Transport Mechanisms and Persistence of Wildfire-related Polycyclic Aromatic Hydrocarbons in a Southern California Coastal Watershed

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November 22, 2022

Abstract

As wildfires become more prevalent and destructive, it is imperative to understand the impacts they have on the watersheds they burn. One particularly understudied aspect of wildfire-associated water quality impairment is the generation of polycyclic aromatic hydrocarbons (PAHs), a class of organic contaminants with carcinogenic, mutagenic, and ecotoxic properties. As a case study, we investigate PAH impacts associated with the 2018 Woolsey Fire, which burned over half of the Malibu Creek Watershed near Los Angeles, California. We collected soil and water samples periodically and during rain events over three years following the fire. Sampling sites were distributed through the watershed to incorporate samples from all major tributaries of Malibu Creek and to capture varying topography, geology, land use, and fire intensity. We found PAH concentrations exceeding EPA Ambient Water Quality Criteria, primarily during rain events, through the second wet season after the fire. Using molecular ratio approaches, the PAHs detected in water samples were directly linked to burned soil. Elevated PAH concentrations were associated with suspended particulate matter, which was in turn directly related to stream discharge and precipitation intensity. However, significant geographic variability was observed during the second wet season, suggesting topography, burn intensity, and other factors play a role in post-fire recovery and the persistence of fire-derived PAHs in the watershed. We investigated the contribution of these factors through a combination of long-term soil and water sampling, assessment of suspended particulate material, analysis of the variation and evolution of PAH compound distributions, and evaluation of geographic controls. Results suggest that an interplay of multiple geographic factors contribute to the observed variations. Understanding these complex mechanisms is critical to predicting long-term wildfire impacts to water quality in diverse settings.

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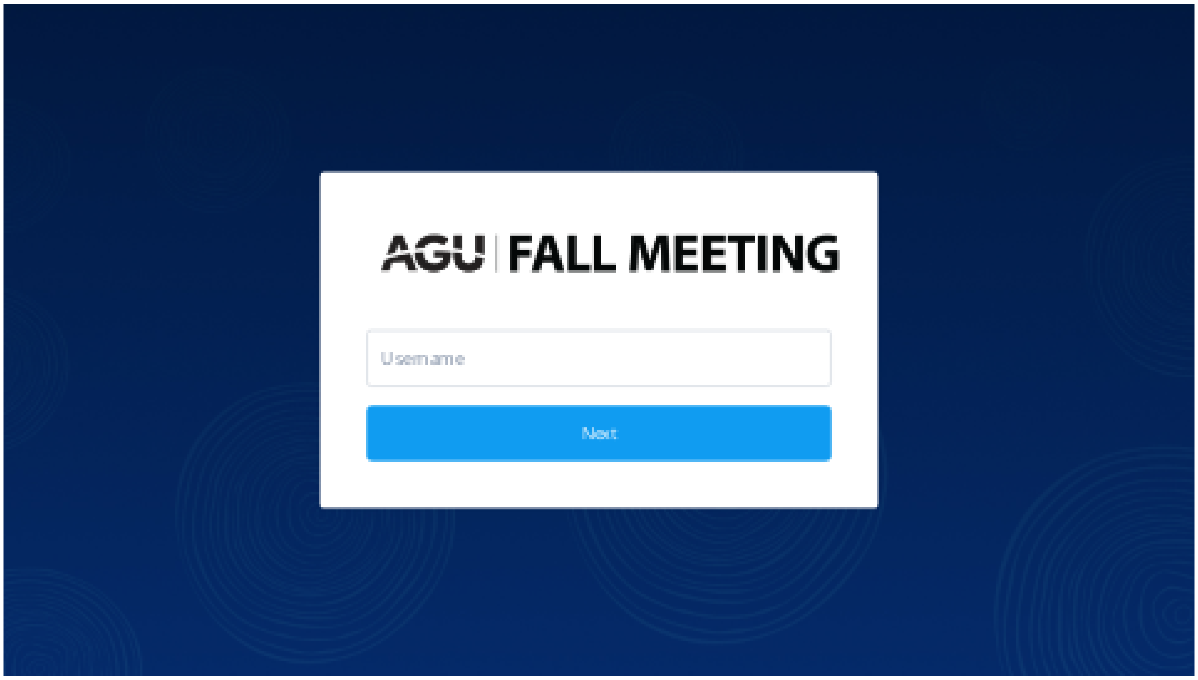

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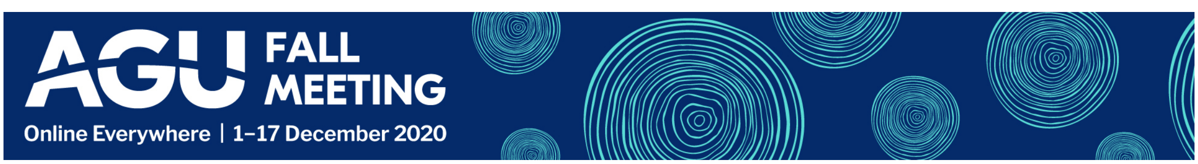

