Short-term effects of PM oxidative potential on mortality

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on behalf of the **RI-URBANS team**

RI-URBANS (101036245)
6th Expert Panel on Clean Air in Cities (EPCAC)
18-19 November, 2025

The RI-URBANS Study

- The objective of **RI-URBANS** is to demonstrate how Service Tools from atmospheric Research Infrastructures can be adapted and enhanced to better **address the challenges and societal needs** in European cities and industrial, harbour, airport and road traffic hotspots **concerning air quality (AQ),** as well as areas with significant levels of air pollution and associated health effects.

- **RI-URBANS** evaluated **novel AQ parameters and source contributions**, and their **associated health effects through epidemiological time series analyses,** to demonstrate the added value of implementing these enhanced observations.

Pollutants and metrics evaluated in RI-URBANS

Particle Number (#/cm³)
- Nucleation [10-25 nm]
- Aitken [25-100 nm]
- UFP [10-100 nm]
- Accumulation [>100 nm]
- Ntotal [> 10 nm]

Particle Mass (µg/m³)
- Black carbon (BC)
- BC sources
- $PM_{2.5}$
- PM_{10}
- PMcoarse (PM_{10}-$PM_{2.5}$)
- PM chemical composition

Oxidative Potential (OP) (nmol/min/µg, nmol/min/ m³)
- $PM_{2.5}$ OP
  PM_{10} OP
- Dithiothreitol (DTT) assay
- Ascorbic acid (AA) assay

Regulated gases (µg/m³)
- NO_2
- SO_2
- O_3

+ many others pollutants (e.g. sources of UFP, sources of BC, sources of OP)

Oxidative potential (OP) as a novel metric for the health effects of Particulate Matter (PM)

✓ **Oxidative potential** of PM (OP) is "a measure of the capacity of particulate matter to **oxidise** potential target molecules." (EC Directive 2024/2881)

The new EU air quality regulation recommends the measurement of OP at supersites.

Oxidative Potential (OP)
(nmol/min/µg, nmol/min/ m^3)

- $PM_{2.5}$ OP
  PM_{10} OP
- Dithiothreitol (DTT) assay
- Ascorbic acid (AA) assay

Current challenges faced by epidemiological studies on OP

- Lack of official standard protocols for OP measurements.
- Results may be inconsistent (due to varying methodology, different PM dominant sources, etc).
- Long-term OP daily data is still limited

Evidence on the effects of OP on health

OP$^{(DTT)}$ was associated with cardiorespiratory emergency department visits (Georgia, USA, time-series) (Abrams et al., 2017).

Research

A Section 508–conforn
is available at ht

Associations between Ambient Fine Particulate Oxidative Potential and Cardiorespiratory Emergency Department Visits

Joseph Y. Abrams,[1] Rodney J. Weber,[2] Mitchel Klein,[3] Stefanie E. Samat,[3] Howard H. Chang,[4] Matthew J. Strickland,[5] Vishal Verma,[6] Ting Fang,[2] Josephine T. Bates,[7] James A. Mulholland,[7] Armistead G. Russell,[7] and Paige E. Tolbert[3]

Prenatal exposure to **OP$^{(DTT\ and\ AA)}$ were associated** with adverse lung function parameters in infants and pre-schoolers (France, Cohort) (Marsal et al., 2023).

Research **Environmental Health Perspectives**

A Section 508–conformant HTML version of this article is available at https://doi.org/10.1289/EHP11155.

Prenatal Exposure to PM$_{2.5}$ Oxidative Potential and Lung Function in Infants and Preschool- Age Children: A Prospective Study

Anouk Marsal,[1,7] Rémy Slama,[2] Sarah Lyon-Caen,[2] Lucille Joanna S. Borlaza,[1] Jean-Luc Jaffrezo,[1] Anne Boudier,[2,3] Sophie Darfeuil,[1] Rhabira Elazzouzi,[1] Yoann Gioria,[2] Johanna Lepeule,[2] Ryan Chartier,[6] Isabelle Pin,[2,3] Joane Quentin,[2,4] Sam Bayat,[4,5] Gaëlle Uzu,[1] Valérie Siroux,[2*] and the SEPAGES cohort study group*

PM$_{2.5}$ OP$^{(DTT)}$ was associated with lower weight and height at birth due to prenatal personal exposure (Grenoble, France, cohort) (Borlaza et al., 2022).

nature > journal of exposure science & environmental epidemiology > articles > article

