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Overview of Main Conclusions of the Integrated Science Assessment for Particulate Matter

Air Pollution and Health: Recent Advances to Inform EU Policies

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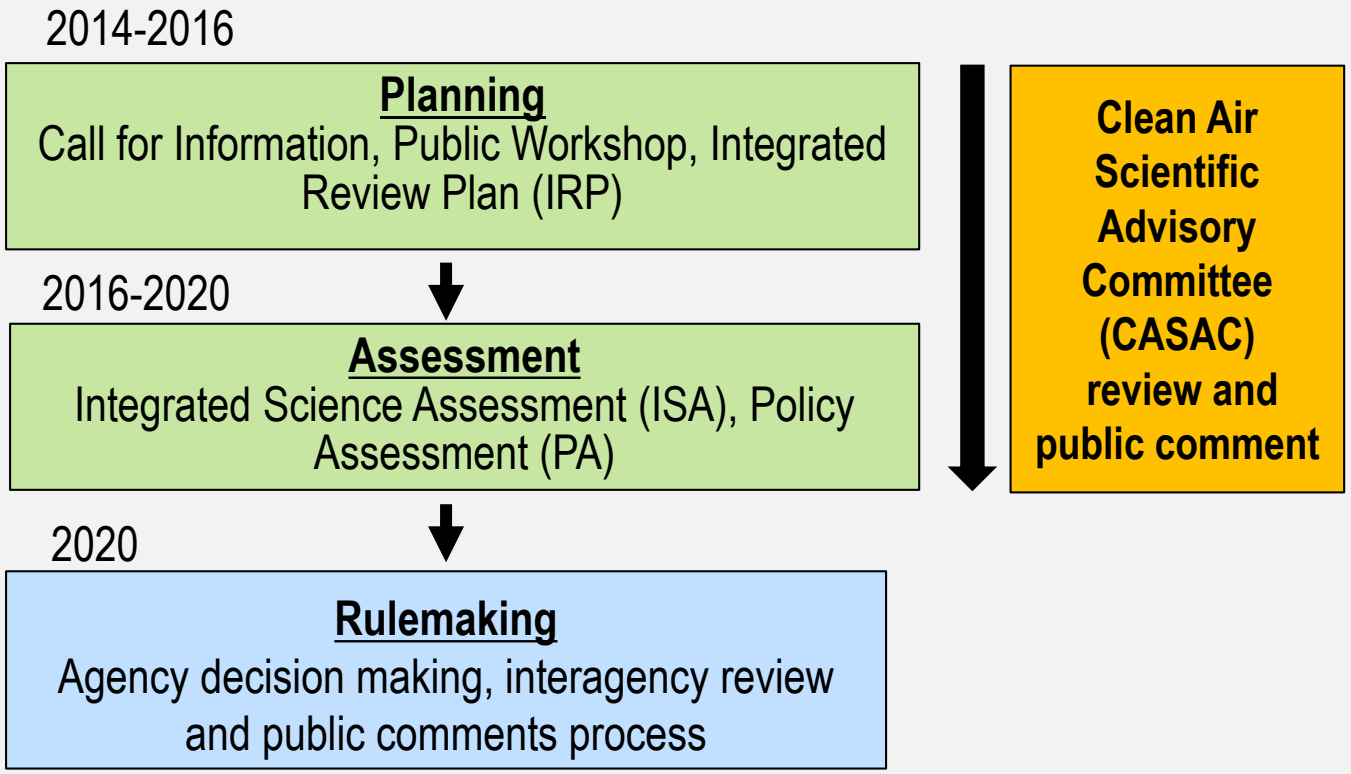
EPA United States Environmental Protection Agency

Disclaimer

This presentation is based on information provided in the Final Integrated Science Assessment for Particulate Matter. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

Overview of the Process for Reviewing the PM NAAQS

- **IRP:** Planned approach, schedule
- **ISA:** Assesses the available scientific information on public health and welfare effects; provides the science foundation for the review
- **PA:** Transparent analysis of the adequacy of the current standards and, as appropriate, potential alternatives



Note: This NAAQS Review Process was originally outlined in Administrator Pruitt's May 9, 2018 "Back to Basics" Memo.

Revisions to Draft PM ISA

- Main CASAC Comments
  - "*The revised ISA should provide a clearer and more complete description of the process and criteria for study quality assessment, including an explanation of how systematic assessments of individual study quality were used in preparing the ISA and the causality determinations*."
    - Response: Developed Appendix that outlined ISA development processes and further linked to ISA Preamble.
  - "*Inadequate evidence for altered causality determinations.*" (i.e., long-term $PM_{2.5}$ exposure and nervous system and cancer; long-term UFP exposure and nervous system)
    - Response: Revised long-term UFP exposure and nervous system effects, but not cancer or others.
  - "*Clearer discussion of causality and causal biological mechanisms and pathways*."
    - Response: Added text in Preface describing biological plausibility sections and revised some text in each section for clarity.

