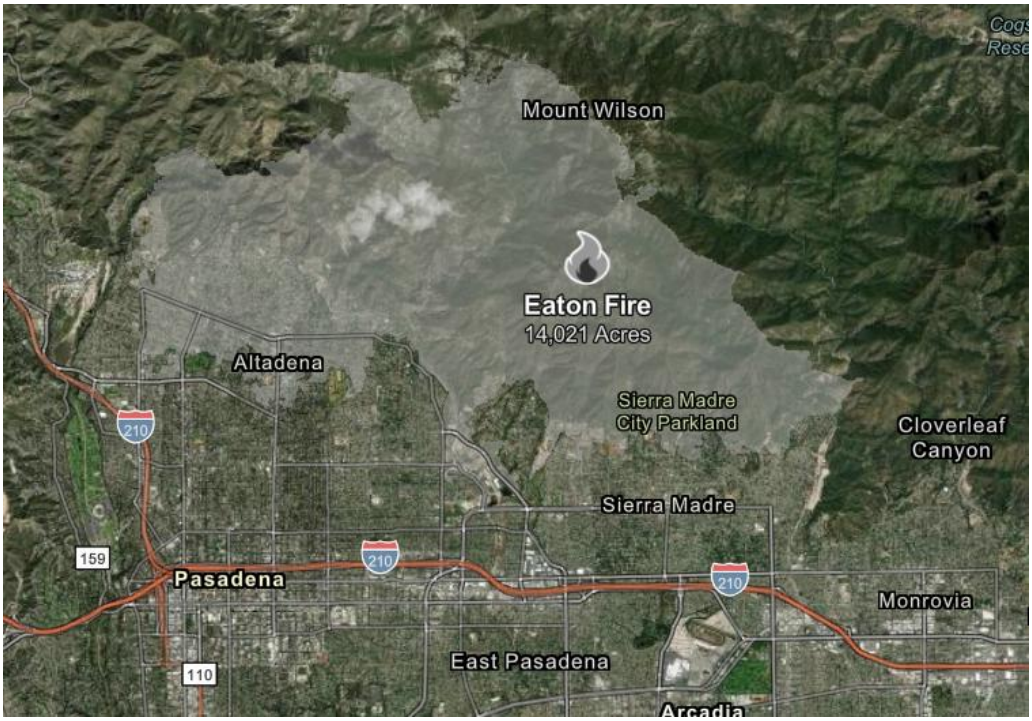

Figure 2. Incident perimeter map of the Eaton Fires, as provided by CAL FIRE (California Department of Forestry and Fire Protection, 2025).

2.2 Soil sample collection

Soil samples were collected from residential properties that voluntarily enrolled in the testing program following the Eaton and Palisades wildfires. From each property in the burned zone, composite samples were collected from several decision units: front, back, right side, and left side, close, and away from standing homes; scraped and not scraped areas from burned homes. Each decision unit composite sample consists of soils collected from the top 5 cm of surface from approximately 15-30 spots using a garden hand shovel. This approach ensured that the samples reflected average conditions without undue influence from any particular spot.

Each soil sample was transferred into a labeled polyethylene bag, sealed, and stored until it was analyzed. Labels included property identifier, sampling location, and date of collection. Samples were logged into a spreadsheet to track location, property type, and collection date, ensuring traceability throughout the analytical process.

2.3 Extraction of Cr(VI) from soil

Cr(VI) was extracted within 3-7 days of sample storage following the US EPA protocol. The extraction steps were described in Figure 3. Soil samples were first organized and labeled according to their field identifiers, with corresponding laboratory designations assigned for subsequent analysis. To ensure representative results, the entire contents of each sample bag were passed through a 2 mm sieve and mixed thoroughly during the sieving process to achieve homogenization. Coarse debris (> 2mm) and organic matter were discarded, and from the sieved fraction (< 2 mm), a 4 g subsample was transferred into a labeled 50 mL centrifuge tube for extraction.

To determine soil moisture content and allow for conversion to dry-weight concentrations, 5–10 g of sieved soil were weighed into aluminum boats and dried at 104 °C for 24 h. The difference between the moist and dry weights was used to calculate the percentage moisture content, which was subsequently applied to estimate the dry weight of subsamples used in the extraction. Between each sample, sieves were carefully cleaned and fully dried to minimize the risk of cross-contamination and to avoid artificially increasing the moisture content of subsequent samples.

Two soil samples were selected for particle size fractionation to evaluate the influence of grain size on Cr(VI) content. These samples were sequentially passed through a series of sieves with standardized mesh openings to obtain fractions of <2 mm, <1.18 mm, <250 µm, and <75 µm. Each fraction was collected and processed separately following the same extraction procedure described below.

For the extraction of reactive chromium, each 4 g subsample was mixed with 16 mL of 10 mM phosphate buffer (K_2HPO_4/KH_2PO_4, pH 7.2), maintaining a 1:4 solid-to-solution ratio (Lopez et al. 2023). The capped centrifuge tubes were secured on a wrist-action shaker and agitated continuously for 24 h at room temperature. After shaking, the samples were centrifuged at 5,000 rpm for 40 minutes at 4 °C. The supernatant was then allowed to settle for an additional 30 minutes to minimize particulate carryover. To further clarify the extracts before instrumental analysis, 1.2 mL of the supernatant was carefully pipetted into sterile 1.5 mL microcentrifuge tubes and centrifuged at 14,000 rpm for 15 min at 4 °C. Specifically, 0.5 mL of the clarified extract was then combined with 9.5 mL of deionized water in 14 mL test tubes to achieve a 10 mL final solution. Samples were stored at 4 °C for a maximum of 24 h before Cr measurement.