Article | Published: 11 November 2022

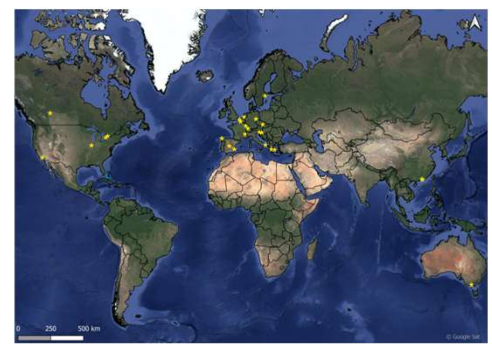
Personal exposure to PM$_{2.5}$ oxidative potential and its association to birth outcomes

Lucille Joanna S. Borlaza, Gaëlle Uzu, Marion Ouidir, Sarah Lyon-Caen, Anouk Marsal, Samuël Weber, Valérie Siroux, Johanna Lepeule, Anne Boudier, Jean-Luc Jaffrezo, Rémy Slama & the SEPAGES cohort study group

Journal of Exposure Science & Environmental Epidemiology **33**, 416–426 (2023) | Cite this article

OP measurement Intercomparison study within RI-UBANS/Actris

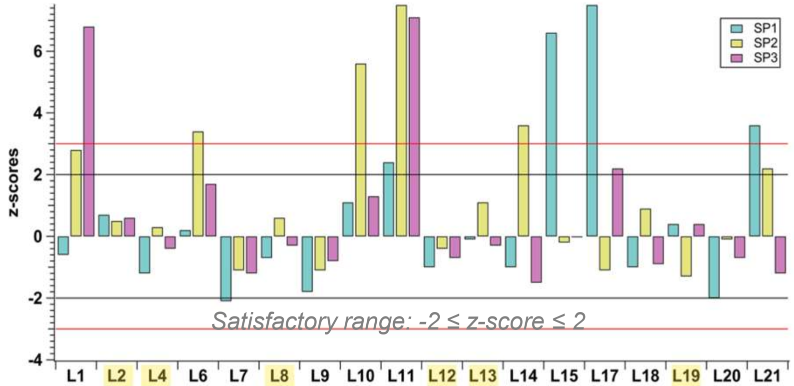
- Two intercomparisons based on:
  - 2 simplified OP protocol AND all “home” OP protocols existing in the participating groups on board.
  - Standard solutions and real filter samples
- 2 main objectives :
  - Develop common simplified OP protocols and evaluate the differences of OP results obtained by the RI-Urbans and OP home protocols.
  - Test results’ homogeneity and investigate the potential sources of discrepancies
- Intercomparisons took place in 2023 and in 2025
  - OP DTT in 2023 : 18 participating labs
  - OP AA in 2025 : 26 participating labs
  - This intercomparison study was lead by CNRS from Grenoble.



OP measurement Intercomparison study - Results

✓ **Independent** data evaluation by the European Joint Research Centre (JRC)

- **OP DTT**
  9 participants (50%) were in the satisfactory interval
- **OP AA**
  14 participants (54%) in the satisfactory interval



Dominutti et al., 2025

✓ **Less variability in the OP AA than the OP DTT** protocol

Short-term effects of OP on mortality: a meta-analysis

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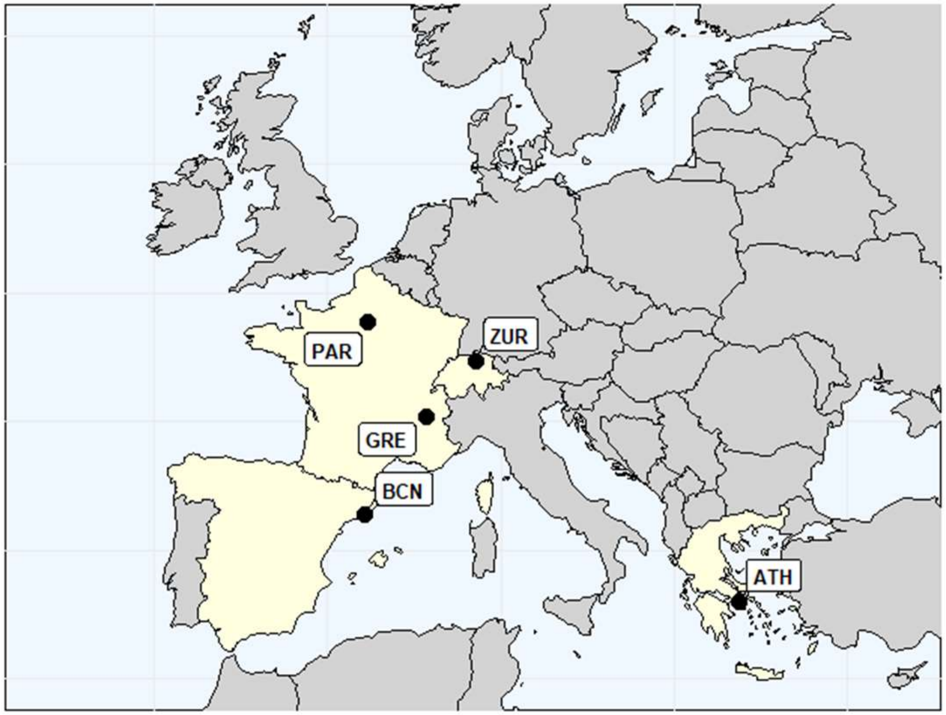
Research questions