CASAC did not come to consensus on other topics

- Additionally,
  - Recommended the development of a 2nd Draft PM ISA
  - Recommended reappointing previous PM CASAC panel (or panel with similar expertise)
- July 2019, Administrator Wheeler directed that PM ISA be finalized by Dec 2019

Scope of PM ISA

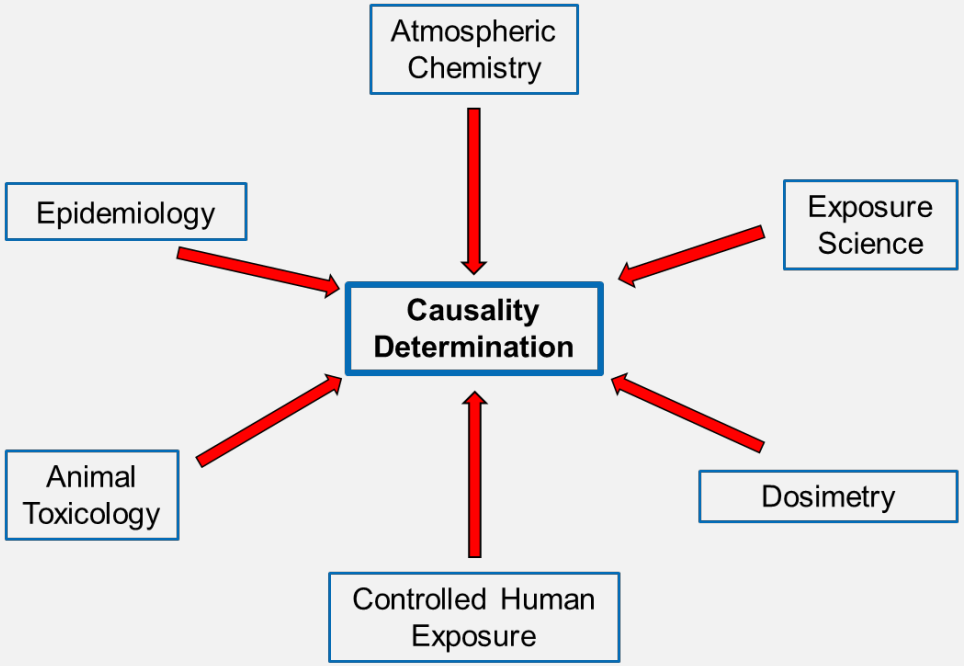
- **Scope:** The ISA is tasked with answering the question "Is there an independent effect of PM on health and welfare at relevant ambient concentrations?"
  - Health Effects
    - Studies were considered if they included a composite measure of PM (e.g., $PM_{2.5}$ mass, $PM_{10\text{-}2.5}$ mass, ultrafine particle (UFP) number)
    - Studies were considered if PM exposures are relevant to ambient concentrations (< 2 mg/m^3; ~1 to 2 orders of magnitude above ambient concentrations)
  - Welfare Effects
    - Focus is on non-ecological welfare effects (i.e., climate, visibility, materials)
    - Still awaiting a final letter from the CASAC review of the 2nd External Review Draft of NOx/SOx/PM-Eco ISA (last discussed Sept 2018)

PM ISA: Overall Observations

- Systematic Review of PM Literature Base
  - Initial search identified ~320,000; ~7,000 read past the title with ~2,800 cited in the ISA
- $PM_{2.5}$
  - Expansive body of literature supports and extends the conclusions of 2009 PM ISA
  - More extensive evaluation of some "newer" health effects (nervous system and metabolic)
  - Extensive analyses across health effects continues to support linear, no-threshold concentration-response (C-R) relationship
  - $PM_{2.5}$ more consistently related to health effects than individual components/sources
  - Effects observed at ever lower long-term average (i.e., annual) concentrations
- $PM_{10-2.5}$
  - Relatively fewer studies examine health effects due to $PM_{10-2.5}$ exposures
  - Uncertainties still remain with respect to differences in methods used in epidemiology studies for estimation of $PM_{10-2.5}$ concentrations across studies
- Ultrafine Particles (UFP)
  - Lack of U.S. monitoring network and limited data on spatial and temporal UFP concentrations, particularly in the U.S.
  - Variability in size distribution and exposure metric examined across studies

Evaluation of the Scientific Evidence

- Organize relevant literature for broad health outcome categories
- Evaluate studies, characterize results, extract relevant data
- Integrate evidence across disciplines for health outcome categories
- Develop causality determinations using established framework
- Evaluate evidence for populations potentially at increased risk
- Consider evidence spanning many scientific disciplines from source to effect:
  - Atmospheric chemistry
  - Exposure
  - Dosimetry
  - Controlled human exposure studies
  - Epidemiologic studies
  - Animal toxicologic studies