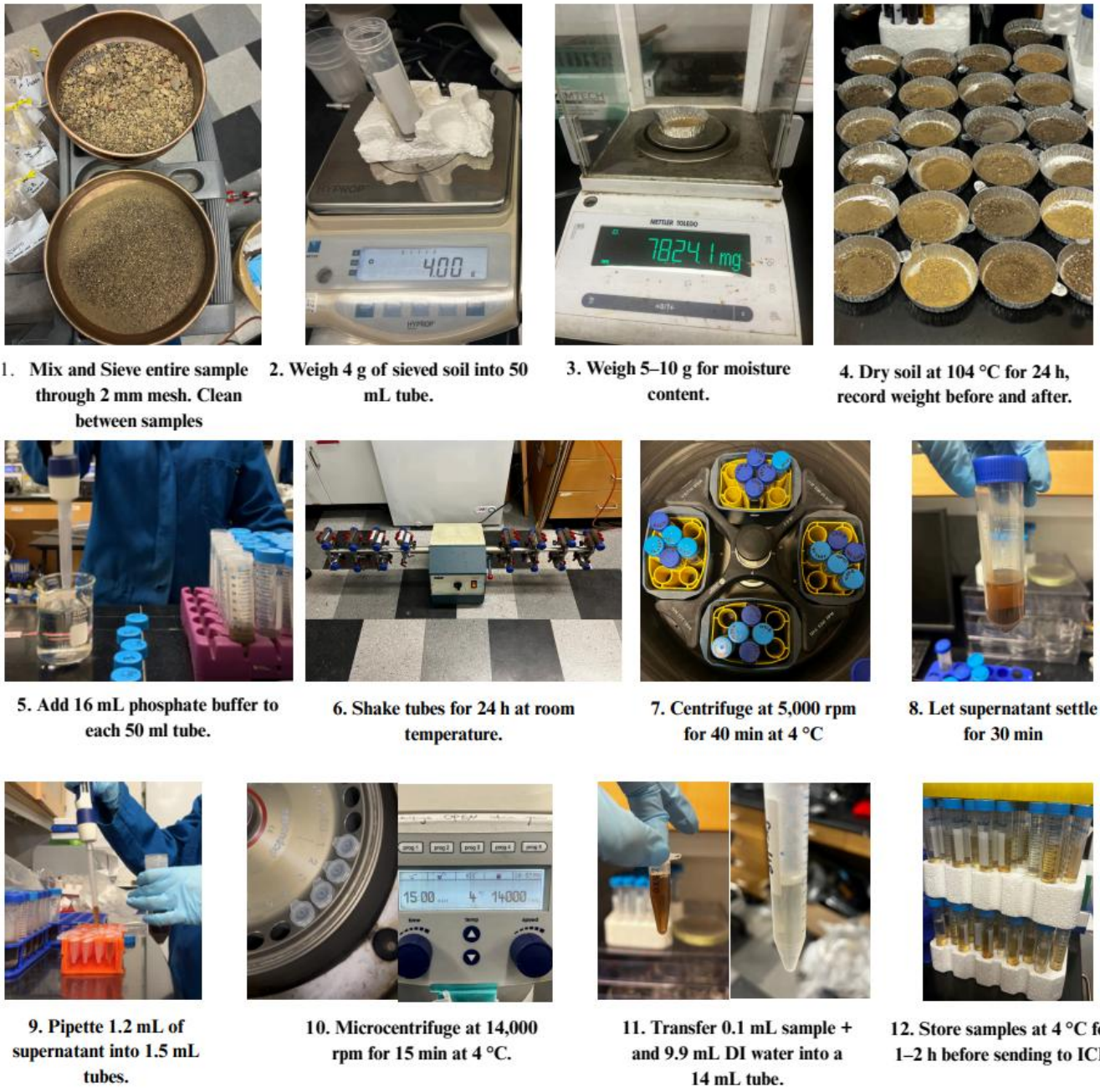

Figure 3. Cr (VI) extraction steps from soil involve mixing with phosphate buffer, centrifugation to separate leachate, and dilution before analysis.

2.4 Analysis of Cr using ICP-MS

Chromium concentrations were determined using Inductively Coupled Plasma–Mass Spectrometry (ICP-MS), enabling highly sensitive quantification of trace elements (Wolf et al. 2008). For this study, clarified phosphate buffer extracts were submitted for ICP-MS analysis, as phosphate ions displace chromate from soil binding sites and mobilize reactive Cr(VI) into solution (EPA 1992; Lopez et al. 2023). As ICP-MS primarily measured total chromium in solution, this method assumed that the phosphate buffer extraction method only dissolved Cr(VI) in the solution.

To express ICP-MS results on a soil basis, the measured concentrations were converted to mg/kg of dry soil. This calculation incorporated several correction factors: first, the dilution factor (either 20× or 100×, depending on the batch and pipetted volume); second, the extraction ratio of 16 mL of phosphate buffer per 4 g of soil; and third, normalization to the actual mass of soil. Depending on the batch, either 0.5 mL or 0.1 mL of leachate was pipetted, and this volume was accounted for in the conversion.

In addition to dilution and extraction corrections, concentrations were adjusted for soil moisture content to ensure reporting on a dry-weight basis. The percentage was calculated by comparing the difference between the wet soil and dry soil weights relative to the drdry soil. The corrected dry soil mass was then obtained by multiplying the moist soil mass by one minus the moisture fraction. Moisture contents ranged from nearly 0% in very dry soils to as high as 40% in the wettest samples, with an average of 3.9%. Final chromium concentrations were thus expressed as mg/kg dry soil.

2.5 Data Processing and Statistical Methods (Python/Collab)

All data processing and visualization were conducted in Python using Google Collab. Chromium concentrations were visualized with Tukey-style box plots, which display medians, interquartile ranges, and outliers. The results were compared against the EPA residential soil screening level (0.95 mg/kg), and the California screening level (0.3 mg/kg).

Group comparisons were evaluated using the Mann–Whitney U test (also known as the Wilcoxon rank-sum test), a nonparametric test well-suited for analyzing skewed environmental data. Chromium concentrations in soils were often right-skewed with extreme outliers, so a nonparametric test was more robust than parametric alternatives. Descriptive statistics (medians, ranges) are presented alongside 95% confidence intervals.

For interpretation of the Mann-Whitney U test, a p-value indicates the probability of observing a difference as large as the one measured if no true difference exists. Values below 0.05 were considered statistically significant. The U statistic represents the test statistic calculated by Mann–Whitney, and it compares the raw numbers directly and looks at how the two groups are ranked when all the values are lined up from smallest to largest. If the groups are mixed together, U will be in the middle. If one group consistently has higher (or lower) values, U will move toward the extremes. The rank-biserial correlation (r) expresses the effect size, where values near 0 indicate negligible differences, ±0.1 to ±0.3 small, ±0.3 to ±0.5 moderate, and above ±0.5 large; the sign reflects the direction of the difference based on the group order.

3 Results

3.1 Comparison of Cr(VI) in soils from burned and non-burned areas.

Comparison of Cr(VI) concentrations in soils from standing homes within the burned zone and outside of the fire-affected area reveals that they are similar (Figure 4). Soils from standing homes in the burned area (n = 90) had a median Cr(VI) concentration of 0.17 mg/kg, with values ranging from 0.04 to 1.75 mg/kg. In contrast, soils from the NB sites (n = 17), had a median value of 0.16 mg/kg, with a range of 0.05 to 0.47 mg/kg. While both distributions overlap considerably, some burned-zone samples exceeded the screening level, whereas all NB samples remained below it. A two-sided Mann–Whitney U test found no statistically significant difference between groups ($U = 899$, $p = 0.255$), and the rank-biserial effect size was small ($r = -0.175$), consistent with only a slight tendency for burned-zone values to exceed NB.