OBJECTIVES & HYPOTHESES

OBJECTIVES:

- determine if the persistance of PAHs derived from the Woolsey Fire (2018) stretches to a 3rd wet season

- characterize and evaluate observed PAH variation in water samples throughout the Malibu Creek Watershed

- determine geomorphologic controls of PAH evolution in burned areas

HYPOTHESES:

- increased burn intensity and steeper topography play a critical role in decreasing the persistance of PAHs generated by the Woolsey Fire

- higher PAH concentrations are found in the fine-grain fraction of soil samples

BACKGROUND

•The Woolsey Fire burned in November of 2018 for 13 days

•Burned ~100k acres in NW Los Angeles including most of the Malibu Creek Watershed

•Burned soils experience increased hydrophobicity and erosion after a fire

•Burned organic material generates Polycyclic Aromatic Hydrocarbons (PAHs) which have both mutagenic and carcinogenic properties

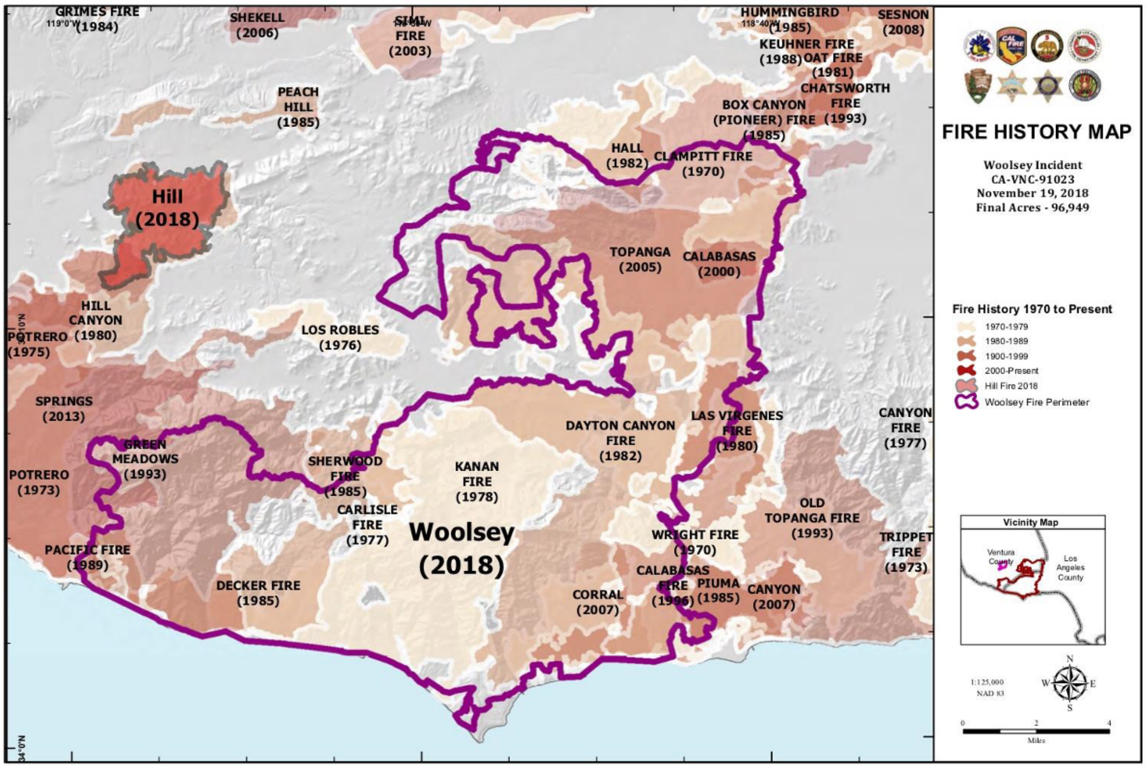

Figure 1. The area burned by the Woolsey Fire is prone to wildfires and is one of many to burn over the last 40 years. Source: National Park Service