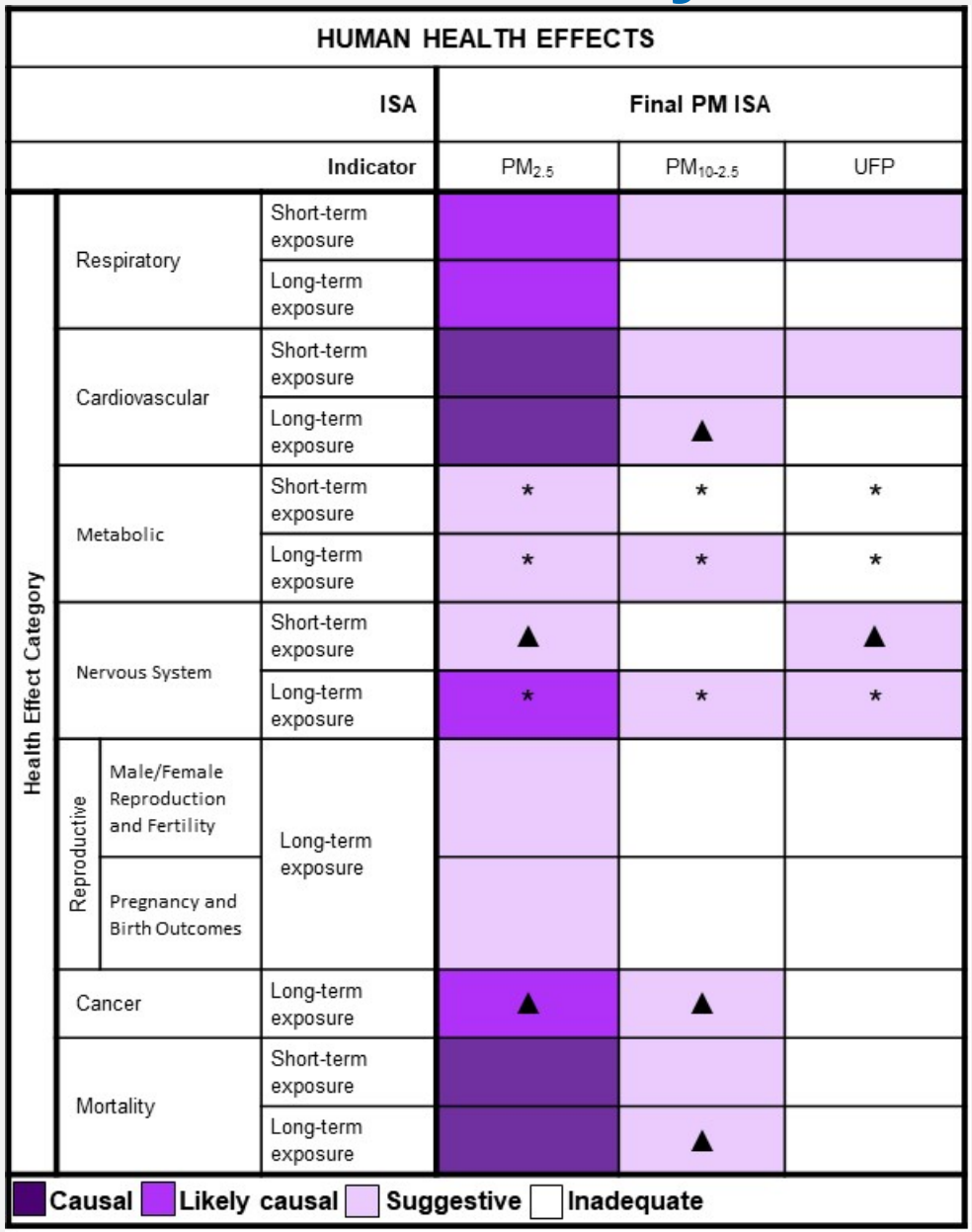


****Informs Hazard Identification step of Risk Assessment Process****

Final PM ISA
Health Effects: Causality Determinations

* = new causality determination

▲ = change in causality determination from 2009 PM ISA



Respiratory Effects

Recent evidence supports the conclusions of the 2009 PM ISA, and continues to support a likely to be causal relationship between short- and long-term $PM_{2.5}$ exposure and respiratory effects

- Short-term $PM_{2.5}$ Exposure **(Likely to be Causal)**
  - Epidemiologic evidence: consistent evidence for asthma exacerbation in children and COPD exacerbation in adults, as well as respiratory mortality.
    - Recent studies examining potential copollutant confounding provide evidence supporting an independent $PM_{2.5}$ effect, particularly for asthma exacerbation and respiratory mortality
  - Experimental evidence: worsening of allergic airways disease and/or subclinical effects related to COPD, provide biological plausibility for asthma and COPD exacerbations
- Long-term $PM_{2.5}$ Exposure **(Likely to be Causal)**
  - Epidemiologic evidence: consistent changes in lung function and lung function growth rate, increased asthma incidence, asthma prevalence and wheeze in children; acceleration of lung function decline in adults; and respiratory mortality
    - Independent $PM_{2.5}$ effect supported by examination of potential copollutant confounding, particularly studies of lung function growth and respiratory mortality; improvements in lung function growth with declining $PM_{2.5}$ concentrations
  - Experimental evidence: impaired lung development and development of allergic airways disease, biological plausibility for decrements in lung function growth in children and asthma development

Cardiovascular Effects

A large body of recent evidence supports and extends the conclusions of the 2009 PM ISA that there is a causal relationship between short- and long-term $PM_{2.5}$ exposure and cardiovascular effects

- Short-term $PM_{2.5}$ Exposure **(Causal)**
  - Epidemiologic evidence: generally consistent positive associations for hospital admissions and ED visits, particularly for ischemic heart disease (IHD) and heart failure (HF), as well as cardiovascular mortality
  - Experimental evidence: endothelial dysfunction, effects indicating impaired cardiac function, arrhythmia, changes in heart rate variability (HRV), increases in blood pressure (BP), and indicators of systemic inflammation, oxidative stress, and coagulation
- Long-term $PM_{2.5}$ Exposure **(Causal)**
  - Epidemiologic evidence: consistent positive associations for cardiovascular mortality; evidence for coronary heart disease (CHD) and stroke particularly in populations with pre-existing disease; evidence for coronary artery calcification (CAC)
    - Cardiovascular mortality studies inform potential copollutant confounding, and linear, no-threshold concentration-response relationship
  - Experimental evidence: impaired heart function, increased blood pressure, endothelial dysfunction, and atherosclerotic plaque progression