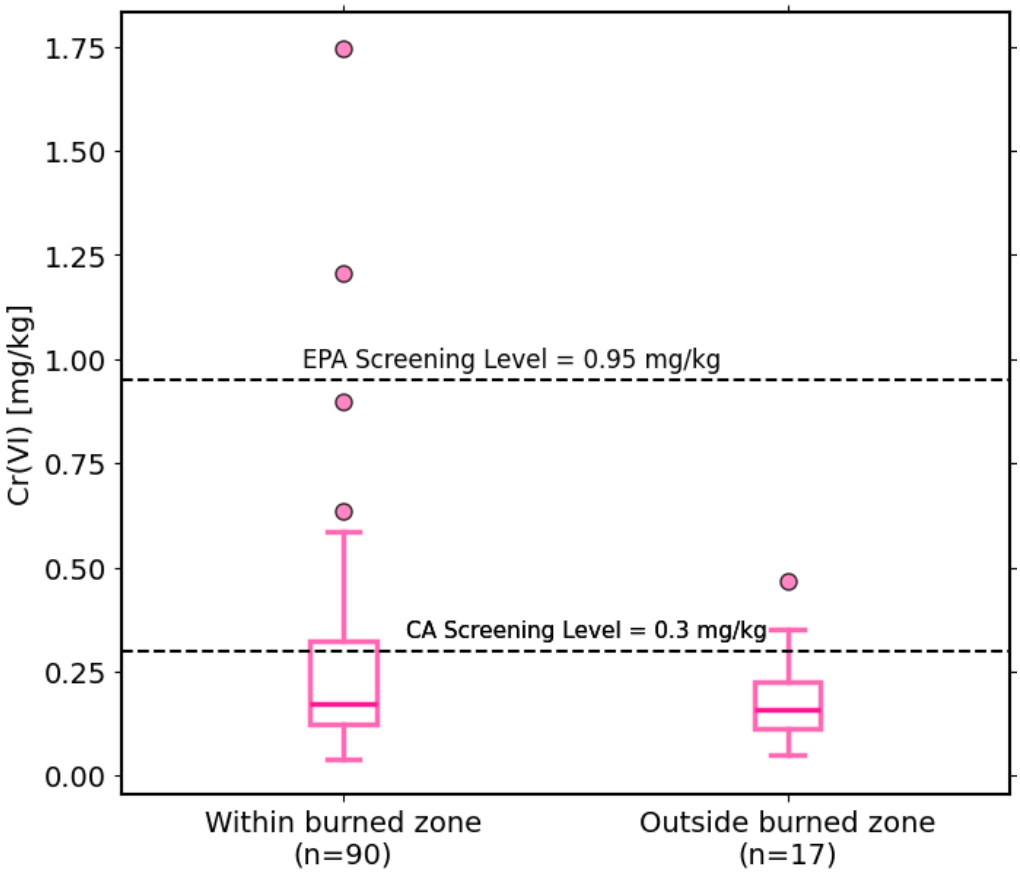

Figure 4. Comparison of Cr (VI) concentrations (mg/kg) in soils from standing homes within the burned area and outside the burned zone (NB). The dashed lines indicate the EPA residential soil screening level of 0.95 mg/kg and the CA screening level of 0.3 mg/kg. n is the number of samples.

3.2 Effect of scraping on Cr (VI) concentrations in burned properties

The results reveal that scraping of topsoil during removal of debris within visible ash footprints has slightly lowered the median concentration of Cr(VI) levels in soil (Figure 5). In Altadena, perimeter soils (n = 14) had a median Cr(VI) concentration of 0.20 mg/kg (range: 0.04–0.70 mg/kg), whereas scraped soils (n = 14) had a median of 0.08 mg/kg (range: 0.04–0.24 mg/kg), a reduction of ≈60% in the median following scraping. A two-sided Mann–Whitney U test indicated this difference did not reach statistical significance (U = 138, p = 0.0695; rank-biserial r

= −0.408, moderate). In Palisades, perimeter soils (n = 12) had a median of 0.15 mg/kg (range: 0.08–0.41 mg/kg), while scraped soils (n = 12) had a median of 0.08 mg/kg (range: 0.02–0.17 mg/kg), a ≈47% median reduction; here the difference was statistically significant (U = 124, p = 0.00295; r = −0.722, large). When pooling both cities, non-scraped soil remained higher than scraped soil (medians 0.166 vs 0.077 mg/kg), with a significant overall difference (U = 516, p = 0.00116; r = −0.527, large). (Note: negative r reflects the input group order and indicates non-scraped > scraped.)