1. Could OP provide additional insights on the health effects of PM in comparison with PM mass alone?

2. Could the effect of PM on mortality be larger on days of high OP levels?

Methodology: Location of sites

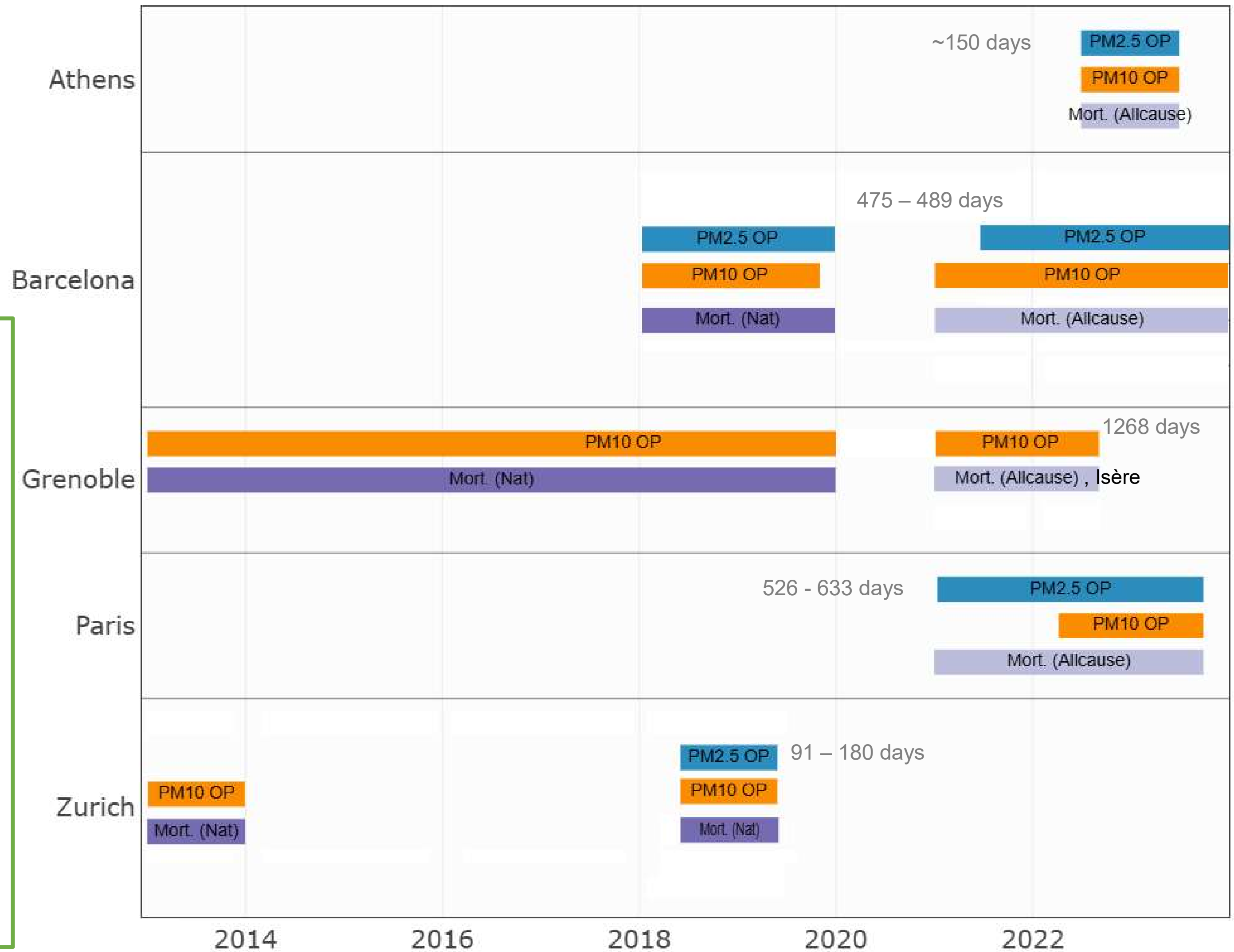


Five cities
- Athens (GR)
- Barcelona (ES)
- Grenoble (FR)
- Paris (FR)
- Zurich (CH)

OP data availability

- ❑ Sampling: 2013 – 2023
- ❑ Non-daily OP data for most cities
- ❑ Year 2020 was excluded (COVID-19)
- ❑ $PM_{2.5}$ OP was unavailable for Grenoble and Zurich (2013).
- ❑ Both natural and all-cause mortality used.