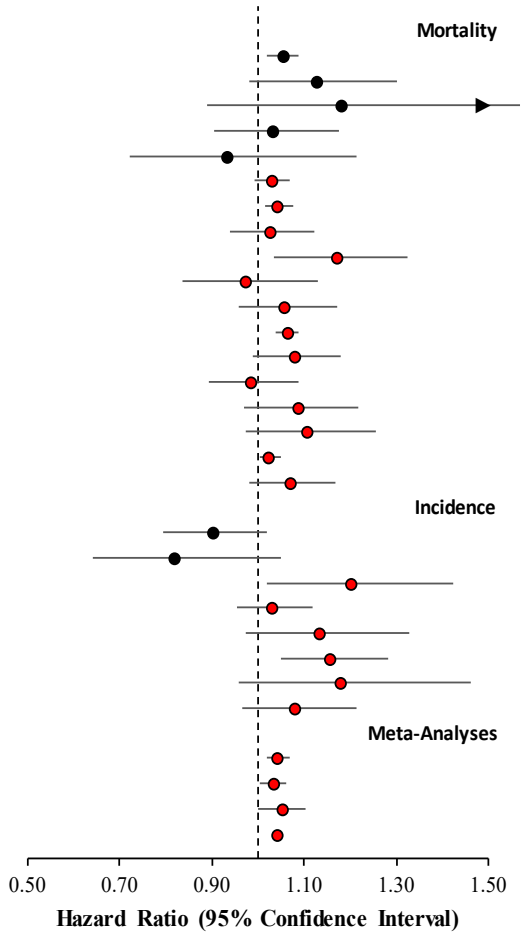
Nervous System Effects

- Long-term $PM_{2.5}$ Exposure **(Likely to be Causal – NEW conclusion)**
  - Epidemiologic evidence
    - Consistent evidence in older adults for cognitive decline/impairment and decreased brain volume; more limited evidence for neurodegeneration (e.g., Alzheimer's disease and dementia)
    - Limited evidence for neurodevelopmental effects (e.g., Autism Spectrum Disorder)
    - Lack of examination of potential copollutant confounding
  - Experimental evidence
    - Consistent evidence for inflammation, oxidative stress, morphologic changes, and neurodegeneration in multiple brain regions of adult animals
    - Limited evidence for early indicators of Alzheimer's disease, impaired learning/memory, altered behavior in adult animals, and morphologic changes during development
    - Evidence supports biological plausibility for cognitive decrements and dementia, and independent $PM_{2.5}$ effect

Cancer

Long-term $PM_{2.5}$ Exposure (Likely to be Causal – NEW conclusion)

Study	Cohort	Location	Follow-up Years	Qualifier
Krewski et al. (2009)	ACS (Re-analysis)	U.S.	1982-2000	
Laden et al. (2006)	HSC	6 U.S. cities	1974-1998	
McDonnell et al. (2000)	AHSMOG	California	1973-1977	Men
Brunekreef et al. (2009)a	NLCS - Air	Netherlands	1987-1996	Full Cohort
Brunekreef et al. (2009)a	NLCS - Air	Netherlands	1987-1996	Case Cohort
†Thurston et al. (2013)	ACS-CPS II	U.S.	1982-2004	
†Turner et al. (2016)	ACS-CPS II	U.S.	1982-2004	
†Hart et al. (2011)	TrIPS	U.S.	1985-2000	Men
†Lepeule et al. (2012)	HSC	6 U.S. cities	1974-2009	
†Lipsett et al. (2011)	CTS	California	2000-2005	Women
†Jerrett et al. (2013)	ACS-CPS II	California	1982-2000	
†Crouse et al. (2015)	CanCHEC	Canada	1991-2006	
†Pinault et al. (2016)	CCHS	Canada	2000-2011	
†Villeneuve et al. (2015)	CNBSS	Canada	1980-2005	Women
†Weichenthal et al. (2016)	CanCHEC	Ontario	1991-2009	
†Carey et al. (2013)	National English	United Kingdom	2003-2007	
†Cesaroni et al. (2013)	RoLS	Rome, Italy	2001-2010	
†Wong et al. (2016)	---	Hong Kong	1998-2011	
Brunekreef et al. (2009)b	NLCS - Air	Netherlands	1987-1996	Full Cohort
Brunekreef et al. (2009)b	NLCS - Air	Netherlands	1987-1996	Case Cohort
†Gharibvand et al. (2016)	AHSMOG-2	U.S.	2002-2011	
†Puett et al. (2014)	NHS	U.S.	1994-2010	Women
†Hystad et al. (2013)	NECSS	Canada	1994-1997	
†Tomczak et al. (2016)	CNBSS	Canada	1980-2004	Women
†Raaschou-Nielsen et al. (2013)	ESCAPE	Europe	1990s	
†Hart et al. (2015)	NCLS	Netherlands	1986-2003	
†Hamra et al. (2014)c	---	---	---	14 studies
†Yang et al. (2015)c	---	---	---	10 studies
†Chen et al. (2015)c	---	---	---	6 studies
†Cui et al. (2015)d	---	---	---	12 studies