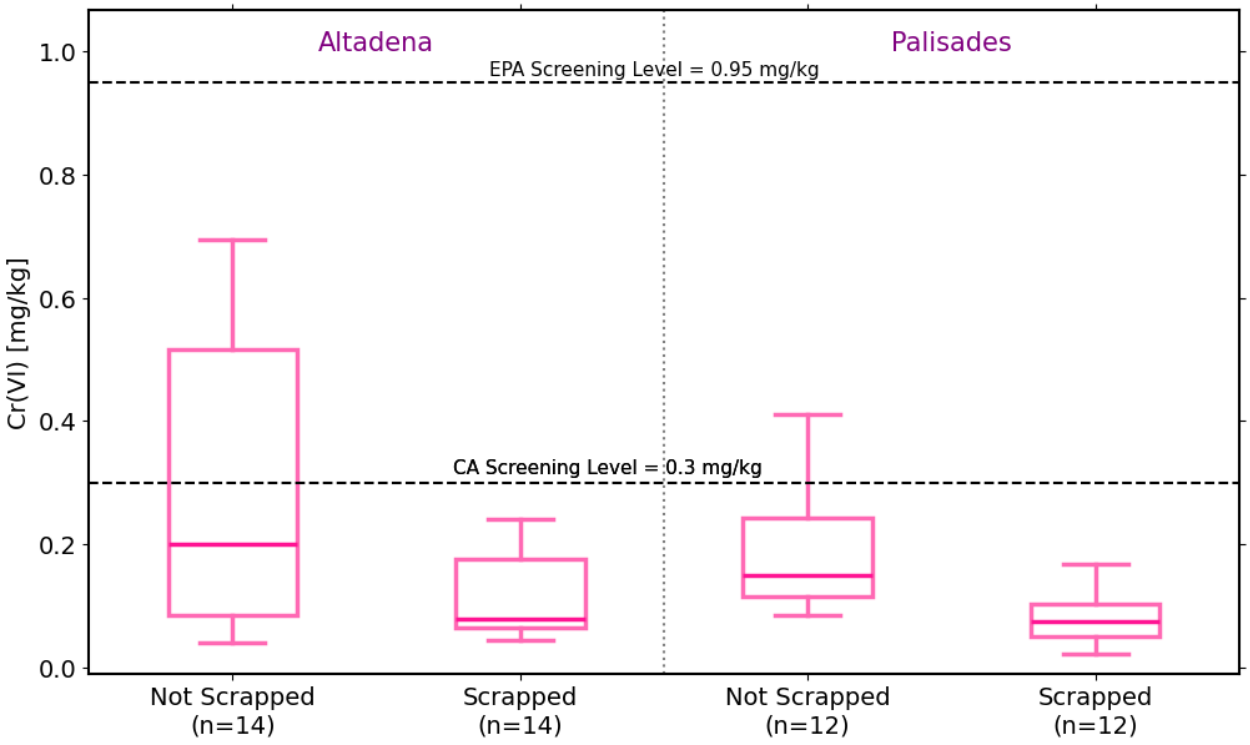

Figure 5. Comparison of Cr (VI) concentrations (mg/kg) in perimeter soils (not scraped, Ns) and scraped soils (Sc) from burned properties in Altadena (n = 14) and Palisades (n = 12). The dashed lines indicate the EPA residential soil screening level of 0.95 mg/kg and the CA screening level of 0.3 mg/kg.

3.3 Cr(VI) concentration in unscraped soils from burned and standing homes

Cr (VI) concentrations in unscraped soils from the perimeters of burned homes (not scraped) were similar to Cr(VI) concentrations in soils from the perimeters of standing homes within the same burn zones (Figures 6 and 7)

Palisades. For burned homes (n = 12), Cr(VI) concentrations ranged from 0.08 to 0.41 mg/kg, with a median of 0.15 mg/kg. Standing home soils (n = 39) ranged from 0.04 to 1.21 mg/kg, with a median of 0.12 mg/kg. A two-sided Mann–Whitney U test indicated no significant difference between the groups ($U = 276$, $p = 0.357$; rank-biserial $r = -0.179$, small). While both medians were well below the EPA residential soil screening level of 0.95 mg/kg, several samples exceeded the more stringent California screening level of 0.3 mg/kg. Exceedances were observed in both burned and standing home soils, and standing homes showed greater variability, including outliers above both the California and EPA thresholds.

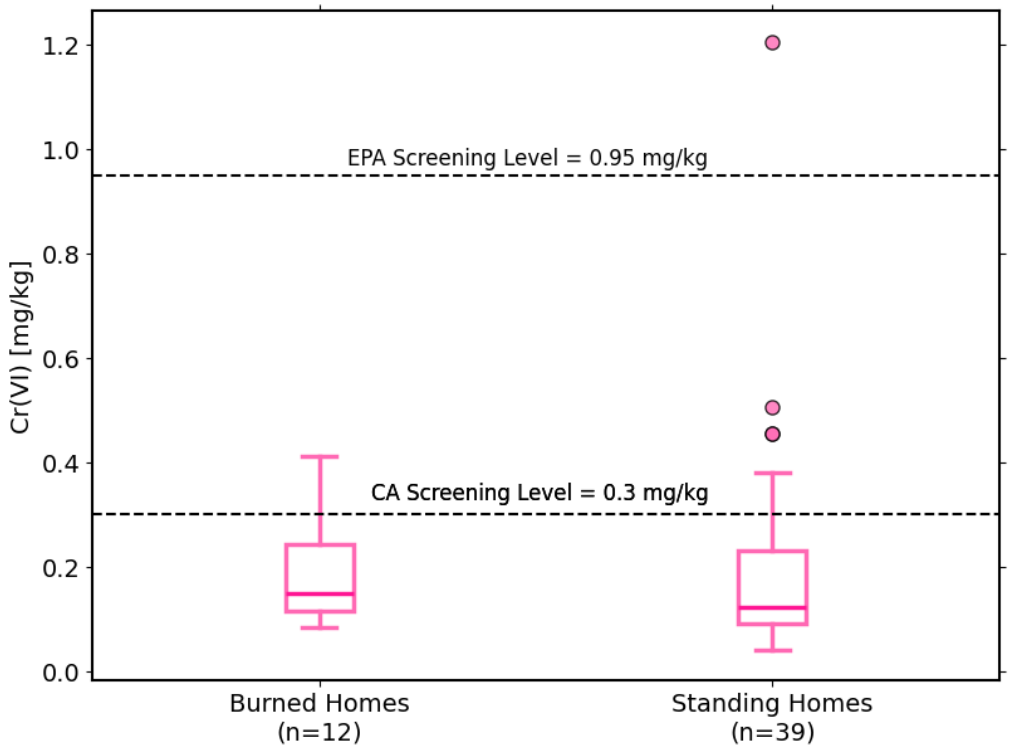

Figure 6. Comparison of Cr(VI) concentrations (mg/kg) in soils from burned home perimeters (n = 12) and standing home perimeters (n = 39) in Palisades. The dashed lines indicate the EPA residential soil screening level of 0.95 mg/kg and the CA screening level of 0.3 mg/kg. n is the number of samples.

Altadena. For burned homes (n = 14), Cr(VI) ranged from 0.04 to 0.70 mg/kg, with a median of 0.20 mg/kg. Standing homes (n = 51) ranged from 0.07 to 1.75 mg/kg, with a median of 0.22 mg/kg. The medians were nearly identical, and the Mann–Whitney test again showed no significant difference (U = 310, p = 0.458; r = +0.132, small). While both groups were below the EPA residential soil screening level of 0.95 mg/kg, a considerable portion of samples exceeded the California screening level of 0.3 mg/kg. Exceedances occurred in both burned and standing home soils, with standing homes showing greater variability and extreme outliers, including several above the EPA threshold.