OP data availability per city



Methodology: OP measurements

- **OP was measured using the <u>same protocol in all cities</u>** (Protocol by Calas et al. 2017, 2018).
- Two commonly used assays: **Ascorbic acid** (AA) and **Dithiothreitol** (DTT) assays.

Results were normalised by **PM mass** and **volume of air:**

➢ **Volume-normalised OP (OP_v)**: oxidative potential of PM particles present in **1 m³ of air** (nmol min^{-1} m^{-3}) → Exposure **(OP levels in the air).**

➢ **Mass normalized OP (OP_m)**: oxidative potential present in **1 µg of PM** (nmol min^{-1} $µg^{-1}$) → **intrinsic toxicity of PM**.

AA assay

Filters containing $PM_{2.5}$ or PM_{10}

↓

PM samples extracted into simulated lung fluid

↓

Reaction with AA (96-well plate)

↓

Determination of reagent depletion rate by **light absorption** (spectrophotometry)

DTT assay

Filters containing $PM_{2.5}$ or PM_{10}

↓

PM samples extracted into simulated lung fluid

↓

Reaction with a buffer followed by DTT (96-well plate)

↓

Titration with Dithionitrobenzoic acid (DTNB)

↓

Determination of reagent depletion rate by **light absorption** (spectrophotometry)

Methodology: Epidemiological study

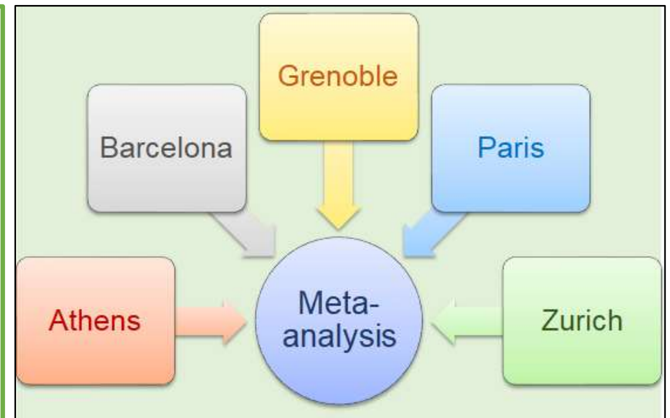
1) Time series analysis

GNM quasi-Poisson regression models adjusted for:

- ✓ Long-term trends and seasonality (time-stratified case-crossover)
- ✓ Temperature (2 splines – cold and warm)
- ✓ Relative humidity (natural spline with 3 degrees of freedom)
- ✓ Bank holidays
- ✓ Day of the week

❑ Delayed effects of exposure were investigated: lag 0 to 7.

➢ **2) Random-effect meta-analysis** to obtain the pooled effects.



Confidential!
Unpublished results

Preliminary Results

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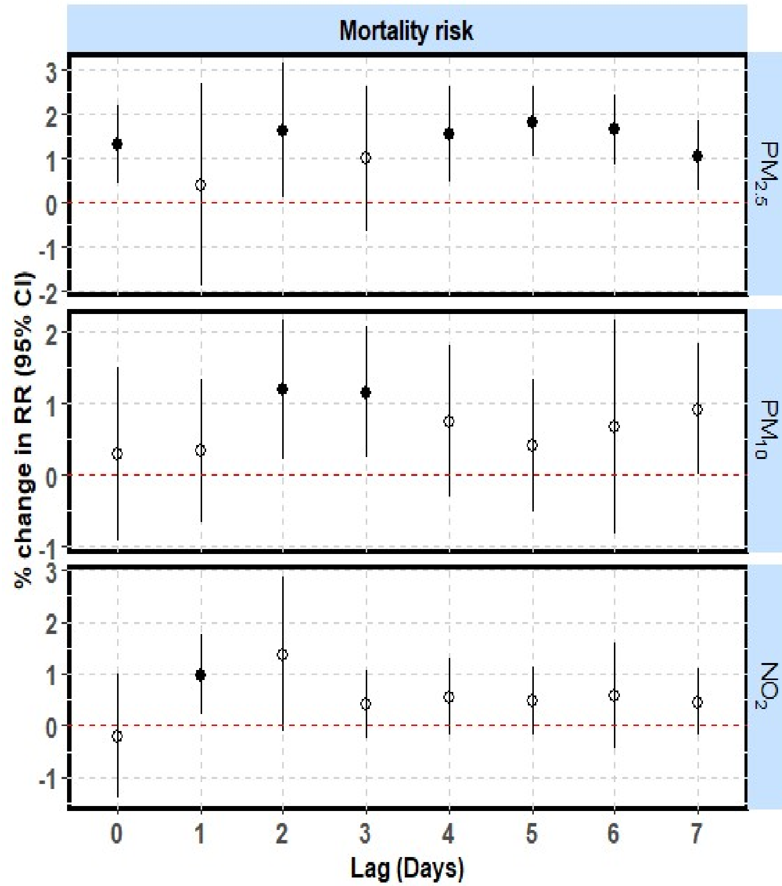
Effects of regulated pollutants on mortality