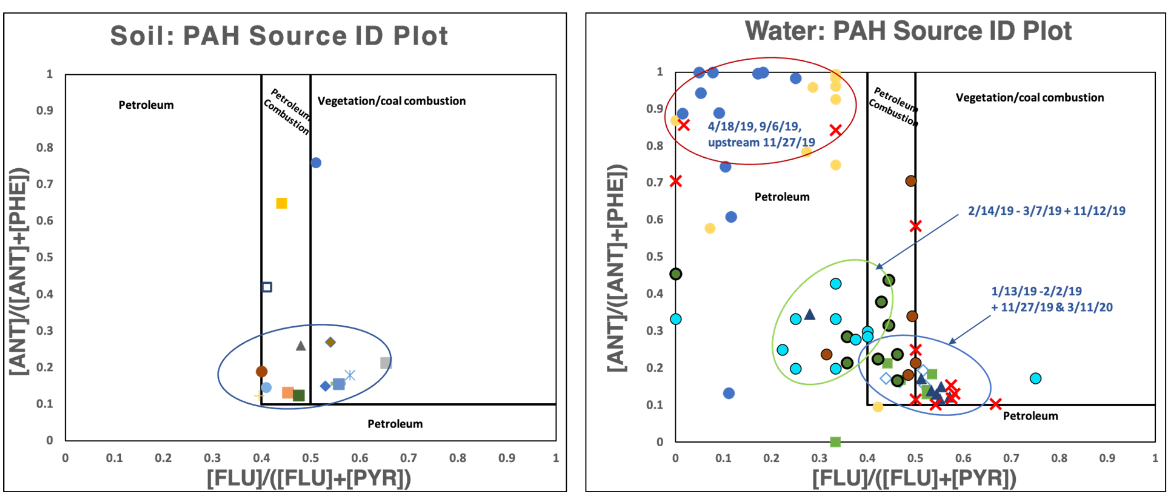

Figure 2. The circled area on the Soil PAH ID plot is the Woolsey "fire signal". Water samples collected during the first wet season contained PAHs showing the fire signal, but in the second wet season the fire signal was lost from select sites (shown as red X's).

METHODS

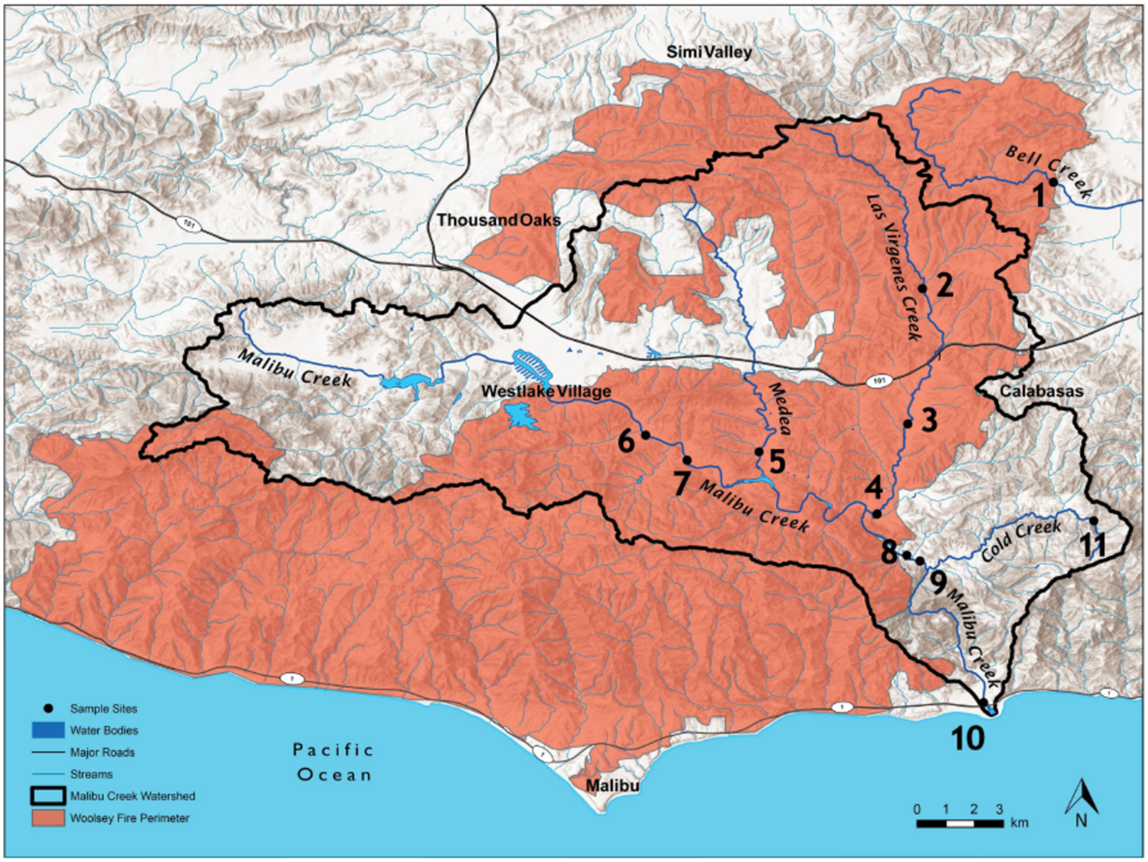

Figure 3. Map showing the Woolsey Fire area and the Malibu Creek Watershed perimeter.