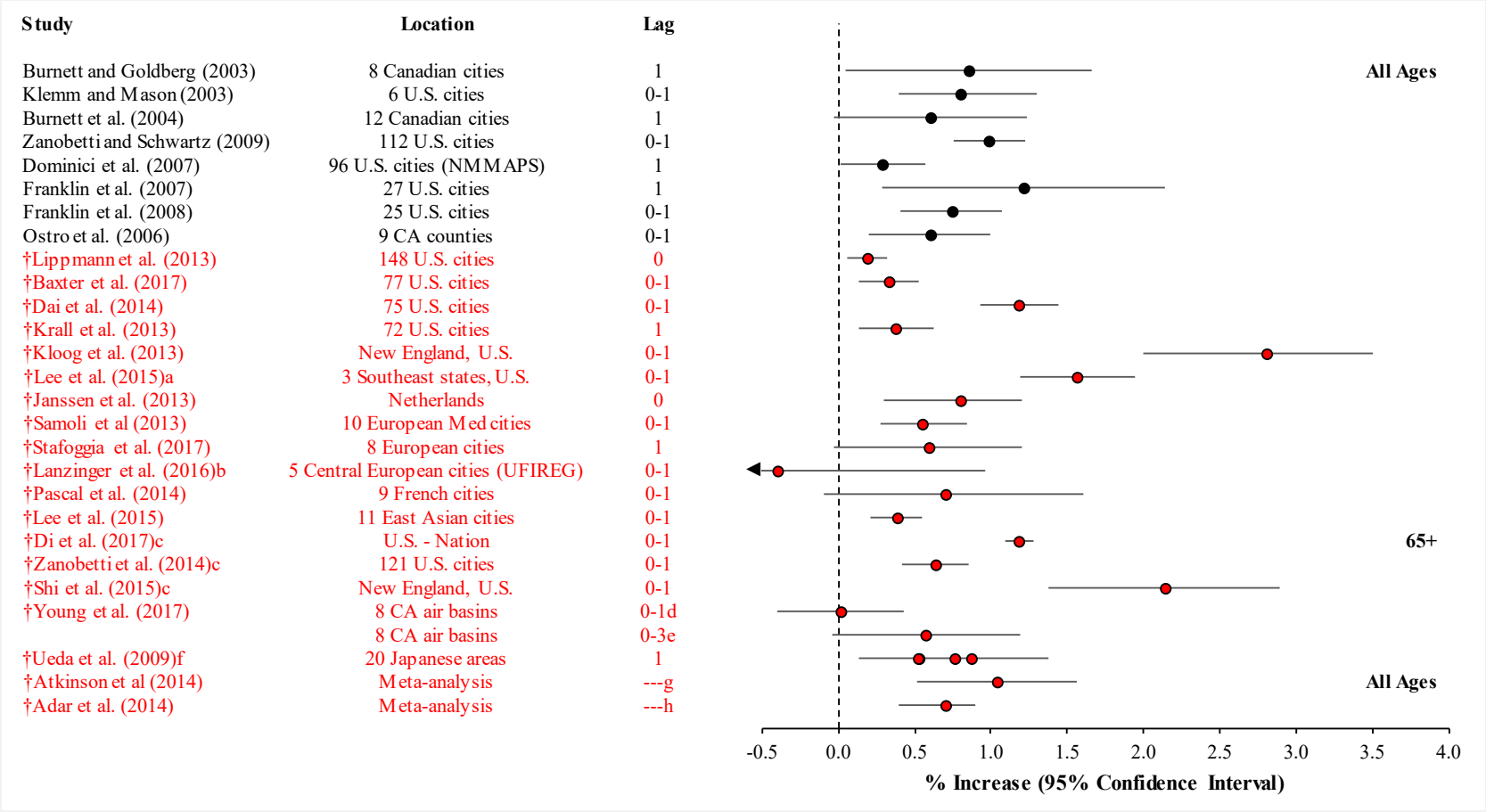


Note: Red = recent studies; Black = studies evaluated in the 2009 PM ISA

Figure 10-3. Summary of associations reported in previous and recent cohort studies that examined long-term $PM_{2.5}$ exposure and lung cancer mortality and incidence.

Mortality – Short-term $PM_{2.5}$ Exposure

Recent evidence supports and extends the conclusions of the 2009 PM ISA that there is a causal relationship between short-term $PM_{2.5}$ exposure and mortality



Note: Red = recent multi-city studies; Black = multi-city studies evaluated in the 2009 PM ISA

Figure 11-1. Summary of associations between short-term PM2.5 exposure and total (nonaccidental) mortality in multicity studies for a 10 µg/m³ increase in 24-hour average concentrations.

Mortality – Long-term $PM_{2.5}$ Exposure

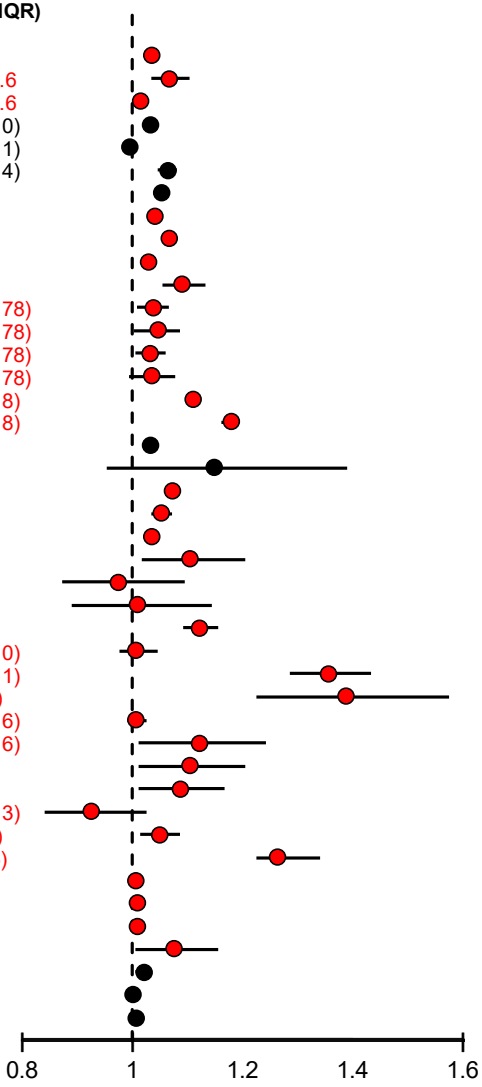
Recent evidence supports and extends the conclusions of the 2009 PM ISA that there is a causal relationship between long-term $PM_{2.5}$ exposure and mortality

Figure 11-18. Associations between long-term $PM_{2.5}$ and total (nonaccidental) mortality in recent North American cohorts.

Note: Associations are presented per 5 µg/m^3 increase in pollutant concentration.