Increased mortality risk was observed for all the evaluated conventional pollutants, particularly for $\mathbf{PM_{2.5}}$

Percentage change in relative risk (**RR**) per mean IQR increase in pollutant concentration

<u>Mean IQR (µg/m³):</u>
$PM_{2.5}$: 8.35
PM_{10}: 12.20
NO_2: 14.90

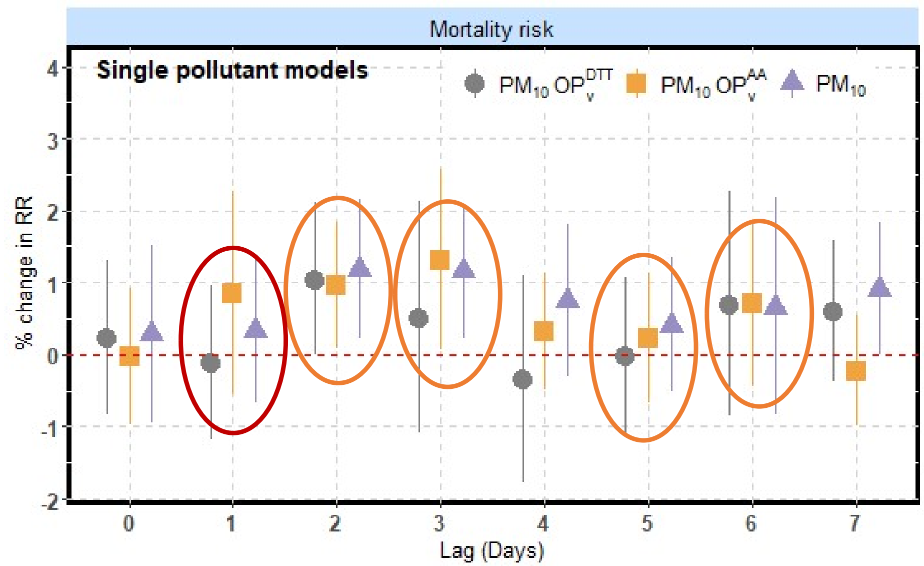


1. Could OP provide additional insights on health effects in comparison with PM mass alone?

Mean IQR (nmol/min/m^3):
$PM_{2.5}$ OP_v^{AA}: 0.66
$PM_{2.5}$ OP_v^{DTT}: 0.74
PM_{10} OP_v^{AA}: 1.12
PM_{10} OP_v^{DTT}: 1.24

PM_{10} OP_v^{AA} exhibited similar and sometimes even stronger effects on mortality than PM_{10} mass, at several lags.
PM_{10} OP_v^{AA} may provide additional information on health effects in comparison with PM_{10} alone.