•Sample sites were selected along major tributaries of Malibu Creek and at Malibu Lagoon

•Sites capture watershed-scale changes in water quality and incorporate burned and unburned regions

•Water, soil, total mercury (HgT), monomethyl mercury (MeHg), and nutrients samples were collected monthly and immediately after or during storm events.

•Unfiltered grab water and surficial soil samples were extracted using methylene chloride

•Select soil samples were sieved before extraction

•Analyzed by gas chromatography-mass spectrometry (GC-MS; Thermo Trace 1310 ISQ).

•Samples run in SIM mode and analyzed for 16 EPA PAHs. A second run in full scan mode confirmed the identified chromatogram peaks

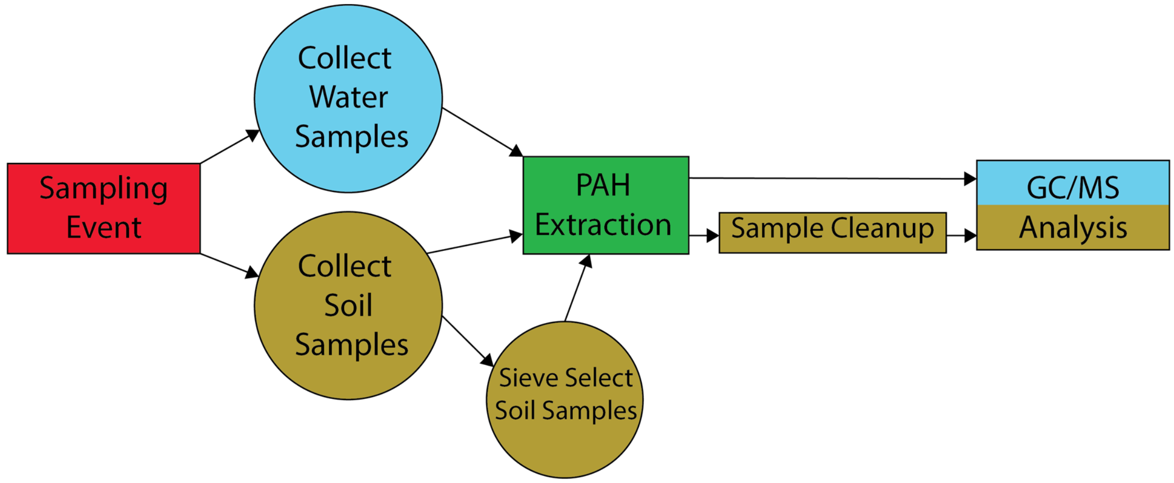

Figure 4. Flowchart showing the sampling and analysis steps steps of the study design.

RESULTS

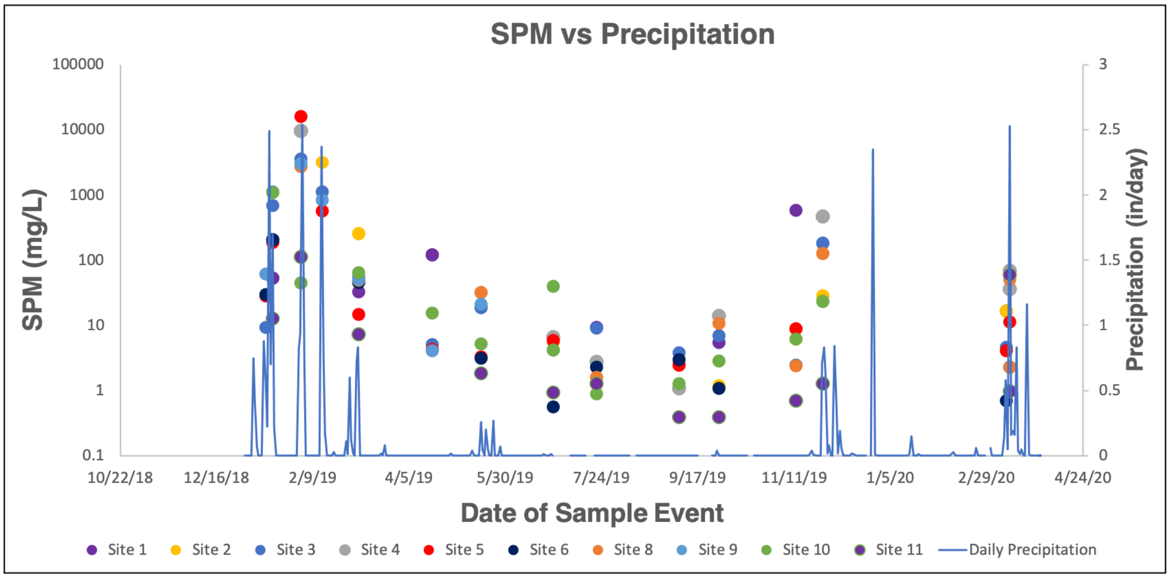

Figure 5. Suspended particulate matter (SPM) concentrations increase with increased precipitation intensity. Precipitation values from Calabasas weather station.