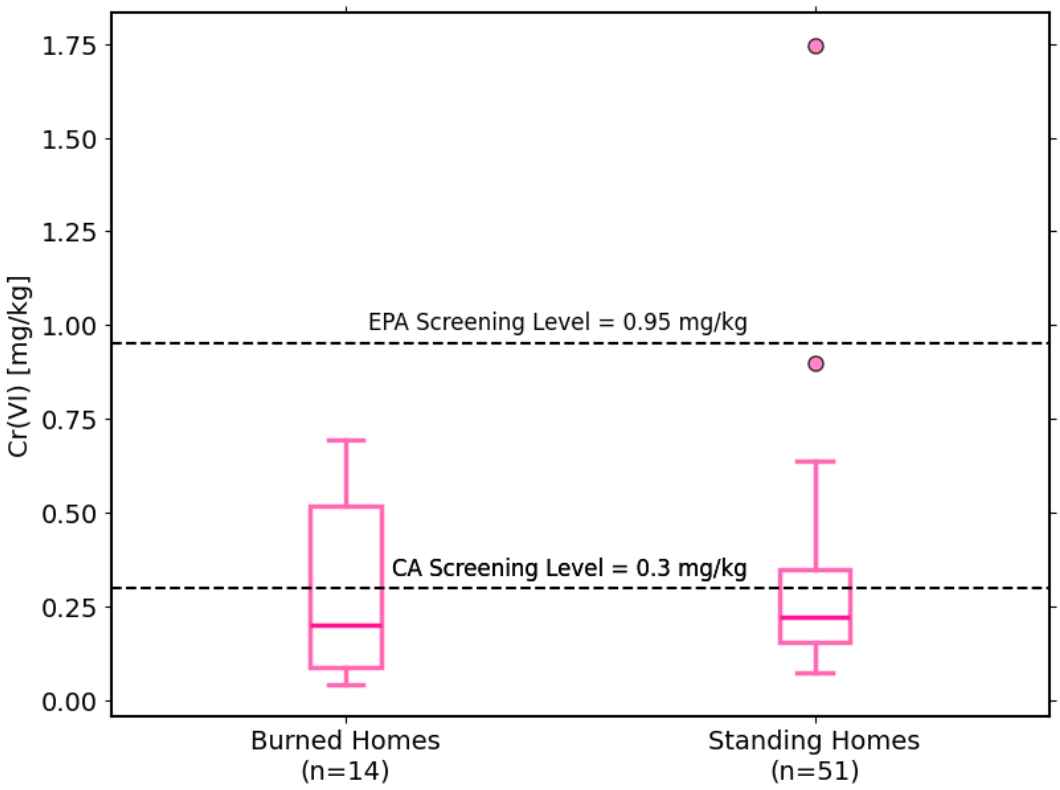

Figure 7. Comparison of Cr(VI) concentrations (mg/kg) in soils from burned home perimeters (n = 14) and standing home perimeters (n = 51) in Altadena. The dashed lines indicate the EPA residential soil screening level of 0.95 mg/kg and the CA screening level of 0.3 mg/kg. n is the number of samples.

3.4 Effect of terrain on Cr(VI) concentrations in soils

Cr(VI) concentrations were compared between soils collected from high-slope properties in Palisades and low-slope properties in Altadena. In Palisades (n = 84), Cr(VI) concentrations ranged from 0.02 to 1.21 mg/kg, with a median of 0.14 mg/kg. In Altadena (n = 98), concentrations ranged from 0.04 to 1.75 mg/kg, with a median of 0.21 mg/kg.

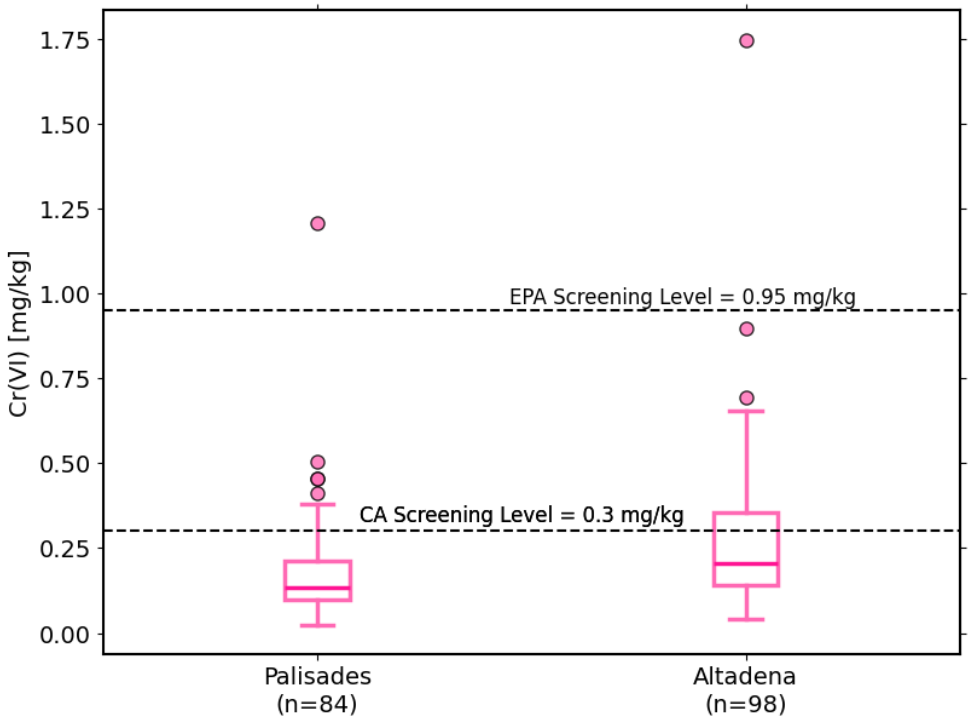

Figure 8. Comparison of Cr (VI) concentrations (mg/kg) in soils from high-slope properties in Palisades (n = 84) and low-slope properties in Altadena (n = 98). The dashed lines indicate the EPA residential soil screening level of 0.95 mg/kg and the CA screening level of 0.3 mg/kg. n is the number of samples.

A two-sided Mann–Whitney U test confirmed that the difference between cities was statistically significant ($U = 2702$, $p = 6.6\times10^{-5}$; rank-biserial $r = 0.344$, moderate effect), indicating significantly higher Cr(VI) concentrations in Altadena than in Palisades. This dataset represents average concentrations across both burned and standing homes, providing a general comparison of terrain-related effects, considering contaminated soils were easily washed off in high-slope terrain during rainfall events after wildfires.

3.5 Proximity to homes and Cr(VI) concentrations in soils

Comparing Cr(VI) concentrations between soils collected close (C) to houses (C) and those collected farther away (A) from standing houses in both burned zones, the results reveal that distance from the standing home towards the fence did not affect Cr(VI) concentration (Figure 9).

