Modulated Air Pollution Interactions: Investigating $PM_{2.5}$ Characteristics as Modifiers of $PM_{2.5}$-Oxidant Gas Health Effects

MSc Proposal Idea

Background/Context

- Established independent acute health risks of $PM_{2.5}$ and Oxidant Gases (O_3, NO_2).
- Growing evidence for *synergistic effects*: Short-term $PM_{2.5}$ health associations appear stronger when oxidant gas levels (Ox) are high (Lavigne et al., JAWMA 2017).
- Parallel evidence: $PM_{2.5}$ *composition* (metals, sulfur) and *oxidative potential* (OP) significantly modify $PM_{2.5}$'s own health effects (Key cites: Toyib et al., 2023; Korsiak et al., 2022; Weichenthal et al., 2020; Lavigne et al., EHP 2016).

Takeaway

We know interactions occur, and we know PM composition matters for PM toxicity.

Research Gaps

- Current research streams largely treat PM-Ox interactions and PM composition/OP effects *separately*.
- **The Unanswered Question:** Does the *specific type or characteristic* of $PM_{2.5}$ influence *how strongly* it interacts with co-occurring oxidant gases to impact acute health?
- Opportunity To integrate these research streams, providing a more nuanced understanding of air pollution mixture toxicity in the real world. This seems like novel and mechanistically plausible area for investigation.

Methodology

- **Research Question**
  - Do specific $PM_{2.5}$ characteristics (key components like transition metals/sulfur and/or measures of Oxidative Potential) modify the association between short-term co-exposure to $PM_{2.5}$ and oxidant gases (Ox) and acute cardio-respiratory health outcomes?
- **Hypothesis**
  - The positive association between $PM_{2.5}$-Ox co-exposure and acute cardiovascular events (e.g., ER visits) is significantly stronger during periods/in locations where $PM_{2.5}$ has higher transition metal content and/or higher inherent oxidative potential (e.g., OPGSH).

Phases of how I “see” this unfold

- Overall design: Multi-city Canadian Case-Crossover Study (Leverages existing frameworks & expertise).
- Phase 1 (MSc core – feasibility/proof-of-concept focus)
  - Confirm baseline $PM_{2.5}$-Ox interaction in accessible dataset(s).
  - Link health events to $PM_{2.5}$ characteristics (e.g., monthly OP/metals measurements or spatial predictions).
  - Test for modification using stratified conditional logistic regression
    - In other words, is interaction odds ratio different in high vs low strata)
- Phase 2 □ Deeper insights
  - Use advanced analysis/machine learning (GAMs with tensor product interactions, potentially Gradient Boosting) to model the 3-way interaction ($PM_{2.5}$ x Ox x PM_Characteristic) more flexibly.

Why I believe this might be a good proposal

- Provides novel insights into complex air pollution mixture effects and potential mechanisms (oxidative stress pathways).
  - Addresses a key knowledge gap.
- Potential application and validation of advanced analytical/ML techniques for complex interaction analysis in environmental epidemiology.
- Could identify conditions (locations, seasons, sources) where combined pollution exposure poses disproportionately higher acute risks.
  - Informs risk assessment (HSS 3303!) and potentially targeted interventions.
- Directly builds upon and extends existing research directions within our group (Dr. Weichenshal, Jue yi Zhang, Colleagues..)

Feasibility/hurdles

- Strength: Builds on established methods (case-crossover), leverages potential access to large Canadian datasets, strong supervisory expertise available (Dr. Éric!)
- Hurdles

What is the realistic availability of *linked* datasets containing:

- *Daily* individual-level health outcomes (ER/Hospitalization data with date/location)?
- *Daily* ambient pollution estimates ($PM_{2.5}$, O_3, NO_2) for those locations/dates?
- *Relevant $PM_{2.5}$ Characteristic Data* (Measured OP/Metals/Sulfur OR high-resolution spatial predictions) assignable to the exposure period? What is the temporal/spatial resolution?

Can this data linkage be achieved with realistic MSc timeline?

Confirmation of data accessibility is biggest hurdle (MIREC data, NAPS, other)

Scope of proposal adapt as needed