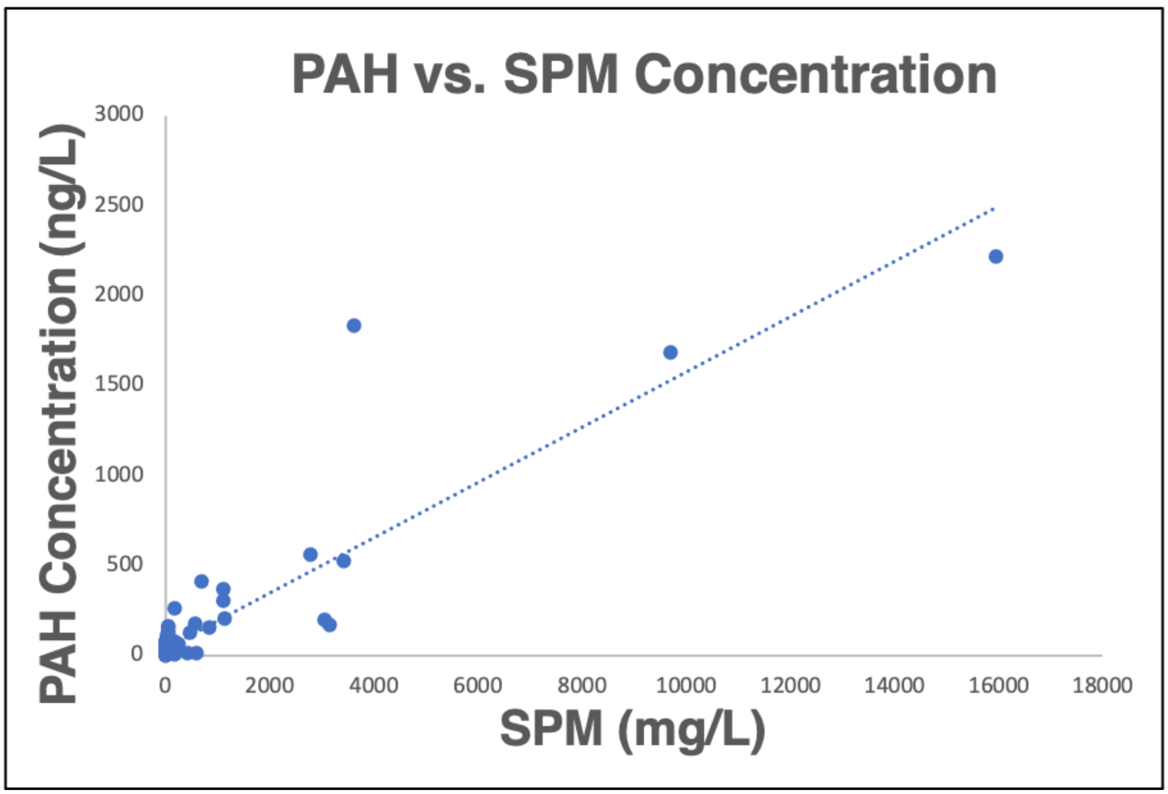

Figure 6. PAH concentrations increase with increased SPM concentrations.