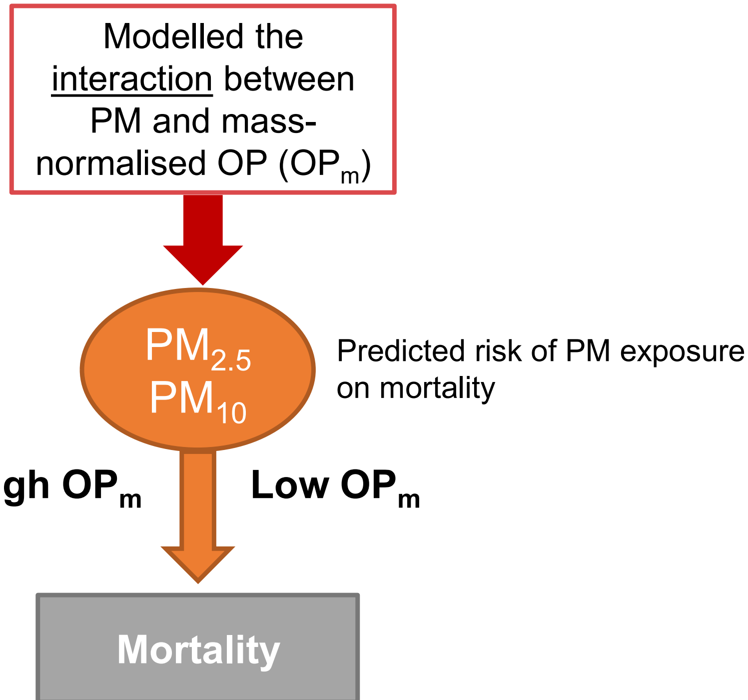
Pooled effects of volume-normalised OP (OP_v) exposure on mortality, from single pollutant models



Mean IQR (µg/m^3):
$PM_{2.5}$: 8.35
PM_{10}: 12.20

2. Could the effect of PM on mortality be larger on days of high OP levels?

Modelled the interaction between PM and mass-normalised OP (OP_m) to predict the relative risk of PM exposure on mortality under **low** and **high** OP levels.



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2. Could the effect of PM on mortality be larger on days of high OP levels? ($PM_{2.5}$)

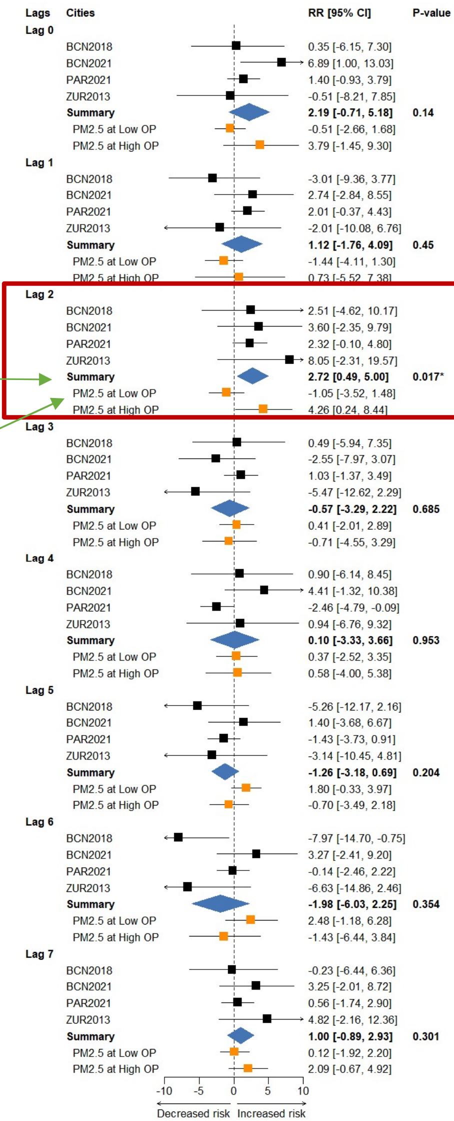
Effects of interaction between **OP_m^{AA} and $PM_{2.5}$** on mortality.

Effects of **$PM_{2.5}$** on mortality **under low and high OP_m^{AA}**.

$PM_{2.5}$ exposure had a larger effect on mortality on days of **high OP_m^{AA}**
(Lag 2: 4.26% [95% CI: 0.24, 8.44 %])

