**Introduction:**

Ambient particulate matter pollution from wildfire smoke is a significant issue in the United States and has grown worse in recent years. Over the past decade, wildfire smoke has accounted for roughly a quarter of PM2.5 pollution (particulate matter with a diameter smaller than 2.5 microns, as opposed to coarse particulate matter with a diameter smaller than 10 microns), and as much as half of all PM2.5 pollution in western states.1 This comes even as the US has made overall reductions in PM2.5 levels. Wildfire smoke PM2.5 is expected to continue harming these efforts, and under climate modeling projections, worsening wildfire seasons may lead to more than a doubling of current smoke PM2.5 levels, which could fully offset successes in PM2.5 reduction in certain regions.2,3 Smoke PM2.5 is not just an issue for the western US, as smoke plumes can extend far into the midwestern and eastern regions. Some projections estimate that up to three quarters of smoke-related mortality in the US is outside the west, in part due to differences in population density.4

PM2.5 pollution has been robustly linked to a wide variety of negative health effects. Due to their small size, these particles are able to travel deeper into the lungs and enter the bloodstream, at which point they can cause inflammation, affect the cardiovascular system, and even affect the central nervous system by crossing the blood-brain barrier.5 The health impact of ambient PM2.5 includes asthma, reduced lung function, increased risk for respiratory infections, cardiovascular disease, diabetes, cancer, and premature mortality.6,7 PM2.5 associated with wildfire smoke is understudied compared to all-source PM2.5, and there is evidence that smoke-related PM2.5 may be particularly harmful, as several studies have examined the impact of both smoke and all-source PM2.5 on hospitalizations and found smoke PM2.5 to be associated with greater increases.8,9 Aguilera et al. explain that this association could be due to wildfire smoke’s higher concentration of organic compounds compared to all-source PM2.5, which increases its ability to cause oxidative stress and inflammation.8

* Disproportionately high in counties with more non-Hispanic whites despite that group having lower exposure to general PM2.5
* especially in the west, where PM2.5 levels have increased 5 µg/m3 from 2010-2020.10
* Wildfire smoke-related PM2.5 has also been associated with respiratory health effects as well as respiratory infections, and recent evidence suggests that smoke-related PM2.5 may be more harmful than general-source PM2.5.
* PM2.5 exposure has been robustly linked to all-cause mortality, but fewer studies have focused on wildfire smoke-related PM2.5.
  + Aguilera et al. and Liu et al. have both linked wildfire smoke PM2.5 to increases in respiratory hospitalizations, with more potent effects than all-source PM2.5.8,9
  + Jegasothy et al. and Johnston et al. have linked Australian bushfire smoke PM2.5 to increased all-cause mortality and hospitalizations.
  + Ye et al. and Chen et al. have also linked wildfire PM2.5 to increased all-cause mortality in different global contexts.
* Lack of studies focusing on wfpm2.5 x mortality association in the US specifically
  + Also have not looked at how important social factors may modify the effect
* Importance of marital status as EMM in epidemiology:
  + major impact on health outcomes, including mortality
* Lit review of other studies looking at PM’s effect on health, using similar methodology:
  + Requirements for being comparable to our study:
    - Must have PM (or a similar environmental variable like temperature) as exposure, and mortality (or a similar count-based health outcome) as an outcome
    - Must not be a time-series study to be truly comparable—i.e. monthly or yearly-level data, since daily provides a level of power that is hard to beat (but data are more difficult to obtain and are not always possible to obtain)
    - Study must seek to estimate the actual association between the exposure and the outcome—many studies in this field use concentration response functions to estimate the impact of the environmental variable, but these rely on preexisting estimations of the true association
  + Takeaways:
    - Vast majority of these studies are from the Schwartz environmental epi lab, and also are associated w Francesca Dominici, and therefore use very similar designs (if not identical, down to the covariates)
    - None are at the month level, which means none have FEs for season, which is an option that is potentially important
    - Mix of population-weighting and area-weighting
    - Nearly all use the `gnm` package in R, which is not the most up-to-date for FE models (fixest)
    - Very little discussion of standard errors, so unclear whether they are designed to be robust to heteroskedasticity or autocorrelation
  + Majority based on Wang et al. 2016 from the Schwartz lab, using quasi-Poisson model with simple FE for district and for time
  + Other studies that are similar but with slightly different modeling approaches:
    - CRF studies
      * O’Dell et al. 2021
      * Matz et al. 2020
      * Johnston et al. 2020
    - Daily-level time series studies using QP-variations
      * Chen et al. 2021
      * Jegasothy et al. 2023
      * Morgan et al. 2010
    - Daily-level data, more studies from Schwartz lab:
      * Di et al. 2017, Air Pollution and Mortality in the Medicare Population
      * Zanobetti and Schwartz 2009: The effect of fine and coarse particulate air pollution on mortality, a national analysis
        + Multi-city time series study with data from general population, used conditional QP
      * Yitshak-Sade et al. 2019/Estimating the causal effect of annual PM2.5 exposure on mortality rates in the NE and mid-Atlantic states
        + Medicare beneficiaries
      * Schwartz et al. 2021/A national DID analysis of the effect of PM2.5 on annual death rates
        + Medicare beneficiaries
      * Wang et al. 2017/Long-term exposure to PM2.5 and mortality among older adults in the SE US
        + Medicare beneficiaries, Cox models
* Design of our study:
  + Includes all of CONUS
  + This design borrows from econometric methods, which the fields of social and environmental epidemiology have a track record of doing.
  + A two-way fixed effects model (TWFE) will be used to control for time-invariant county-level confounders, and country-wide temporal confounders
  + A key limitation of the TWFE is that it cannot control for confounders that vary across both time and county.
    - Temperature and precipitation are two such variables, and they will be controlled for directly
* Why this specific topic is worth studying:
  + Wfpm2.5 is a growing source of PM pollution in the US
  + Estimates from other countries are not necessarily generalizable to the US for a multitude of reasons (including lower levels of all-source PM2.5 in the US compared to other areas, plus SES)
  + Other studies looking at wfpm2.5 do so by examining fine-grain data from acute wildfire events.
  + This study’s decade-long time-series approach may capture how low levels of smoke PM2.5 across wide geographic ranges and provide potentially a more generalizable metric of the smoke PM2.5-mortality association

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