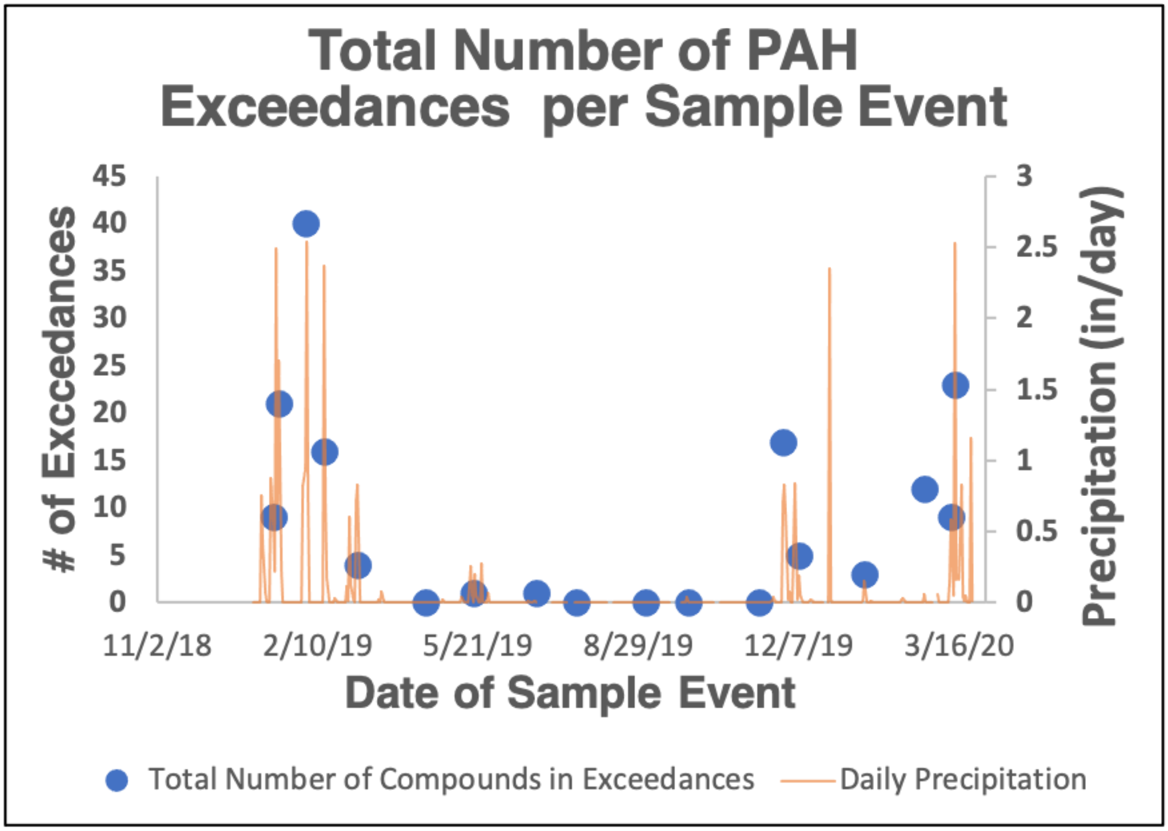

Figure 7. PAH concentrations exceeded the EPA Ambient Water Quality Criteria during the first wet season. The exceedances nearly disappear during the dry months, but return in the second wet season.

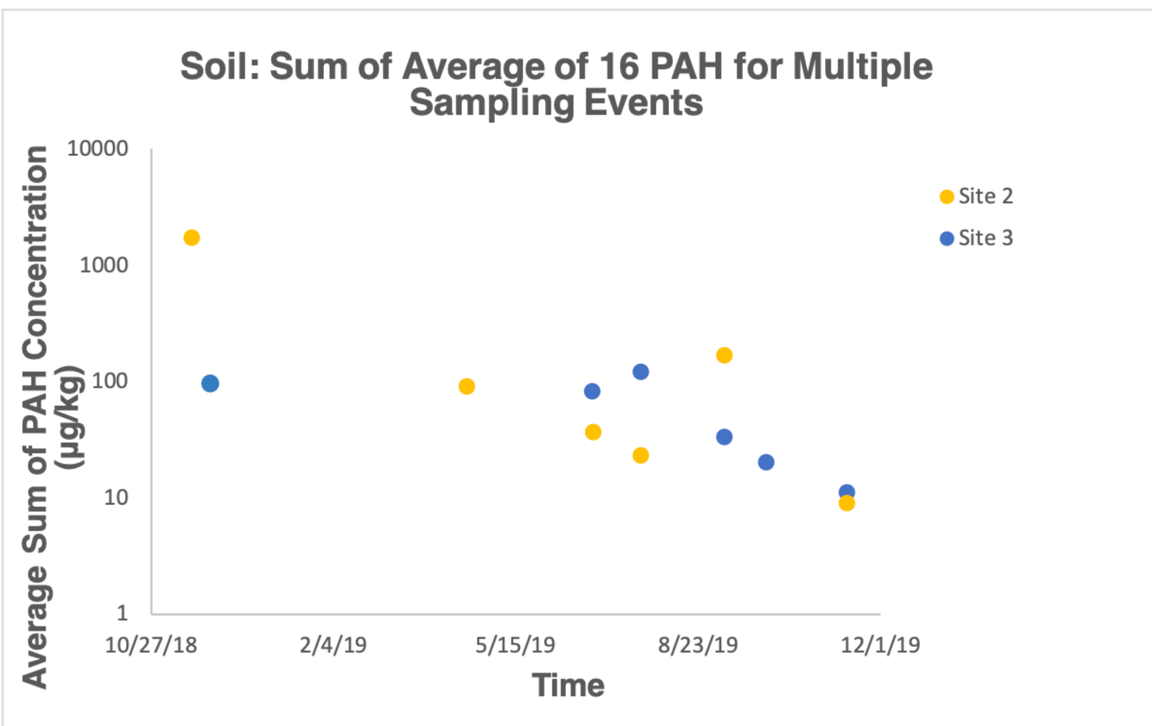

Figure 8. Soil PAH concentrations decrease rapidly following the fire.