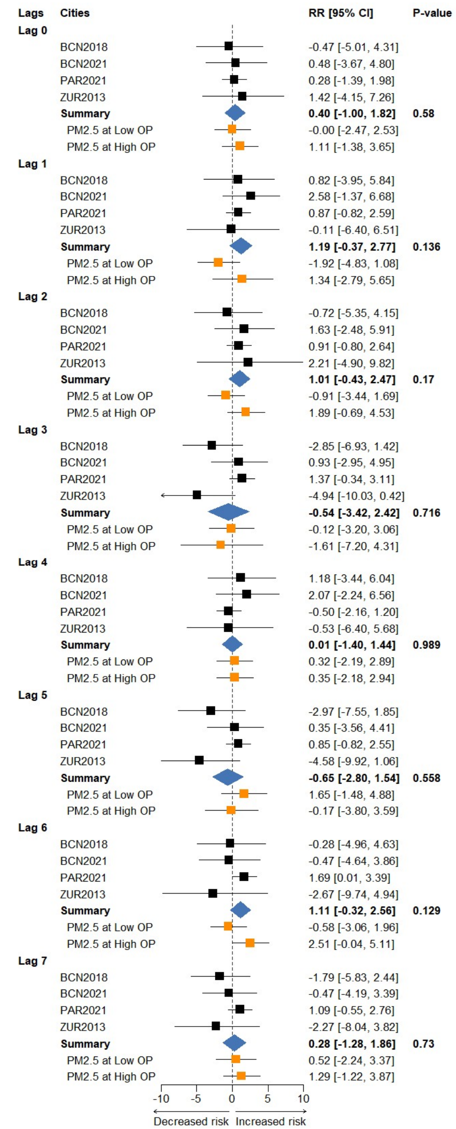
Mean IQR (µg/m³):
$PM_{2.5}$: 8.35

Effects of the $PM_{2.5}$ – OP_m^{AA} interaction



The interaction between **OP_m^{DTT}** and **$PM_{2.5}$** was not statistically significant.

Effects of the $PM_{2.5}$ – OP_m^{DTT} interaction



2. Could the effect of PM on mortality be larger on days of high OP levels? (PM_{10})

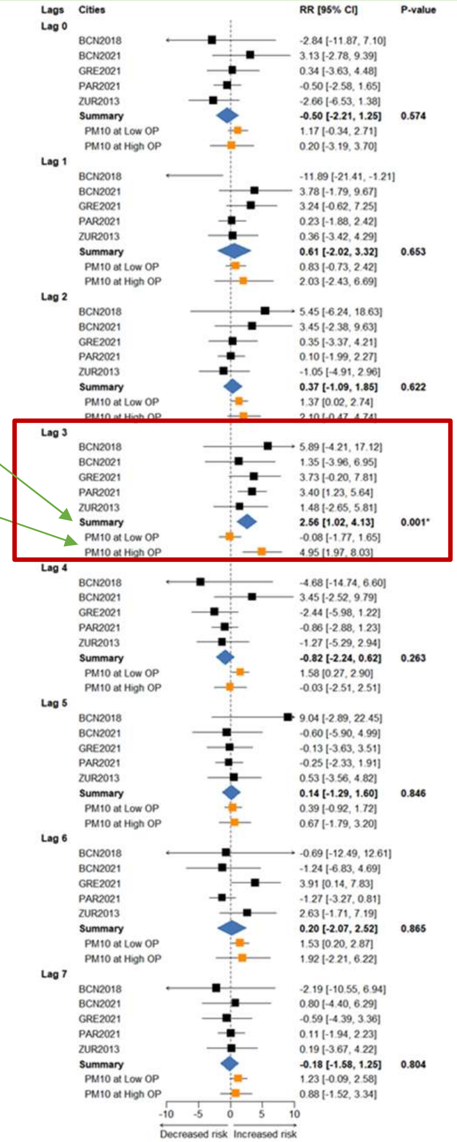
Effects of interaction between OP_m^{AA} **and** PM_{10} on mortality.

Effects of PM_{10} on mortality **under low and high** OP_m^{AA}.

PM_{10} exposure had a larger effect on mortality on days of **high** PM_{10} OP_m^{AA}
(Lag 3: 4.95% [95% CI: 1.97, 8.03 %])