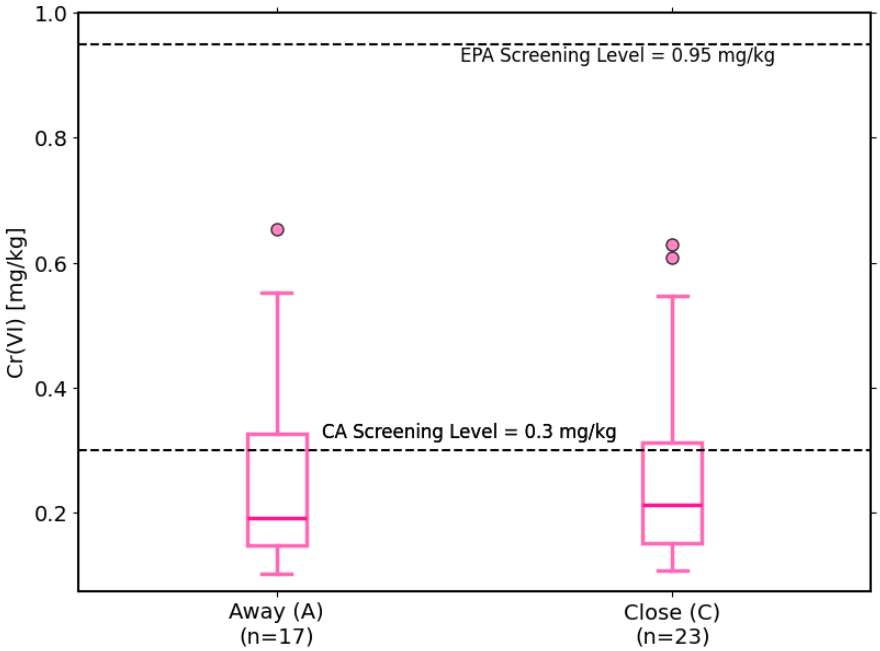

Figure 9. Comparison of Cr(VI) concentrations (mg/kg) in soils collected away from houses (A, n = 17) and close to houses (C, n = 23). The dashed lines indicate the EPA residential soil screening level of 0.95 mg/kg and the CA screening level of 0.3 mg/kg. n is the number of samples.

For away soils (n = 17), Cr(VI) concentrations ranged from 0.10 to 0.65 mg/kg, with a median of 0.19 mg/kg. For close soils (n = 23), concentrations ranged from 0.11 to 0.63 mg/kg, with a median of 0.21 mg/kg. A two-sided Mann–Whitney U test indicated no significant difference between groups (U = 187, p = 0.827; rank-biserial r = 0.043, negligible), confirming that central tendencies were nearly identical.

3.6 Comparison of Cr(VI) concentration in soils from Palisades and Altadena areas

A summary of the median concentration of Cr(VI) with 95% confidence interval was provided in Table 2. The results suggest that the median concentration of soils from standing homes in the Altadena area is more likely to exceed the California screening level (0.3 mg/kg), whereas soils from standing homes in Palisades are less likely to exceed the screening level. In all other places, the concentration is more likely to be similar to the background contamination level expected in Los Angeles areas.

Table 2. Summary of Cr(VI) concentration (mg/kg) in burned and standing homes in Altadena and Palisades areas following the 2025 LA wildfires.

Site	Property type	Subcategories	No. of Samples	Median (mg/kg)	95% Confidence Interval (mg/kg)
Altadena	Standing Homes	Front	17	0.354	[0.159, 0.548]
		Back	15	0.269	[0.159, 0.378]
		Side Right	10	0.280	[0.143, 0.417]
		Side Left	9	0.250	[0.166, 0.334]
		Away	8	0.350	[0.175, 0.524]
		Close	11	0.352	[0.228, 0.477]
	Burned Homes	Scrapped	14	0.114	[0.075, 0.152]
		Not Scrapped	14	0.279	[0.143, 0.415]
Palisades	Standing Homes	Front	15	0.200	[0.124, 0.276]
		Back	14	0.256	[0.084, 0.429]
		Side Right	5	0.086	[0.052, 0.121]
		Side Left	5	0.144	[0.024, 0.313]
		Away	9	0.185	[0.135, 0.234]
		Close	12	0.187	[0.144, 0.230]
	Burned Homes	Scrapped	12	0.082	[0.055, 0.109]
		Not Scrapped	12	0.188	[0.123, 0.252]
Control	Outside of the Burned Area	Composite	17	0.180	[0.122, 0.238]

Based on the CalEPA screening level (0.3 mg/kg) for cancer endpoint, many properties exceed the health screening level, indicating the soils are still contaminated with elevated levels of Cr(VI) (Table 3). The scraped areas in the burned homes from both Altadena and Palisades did not have any exceedance, indicating that topsoil removal is an effective remediation strategy. However, the exceedances for non-scraped areas in the burned homes are 16.7% for Palisade and 35.7% for Altadena, indicating that homes in Altadena are more likely to be contaminated with Cr(VI) after the wildfires. The pattern is similar for standing homes in both regions, although the exceedance depended on specific sides of the standing homes. Measuring exceedance in control locations (not affected by fire), the data reveal that soil may have already been contaminated with Cr(VI) due to industrial activities or other sources. However, the sample sizes are too small to draw any conclusions from the results. As more samples are being analyzed, the results may change.

Table 3. Exceedance of Cr(VI) concentrations relative to the California residential soil screening level (0.3 mg/kg).

Site	Property type	Subcategories	No. of Samples	No. of Samples > 0.3 mg/kg	% Exceedance
Altadena	Standing Homes	Front	17	7	41.2
		Back	15	4	26.7
		Side Right	10	3	30
		Side Left	9	3	33.3
		Away	8	4	50
		Close	11	6	54.5
	Burned Homes	Scrapped	14	0	0
		Not Scrapped	14	5	35.7
Palisades	Standing Homes	Front	15	3	20
		Back	14	4	28.6
		Side Right	5	0	0
		Side Left	5	1	20.0
		Away	9	1	11.1
		Close	12	1	8.3
	Burned Homes	Scrapped	12	0	0
		Not Scrapped	12	2	16.7
Control	Outside of the Burned Area	Composite	17	2	11.8

3.7 Particle size distribution of Cr(VI) in soils

Comparing Cr(VI) concentrations in different size fractions (<2 mm, <1.18 mm, <250 µm, and <75 µm) of selected soil sample from Palisades and Altadena, we showed that the fraction (< 75 µm) susceptible to wash off by stormwater runoff carried the maximum amount of Cr(VI) (Figure 10 and 11). However, this trend can change as more samples are analyzed to examine how Cr(VI) concentrations change with size fractionation.

Palisades. Cr(VI) concentrations increased as particle size decreased. The <2 mm fraction contained 1.93 mg/kg, while the <1.18 mm and <250 µm fractions contained 1.67 and 1.52 mg/kg, respectively. The <75 µm fraction had the highest concentration at 2.73 mg/kg, nearly three times the EPA screening level.