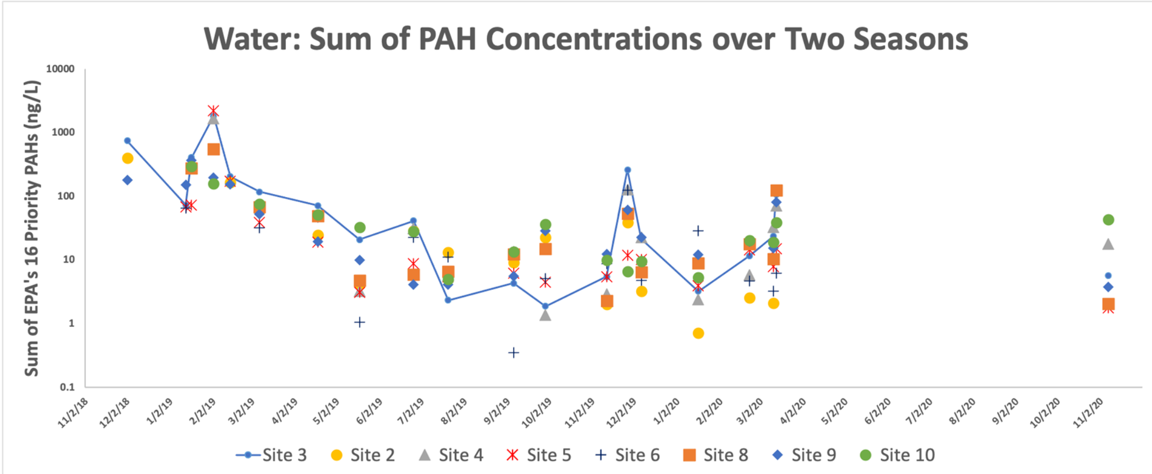

Figure 9. PAH concentrations of water samples from 8 sites shown over time. The trendline for site 3 shows a decline in PAH concentrations following the first wet season. PAH levels are elevated in the 2nd wet season compared to the preceding dry months. COVID regulations restricted sampling from April to November.

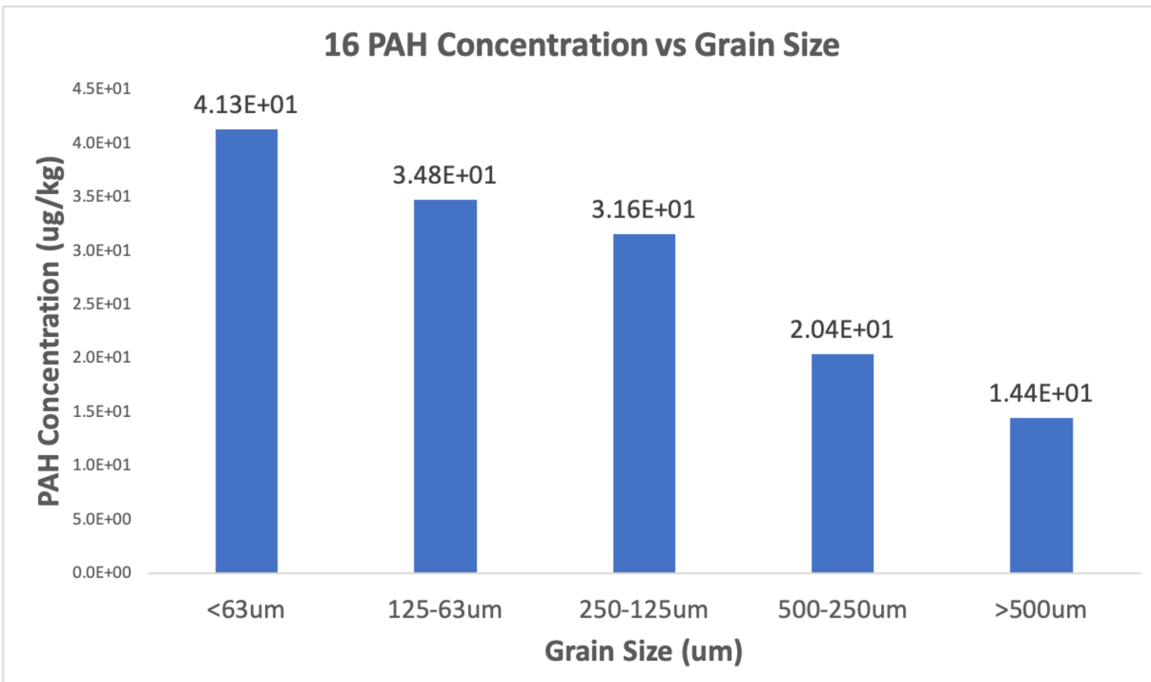

Figure 10. PAH concentrations decrease with increasing soil grain size.