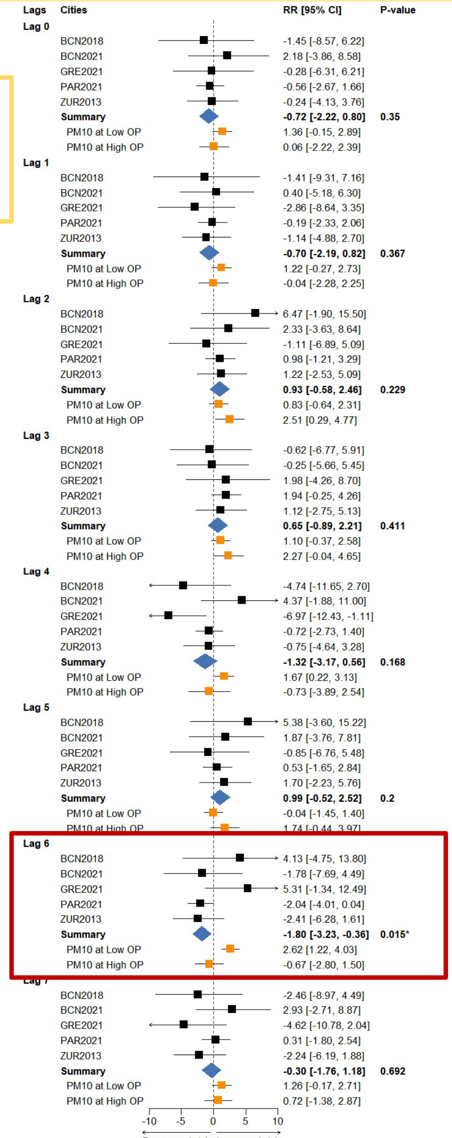
Mean IQR (µg/m³):
PM_{10}: 12.20

Effects of the PM_{10} – OP_m^{AA} interaction



Unlike AA, the effects of PM_{10} on mortality were stronger on days of **low** OP_m^{DTT}.
(Lag 6: 2.62 % [1.22, 4.06%])

Effects of the PM_{10} – OP_m^{DTT} interaction



Contrasting results between AA and DTT

DTT and AA assays can be sensitive to different chemical species in PM

Further investigation is needed!

"**OP^{DTT}** were similar in $PM_{2.5}$ and PM_{10} and highly associated with **OC, EC and K^{+}.**"

"**OP^{AA}** were higher in PM_{10} than in $PM_{2.5}$ and highly associated with **Cu and Fe**." (Mediterranean site) (Perrone et al., 2019)

Atmos. Chem. Phys., 16, 3865–3879, 2016
www.atmos-chem-phys.net/16/3865/2016/
doi:10.5194/acp-16-3865-2016

Atmospheric Chemistry and Physics
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Oxidative potential of ambient water-soluble $PM_{2.5}$ in the southeastern United States: contrasts in sources and health associations between ascorbic acid (AA) and dithiothreitol (DTT) assays

Ting Fang[1], Vishal Verma[2], Josephine T. Bates[3], Joseph Abrams[4], Mitchel Klein[4], Matthew J. Strickland[4], Stefanie E. Sarnat[4], Howard H. Chang[5], James A. Mulholland[3], Paige E. Tolbert[4], Armistead G. Russell[3], and Rodney J. Weber[1]

"**AA** activity was nearly exclusively correlated with **water soluble Cu** (r = 0.70–0.94 at most sites), whereas **DTT** activity was correlated with **organic and metal species**."

"Estimated **AA** activity **was not statistically associated** with any tested health outcome, while **DTT** activity **was associated with ED visits** for both asthma or wheeze and congestive heart failure." (Fang et al., 2016)

Conclusions

- Our preliminary results indicate that PM_{10} OP_v^{AA} may provide additional information on adverse health effects in comparison with PM_{10} mass alone, although this was not the case for $PM_{2.5}$ OP_v, regardless of the assay.

- When evaluating the effects of PM on mortality in days of low or high OP levels, $PM_{2.5}$ and PM_{10} exposure had stronger effects in days of high OP_m^{AA}. However, the opposite was observed for PM_{10} OP_m^{DTT}. PM_{10} had the largest effects on mortality in days of low PM_{10} OP_m^{DTT}.

- Harmonised OP measurements are important for consistency in epidemiological studies.

- Long-term time series are needed to evaluate the effects of OP on health.

Considerations

Strengths

- Includes relatively long time-series (e.g., Grenoble: 1268 days).
- OP measured by the same laboratory, using the same methodology for all cities.
- To our knowledge, first meta-analysis on the effects of OP on mortality.

Limitations

- Inconsistent mortality data types depending on the city (mortality data will be updated).
- Long-term time series were unavailable for some of the cities.

Next steps

- Re-analyse the data using natural mortality, and extend OP data for some of the cities.

Acknowledgements

We would like to thank the RI-URBANS WP1 researchers for their efforts in compiling the air pollution datasets. A special thanks goes to **Anouk Marsal, Antonis Analitis, and Evangelia Samoli** for their help in running some of the analyses, and AIRPARIF, the Swiss Federal Laboratories for Materials Science and Technology (EMPA) and the Swiss National Air Pollution Monitoring Network (NABEL) for providing air quality data for this study.

We would like to acknowledge the EARLY-ADAPT project (funded by the European Research Council under the European Union's Horizon 2020 research and innovation programme; grant agreement No. 865564), its research team, and the statistics centers below for providing mortality data for this study.

- Barcelona, Madrid and Granada: Spanish Statistical Office (INE)
- Athens: Hellenic Statistical Authority (ELSTAT)
- Zurich: Swiss Federal Statistical Office (BFS)
- Paris: Center for Epidemiology on Medical Causes of Death (Inserm)

Note: The calculations and the conclusion presented are the sole intellectual products of the Authors.

Thank you!