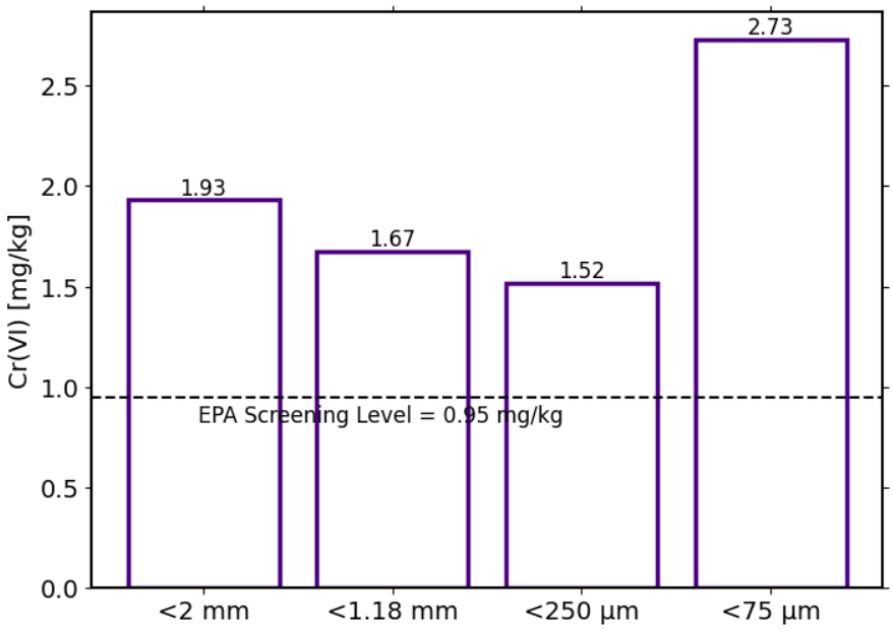

Figure 10. Comparison of Cr(VI) concentrations (mg/kg) across particle size fractions in Palisades soils. The <75 µm fraction shows the highest concentration (2.73 mg/kg). The dashed line indicates the EPA residential soil screening level of 0.95 mg/kg. n is the number of samples.

Altadena. A similar trend was observed, with concentrations rising in finer fractions. The <2 mm fraction contained 0.51 mg/kg, <1.18 mm had 0.65 mg/kg, <250 µm had 0.84 mg/kg, and <75 µm reached 1.36 mg/kg, exceeding the EPA screening level.

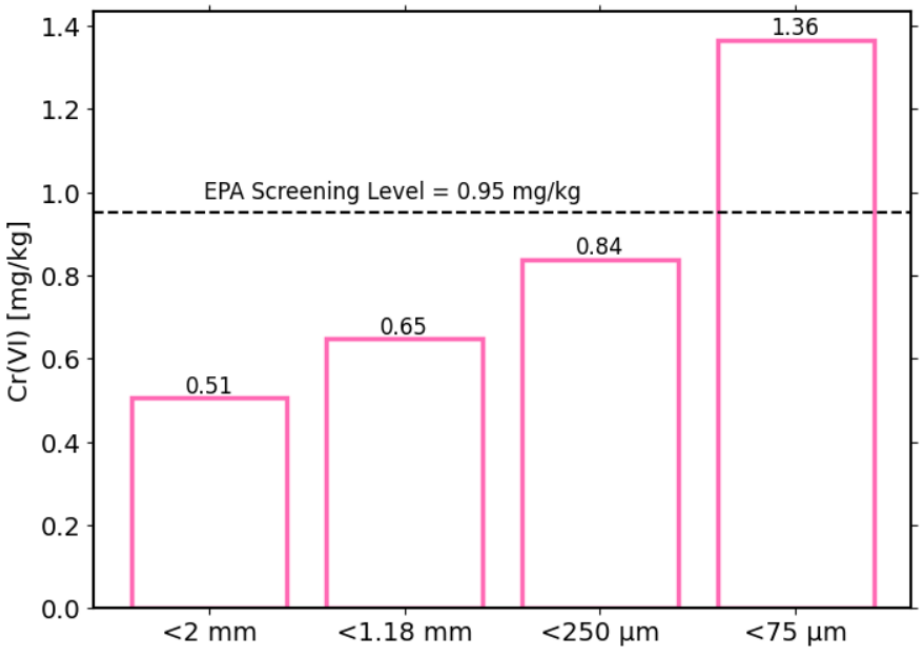

Figure 11. Comparison of Cr(VI) concentrations (mg/kg) across particle size fractions in Altadena soils. The <75 µm fraction had the highest concentration (1.36 mg/kg). The dashed line indicates the EPA residential soil screening level of 0.95 mg/kg. n is the number of samples.

4 Discussion

4.1 Elevated Cr(VI) levels in residential soils after the wildfires

Median Cr(VI) concentrations in standing-home soils were 0.22 mg/kg in Altadena and 0.12 mg/kg in Palisades, both well below the federal EPA residential soil screening level of 0.95 mg/kg. However, when compared to the more stringent California human health screening level of 0.3 mg/kg, a different pattern emerges. Many soils from fire-affected properties—including both standing homes and burned-home perimeters—exceeded the 0.3 mg/kg threshold**,** indicating that wildfires did in fact elevate Cr (VI) in residential soils to levels of regulatory concern.

Several factors likely contributed to these exceedances. First, fire-driven oxidation of Cr(III) to Cr(VI) is enhanced in surface soils where Fe (III) oxides host chromium and act as

catalysts during high-temperature exposure (Burton et al. 2019; Pavichev et al. 2008). Second, localized variability in heating intensity and deposition of ash likely created “hot spots” with elevated concentrations, consistent with the outliers observed above the California screening level. Finally, although heavy rainfall events occurred shortly after the fires—conditions known to wash mobile Cr(VI) from surface soils (Wolf et al. 2008)—enough Cr(VI) persisted in fire-affected zones to remain above health-based thresholds.

Taken together, these results demonstrate that wildfire significantly impacted Cr(VI) concentrations in Los Angeles soils. While the exceedances were not uniform across all samples, the data show clear evidence that fire contributed to contamination requiring further monitoring and potential remediation.

4.2 Difference in Cr(VI) level between Altadena and Palisades

Although both regions burned during the same fire event, Cr (VI) levels were higher in Altadena soils than in Palisades. The difference in concentration was attributed to site history that resulted in greater contamination during wildfire, and terrain that may have helped wash off contaminated particles during rainfall events after the wildfires. Altadena lies closer to historical industrial activity and therefore has a legacy of more contaminated soils, while Palisades is more residential and coastal, with generally cleaner baseline conditions. In addition, topography likely played a role: Palisades properties are located on steeper slopes, where rainfall-driven runoff can accelerate the removal of mobile Cr (VI). Altadena, in contrast, is characterized by lower slopes, favoring the retention of contaminants in surface soils. These findings align with reports that slope, and hydrology are major controls on post-fire contaminant persistence (Thery et al. 2024).