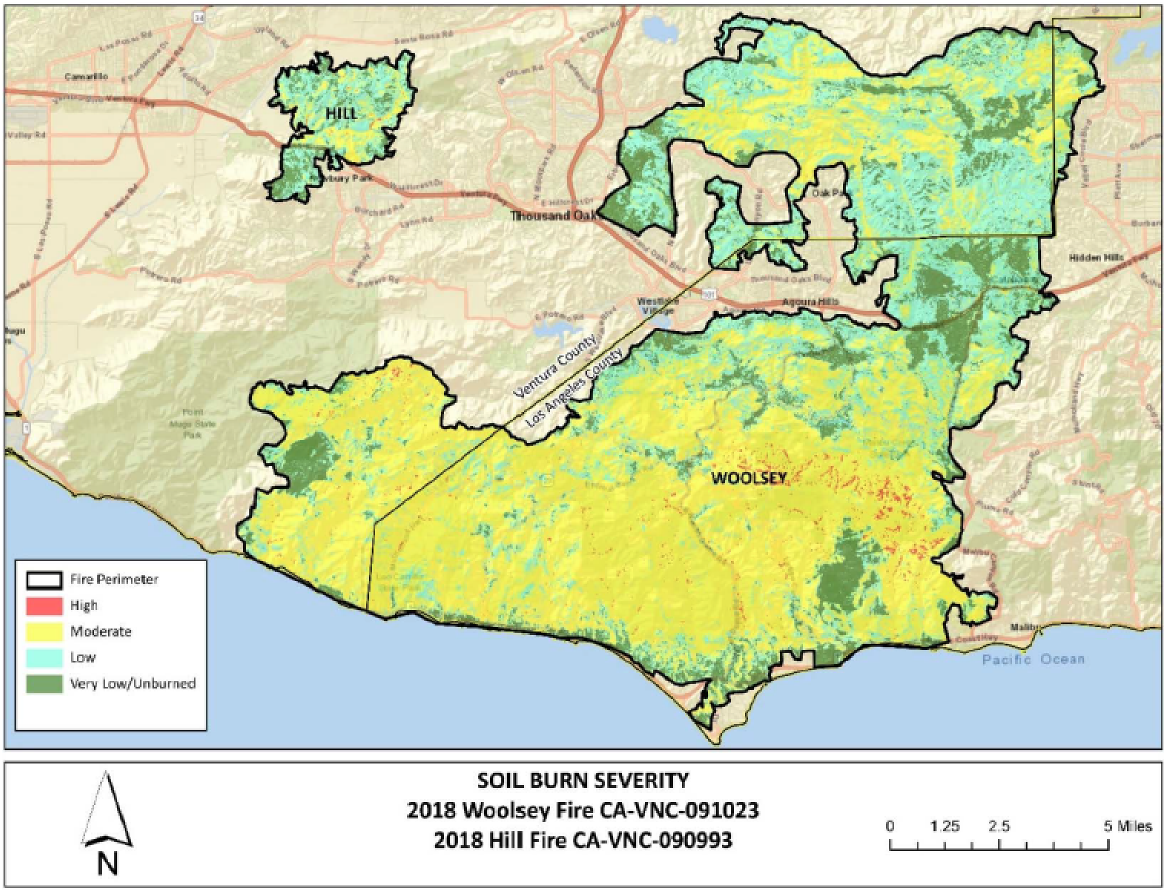

Figure 11. Soil burn severity map for the Woolsey Fire.

ABSTRACT

As wildfires become more prevalent and destructive, it is imperative to understand the impacts they have on the watersheds they burn. One particularly understudied aspect of wildfire-associated water quality impairment is the generation of polycyclic aromatic hydrocarbons (PAHs), a class of organic contaminants with carcinogenic, mutagenic, and ecotoxic properties. As a case study, we investigate PAH impacts associated with the 2018 Woolsey Fire, which burned over half of the Malibu Creek Watershed near Los Angeles, California. We collected soil and water samples periodically and during rain events over three years following the fire. Sampling sites were distributed through the watershed to incorporate samples from all major tributaries of Malibu Creek and to capture varying topography, geology, land use, and fire intensity. We found PAH concentrations exceeding EPA Ambient Water Quality Criteria, primarily during rain events, through the second wet season after the fire. Using molecular ratio approaches, the PAHs detected in water samples were directly linked to burned soil. Elevated PAH concentrations were associated with suspended particulate matter, which was in turn directly related to stream discharge and precipitation intensity. However, significant geographic variability was observed during the second wet season, suggesting topography, burn intensity, and other factors play a role in post-fire recovery and the persistence of fire-derived PAHs in the watershed. We investigated the contribution of these factors through a combination of long-term soil and water sampling, assessment of suspended particulate material, analysis of the variation and evolution of PAH compound distributions, and evaluation of geographic controls. Results suggest that an interplay of multiple geographic factors contribute to the observed variations. Understanding these complex mechanisms is critical to predicting long-term wildfire impacts to water quality in diverse settings.