Red = recent studies;
Black = studies evaluated in the 2009 PM ISA

Reference	Cohort	Notes	Years	Mean (IQR)
†Pope et al. 2014	ACS		1982-2004	12.6
†Lepeule et al. 2012	Harvard Six Cities		1974-2009	11.4-23.6
†Thurston et al. 2015	NIH-AARP		2000-2009	10.2-13.6
Zeger et al. 2008	MCAPS	Eastern	2000-2005	14.0 (3.0)
Zeger et al. 2008	MCAPS	Western	2000-2005	13.1 (8.1)
Zeger et al. 2008	MCAPS	Central	2000-2005	10.7 (2.4)
Eftim et al. 2008	ACS-Medicare		2000-2002	13.6
†Di et al. 2017	Medicare		2000-2012	11.5
†Di et al. 2017	Medicare	exp<12	2000-2012	11.5
†Di et al. 2017	Medicare	nearest monitor	2000-2012	11.5
†Kioumourtzoglou et al. 2016	Medicare		2000-2010	12
†Shi et al. 2015	Medicare	mutual adj	2003-2008	8.12 (3.78)
†Shi et al. 2015	Medicare	exp <10, mutual adj	2003-2008	8.12 (3.78)
†Shi et al. 2015	Medicare	no mutual adj	2003-2008	8.12 (3.78)
†Shi et al. 2015	Medicare	exp <10, no mutual adj	2003-2008	8.12 (3.78)
†Wang et al. 2017	Medicare		2000-2013	10.7 (3.8)
†Wang et al. 2017	Medicare	exp<12	2000-2013	10.7 (3.8)
Lipfert et al. 2006	Veterans Cohort		1997-2001	14.34
Goss et al. 2004	U.S. Cystic Fibrosis		1999-2000	13.7
†Crouse et al. 2012	CanCHEC	Satellite data	1991-2001	8.9
†Crouse et al. 2012	CanCHEC	Monitor data	1991-2001	11.2
†Crouse et al. 2015	CanCHEC		1991-2006	8.9
†Chen et al. 2016	EFFECT		1999-2011	10.7
†Weichenthal et al. 2014	Ag Health		1993-2009	8.84
†Weichenthal et al. 2014	Ag Health	more precise exp	1993-2009	8.84
†Pinault et al. 2016	CCHS		1998-2011	6.3
†Lipsett et al. 2011	CA Teachers		2000-2005	15.6 (8.0)
†Ostro et al. 2010	CA Teachers	within 30 km	2002-2007	17.5 (6.1)
†Ostro et al. 2010	CA Teachers	within 8 km	2002-2007	17 (6.1)
†Ostro et al. 2015	CA Teachers		2001-2007	17.9 (9.6)
†Puett et al. 2009	Nurses Health		1992-2002	13.9 (3.6)
†Hart et al. 2015	Nurses Health	nearest monitor	2000-2006	12.7
†Hart et al. 2015	Nurses Health	spatio-temp. model	2000-2006	12
†Puett et al. 2011	Health Prof	full model	1989-2003	17.8 (4.3)
†Hart et al. 2011	TrIPS		1985-2000	14.1 (4)
†Kloog et al. 2013	MA cohort	CVD+Resp	2000-2008	9.9 (1.6)
†Garcia et al. 2015	CA cohort	Kriging	2006	13.06
†Garcia et al. 2015	CA cohort	IDW	2006	12.94
†Garcia et al. 2015	CA cohort	closest monitor	2006	12.68
†Wang et al. 2016	NJ Cohort		2004-2009	11.3
Enstrom 2005	CA Cancer Prev		1973-1982	23.4
Enstrom 2005	CA Cancer Prev		1983-2002	23.4
Enstrom 2005	CA Cancer Prev		1973-2002	23.4



Next Steps for the PM NAAQS

Released Final ISA	**December 31, 2019**
Proposed PM NAAQS	Spring 2020
Final PM NAAQS	December 2020

Final PM ISA available at:
https://www.epa.gov/isa/integrated-science-assessment-isa-particulate-matter

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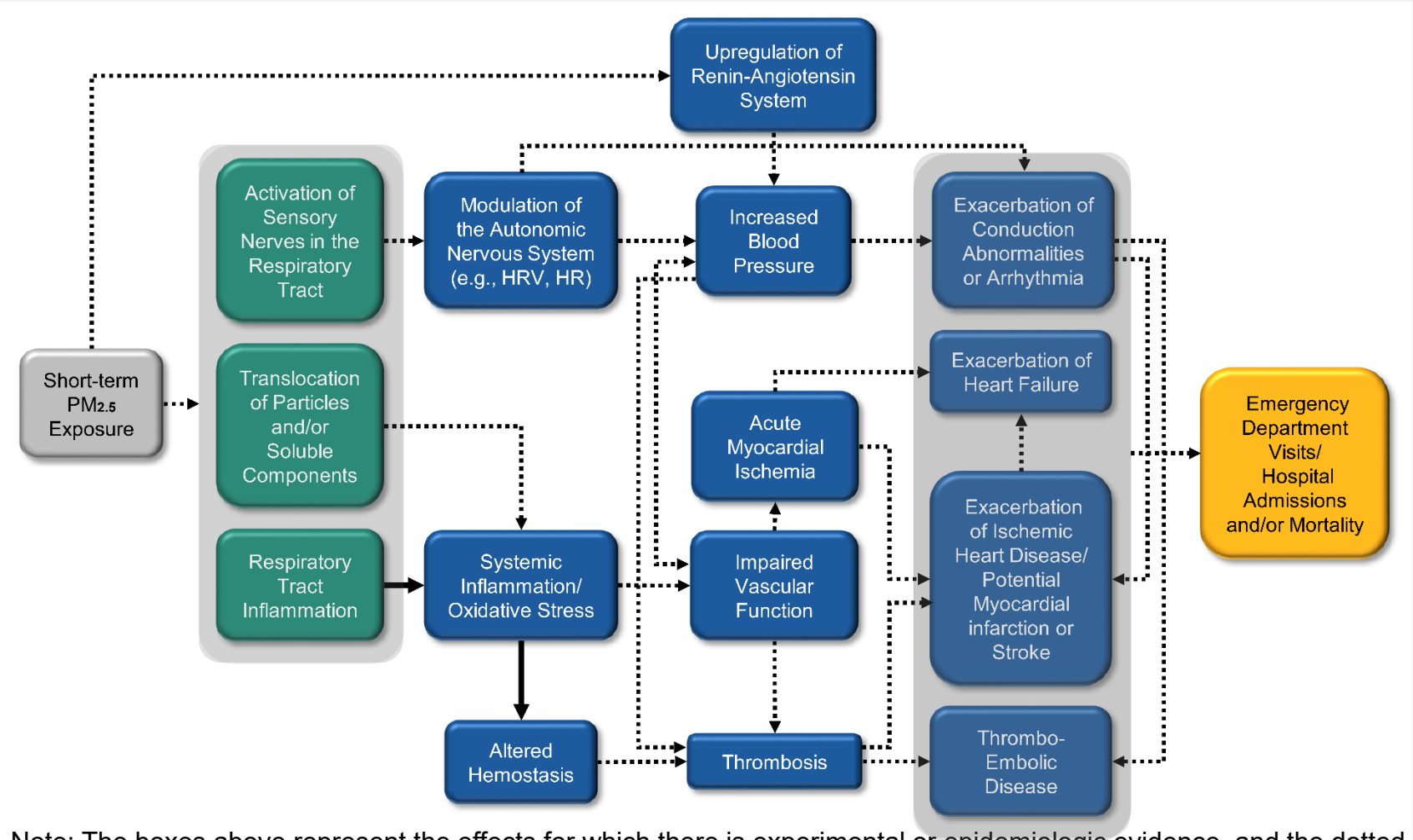
Supplemental Material