4.3 Effect of scraping on Cr(VI) in soils

Comparisons between scraped and not-scraped soils confirm that scraping reduces Cr(VI) concentrations, with reductions of nearly half the median values in both burned zones. This supports the idea that Cr (VI) is mostly formed and located in the uppermost soil layers. The surface soil is where fire temperatures are highest, promoting Cr (III) oxidation, and where deposition of contaminated ash and dust occurs (Burton et al., 2019). Because subsurface layers experience lower fire temperatures, Cr(III) is less likely to be converted to Cr (VI) at depth. Thus, removing the top ~6 inches of soil by scraping removed a fraction of Cr(VI).

4.4 Effect of particle size on Cr (VI) distribution

Cr(VI) analysis for different size fractions of soils showed that the finest soil fraction (<75 μm) contained the highest concentrations of Cr (VI). Finer particles have greater surface area, which enhances the adsorption and retention of oxidized chromium species (Burton et al. 2019). These particles are also more easily transported by wind and stormwater, raising concerns about inhalation and waterborne exposure (Lopez et al. 2023). The concentration of Cr (VI) in the fine fraction suggests that even if bulk soil concentrations remain below screening thresholds, the mobility of fine particles represents a potential pathway for exposure in post-fire environments.

4.5 Implications for rebuilding and health

This study shows that when evaluated against the California residential screening level of 0.3 mg/kg**,** many soils in Los Angeles exceeded regulatory thresholds after the Eaton and Palisades fires. Exceedances were observed in standing-home perimeters, burned-home perimeters, and even in some scraped properties, indicating that wildfire contamination persists across different site

conditions. These findings confirm that fire significantly elevated Cr(VI) in residential soils, and remediation is necessary in affected areas.

For communities rebuilding after wildfire, these results emphasize the importance of routine soil testing to identify contaminated properties. Scraping demonstrated partial effectiveness in lowering Cr(VI), but in many cases it was insufficient to reduce concentrations below health-based limits, suggesting that additional or repeated interventions may be required. Moreover, the enrichment of Cr(VI) in fine soil fractions (<75 μm) raises concern about airborne transport and inhalation risks, as these particles can remain suspended and migrate off-site.

Overall, the data indicate that while rainfall and slope may mitigate contamination in some areas, wildfire-affected soils in the wildland–urban interface remain a potential public health hazard. Addressing these risks through targeted monitoring, remediation, and dust management will be essential for safe recovery and rebuilding.

5 Conclusion

This study evaluated the extent of chromium (VI) contamination in soils from the Eaton and Palisades fire zones in Los Angeles. Across all categories of samples—including burned-home perimeters, standing-home perimeters, scraped soils, and non-burned reference sites—median concentrations remained below the federal EPA residential soil screening level of 0.95 mg/kg. However, when compared to the more stringent **C**alifornia screening level of 0.3 mg/kg, many soils were found to exceed regulatory limits. These exceedances demonstrate that wildfire did contribute to Cr(VI) contamination in residential soils.

Differences between fire zones highlight the influence of site conditions. Altadena soils contained higher Cr(VI) than Palisades, a pattern attributed to legacy industrial activity, lower slopes, and reduced wash-off compared to steeper coastal terrain. Scraping generally reduced Cr(VI) concentrations, confirming that contamination is concentrated in the uppermost soil layers that experience direct heating and ash deposition. Yet, in many cases, scraping did not reduce concentrations below the California threshold, indicating that remediation remains necessary. Particle-size analysis further revealed that fine fractions (<75 μm) were enriched in Cr(VI), underscoring the risk of airborne and waterborne transport.

Overall, this work demonstrates that wildfires in the wildland–urban interface can mobilize chromium to levels of health concern under California guidelines. These findings provide a scientific basis for targeted soil monitoring, slope- and site-specific remediation strategies, and dust management practices to protect public health during recovery and rebuilding.

6 Recommendations

The results of this study show that many soils in the Eaton and Palisades fire zones exceeded the California residential screening level of 0.3 mg/kg, even though they remained below the federal EPA level of 0.95 mg/kg. These exceedances demonstrate that wildfire did elevate Cr(VI) in residential soils to levels of regulatory concern. Based on these findings, several recommendations can be made for soil management, monitoring, and future research.

First, practical actions for post-fire recovery should prioritize soil remediation in properties where concentrations exceed 0.3 mg/kg. Scraping was shown to reduce Cr(VI), confirming its effectiveness at removing the most contaminated surface layers. However, scraping alone was not

sufficient in all cases to lower soils below the California threshold. For this reason, additional interventions such as soil replacement, stabilization, or repeated removal may be necessary. Special attention should be given to low-slope areas, where contaminants are more likely to accumulate, and to fine soil fractions that are enriched in Cr(VI) and pose higher risks of mobility and inhalation.

Second, monitoring programs should be expanded to track post-fire chromium dynamics over time**.** Rainfall is known to redistribute Cr (VI), both reducing surface concentrations and transporting contaminants into stormwater systems (Wolf et al. 2008). Systematic testing should therefore target both soil and stormwater outlets to assess whether urban infrastructure traps or transports Cr (VI). This will be especially important in Los Angeles, where heavy rainfall events shortly after the fires may have already altered contaminant distribution.

Third, methodological improvements are needed to refine chromium speciation analysis**.** While phosphate buffer extractions enable mobilization of reactive Cr(VI), there remains uncertainty whether ICP-MS detects Cr(VI) directly or primarily total Cr. Future studies should incorporate parallel nitric acid digestions to quantify total Cr, with Cr(VI) estimated by subtraction. Sample preservation also requires improvement: according to the EPA, soils for Cr(VI) analysis must be extracted within 30 days of collection and analyzed within **7** days of extraction to avoid underestimation due to degradation (Hazardous Waste Test Methods / SW-846). Faster submission and standardized handling protocols are essential for reliable results.

Finally, long-term research is recommended to evaluate chromium persistence and risk across multiple fire and rainfall cycles**.** Future work should assess changes in soil chemistry (pH, Fe oxides, organic matter) that influence Cr(III)–Cr(VI) dynamics, as well as track the mobility of

fine particles that concentrate Cr(VI). Answering unresolved questions—such as whether stormwater infrastructure provides meaningful protection or acts as a secondary pathway for chromium transport—will be critical for designing effective management strategies.

These results are based on a small subset of soil samples, which results in weaker statistical analysis. Including results from over 1000 properties could increase the strength of the statistics and may change the outcome of the study. Nevertheless, the study validated the importance of Cr(VI) in residential soils following wildfires in wildland-urban interfaces.

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