Overview of Current PM NAAQS

Current Standards					Decisions in 2012 Review
Indicator	**Averaging Time**	**Primary/Secondary**	**Level**	**Form**	
$PM_{2.5}$	Annual	Primary	12.0 µg/m^3	Annual arithmetic mean, averaged over 3 years	Revised level from 15 to 12 µg/m^3*
		Secondary	15.0 µg/m^3		Retained*
	24-hour	Primary and Secondary	35 µg/m^3	98th percentile, averaged over 3 years	Retained
PM_{10}	24-hour	Primary and Secondary	150 µg/m^3	Not to be exceeded more than once per year on average over a 3-year period	Retained

*EPA eliminated spatial averaging for the annual standards

Example: Potential Biological Pathways Figure



Note: The boxes above represent the effects for which there is experimental or epidemiologic evidence, and the dotted arrows indicate a proposed relationship between those effects. Solid arrows denote direct evidence of the relationship as provided, for example, by an inhibitor of the pathway or a genetic knock-out model used in an experimental study. Shading around multiple boxes denotes relationships between groups of upstream and downstream effects. Progression of effects is depicted from left to right and color-coded (gray, exposure; green, initial event; blue, intermediate event; orange, apical event). Here, apical events generally reflect results of epidemiologic studies, which often observe effects at the population level. Epidemiologic evidence may also contribute to upstream boxes. When there are gaps in the evidence, there are complementary gaps in the figure.

Example: Evaluation of PM Components Studies

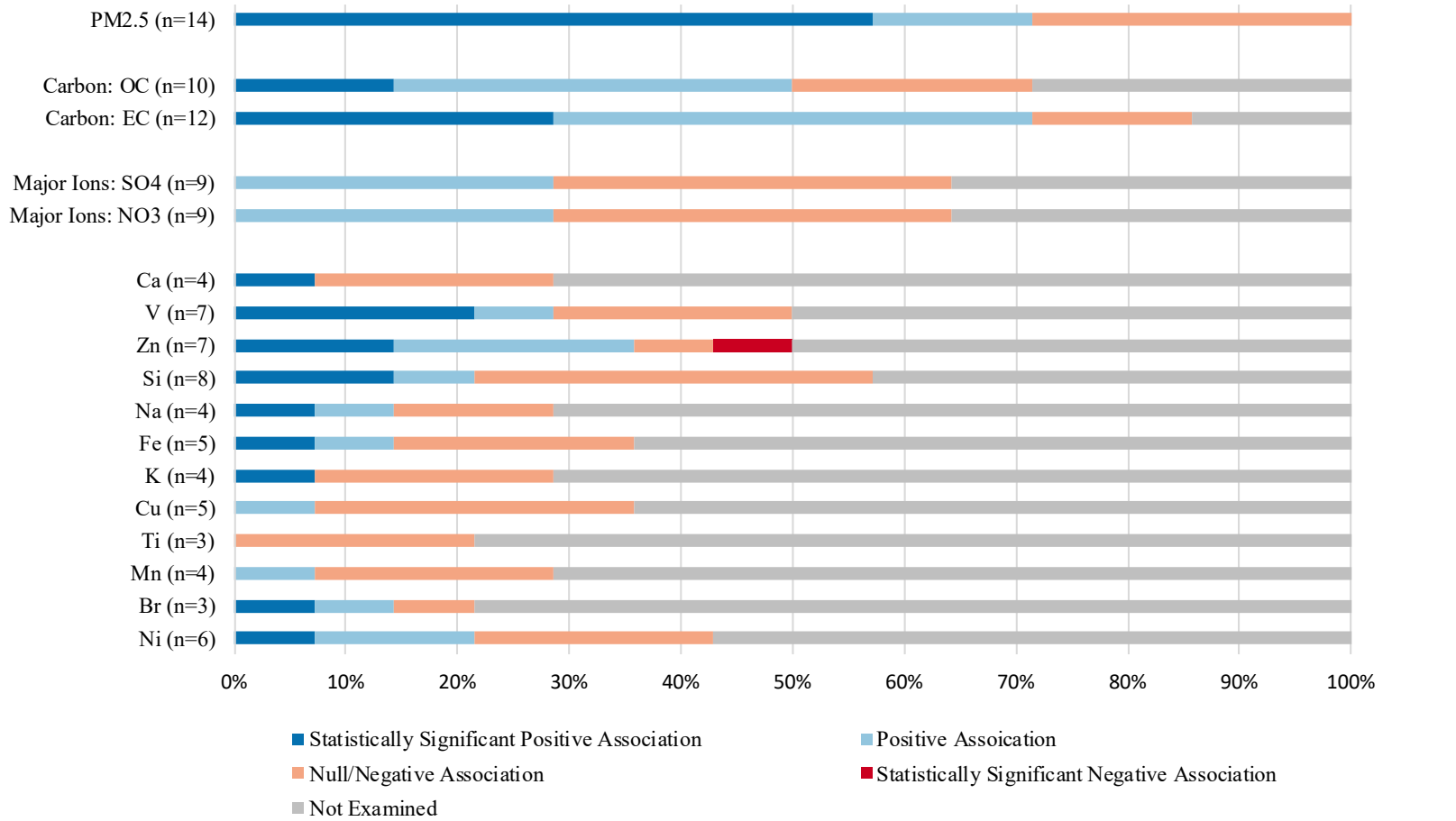
Short-term $PM_{2.5}$ and $PM_{2.5}$ Components Exposure and Cardiovascular Effects: Hospital Admissions and Emergency Department (ED) visits – Heat Map

	Ito et al. (2013)	Lall et al. (2011)	Kioumourtzoglou et al. (2015)	Osto et al. (2016)	Kim et al. (2012)	Samet et al. (2015)	Zanobetti et al. (2009)	Peng et al. (2009)	Levy et al. (2012)	Bell et al. (2014)	Ito et al. (2011)	Lu et al. (2016)	Basagaña et al. (2014)	Samoli et al. (2016)
	CVD	CVD	CVD	CVD	CVD	CVD	CVD	CVD	CVD	CVD	CVD	CVD	CVD	CVD
$PM_{2.5}$	0-3	0, 0-3	0-1	2	0-1	0-2	0-1	0	0	0	0	0	0	1, 0-6
Carbon														
OC	0-3		0-1	0,1,2	0	0-2		0,1,2	0		0	0	0	
EC	0-3	0	0-1	0,2	0	0-2		0,1,2	0		0	0	0	1
Major Ions														
SO_4^{2-}	0-3			0,1,2	0	0-2		0,1,2	0		0	0	0	
NO_3^-	0-3			2	0	0-2		0,1,2	0		0	0	0,1,2	
Metals, Metalloids, Non-Metals														
Ca						0-2				0		0	0,1,2	
V	0-3			0,1,2			0-1			0	0	0	0,1,2	
Zn	0-3			0		0-2				0	0	0	1	
Si	0-3	1,2		1		0-2		0,1,2			2,3	0	0,1,2	
Na							0-1	0,1,2			0	0		
Fe	0-3			0,1,2		0-2						0	0	
K				2		0-2						0	0,1,2	
Cu	0-3			0,1,2		0-2						0	0,1,2	
Ti				0,1,2								0	0,1,2	
Mn		0,1,2,3		0,1,2								0	0	
Br							0-1				0	0		
Ni		3		0,1,2			0-1				0	0	0,1,2	

- Numbers represent lags for which associations observed.
- $PM_{2.5}$ mass or $PM_{2.5}$ components associations categorized by results that are statistically significant positive (dark blue), positive/null (light blue), null/negative (light orange), statistically significant negative (red), or not examined (gray).

Example: Evaluation of PM Components Studies

Short-term $PM_{2.5}$ and $PM_{2.5}$ Components Exposure and Cardiovascular Effects: Hospital Admissions and ED visits – Distribution of Risk Estimates



Bars represent the percent of associations across studies for $PM_{2.5}$ mass or $PM_{2.5}$ components that are statistically significant positive (dark blue), positive (light blue), null/negative (light orange), statistically significant negative (red), or not examined (gray). n = number of studies that provided an estimate for $PM_{2.5}$ mass and individual $PM_{2.5}$ components.

Populations Potentially at Increased Risk of a PM-related Health Effect

- The NAAQS are intended to protect both the population as a whole and those potentially at increased risk for health effects in response to exposure to criteria air pollutants
  - *Are there specific populations and lifestages at increased risk of a PM-related health effect, compared to a reference population?*
- The ISA identified and evaluated evidence for factors that may increase the risk of $PM_{2.5}$-related health effects in a population or lifestage, classifying the evidence into four categories:
  - Adequate evidence; suggestive evidence; inadequate evidence; evidence of no effect
- Conclusions:
  - Adequate: children and nonwhite populations
  - Suggestive: pre-existing cardiovascular and respiratory disease, overweight/obese, genetic variants glutathione pathways, low SES, current/former smokers
  - Inadequate: pre-existing diabetes, older adults, residential location, sex, diet, and physical activity

Welfare Effects

Recent evidence supports and extends the conclusions of the 2009 PM ISA that there is a causal relationship between PM and welfare effects

- Visibility Impairment **(Causal)**
  - Long-term visibility improvements throughout the U.S as PM concentrations have decreased
  - Regional and seasonal patterns in atmospheric visibility parallel PM concentration patterns
  - More evidence supporting the relationship between visibility and PM composition
- Climate Effects **(Causal)**
  - New evidence provides greater specificity about radiative forcing
  - Increased understanding of additional climate impacts driven by PM radiative effects
  - Improved characterization of key sources of uncertainty particularly with response to PM-cloud interactions
- Materials Effects **(Causal)**
  - New information for glass and metals including modeling of glass soiling
  - Progress in the development of quantitative dose-response relationships and damage functions for materials in addition to stone, including glass and metals
  - Quantitative research on PM impacts on energy yield from photovoltaic systems