What Experts Know About PM Risks:

How Many Deaths Are Attributable to the Kuwait Oil Fires?

How Uncertain Are the Estimates of this Number?

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The Kuwait Oil Fires

- More Than 700 Fires Burned
  - From January/February 1991
  - Until November 1991
- Measured PM_{10} Levels
  - Typical Day 300 $\mu g/m^3$
  - High Days 1000 - 2000 $\mu g/m^3$
- Contribution of Smoke
  - Initial US DOD Estimates ~ 10 $\mu g/m^3$
  - Revised HSPH Estimates ~ 40 $\mu g/m^3$
- Kuwaiti Population ~ 600,000
  - Very Young – only 25% > 30 years old
  - 50% Out of Kuwait When Fires Began
  - ~ 90% In Country By November

Acknowledgement and Disclaimer

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- Disclaimer – The views that are presented in this talk are those of the authors and do not necessarily represent the official positions of the State of Kuwait or the Public Authority for Accounting for Compensation (PAAC).

Back of the Envelope Risk Assessment

- $R \sim \beta C M_o P$
  - Where β is the risk coefficient (0.4% per $\mu g/m^3$ $PM_{2.5}$ cohort or 0.1% per $\mu g/m^3$ PM_{10} time series)
  - C is the concentration (300 $\mu g/m^3$ PM_{10} or 10 $\mu g/m^3$ $PM_{2.5}$ due to fires)
  - M_o is the background mortality rate (3/1000 p-yr or 9/1000 adult-yr)
  - P is the population (600,000 total OR 150,000 adults)
- "Back of the envelope" screening estimates:
  - 35 deaths (2/10,000 risk among 150,000 adults) – using ACS cohort coefficient
  - 116 deaths – using Six Cities cohort coefficient
  - 0 deaths – if epidemiology does not reflect causal relationships

Key Issues

- Exposure Level and Pattern –
  - Kuwait oil fire exposure level and pattern is different than those of interest for most regulation, with background PM_{10} levels in Kuwait of 200 or 300 $\mu g/m^3$, and $PM_{2.5}$ increment due to fires averaging 10 $\mu g/m^3$ with spikes of several hundred $\mu g/m^3$.
  - ***Should time-series or cohort studies be used to estimate risk?***
- Composition of Smoke –
  - Oil fire smoke differs in composition from typical urban aerosols in the U.S. and Europe.
  - ***Should an adjustment be made for differential toxicity?***
- Age-Structure of Population –
  - Kuwaiti population is far younger than US or European populations.
  - ***Do relative risk estimates from US/European studies apply directly?***
- Do Epidemiologic Studies Reflect Causal Associations?

The Experts --
European Elicitations

- **H. Ross Anderson, M.D.**
  Professor of Medicine, University of London, England
- **Bert Brunekreef, Ph.D.**
  Professor of Environmental Epidemiology, University of Utrecht, Netherlands
- **Ken Donaldson, M.D.**
  Professor of Medicine, University of Edinburgh, Scotland
- **Nino Kuenzli, M.D., Ph.D.**
  Assistant Professor, University of Basel, Switzerland (now at USC)
- **Juha Pekkanen, M.D., Ph.D.**
  Head of Environmental Epidemiology, National Public Health Institute (KTL), Finland
- **Annette Peters, M.D., Ph.D.**
  Assistant Professor, GSF National Research Center for Environment and Health, Germany

The Sequence

Exposure Duration	Effect Window	US (Baseline: 18 µg/m^3)	MCMA (Baseline: 35 µg/m^3)	Europe (Baseline: 20 µg/m^3)
Permanent	*Long-term*	Q1		Q2
One day	*1 week*	Q3	Q4	Q5
One day	*3 months*	Q6		
Timing of Expression of Impact		Q7 & Q8		
Differential Toxicity		Q9 & Q10		

Pre-Elicitation "Warm Up" Questions

- What are the key properties of an ideal epidemiology study for measuring long-term mortality impacts of PM exposure?
- Similarly, what are the key properties of an ideal epidemiological study of short-term mortality impacts of PM exposure?
- What factors need to be considered to decide whether epidemiology results should be viewed as causal?

Mortality Impact of Permanent Decrease in $PM_{2.5}$ of 1 μg/m^3 in the US

Question	*Setting*	*Exposure (Effect Interval)*	*Change*	*Pollutant*	*Composition*	*Baseline*
1	US	Long-term	1 μg/m^3	$PM_{2.5}$	Ambient	18 ug/m3

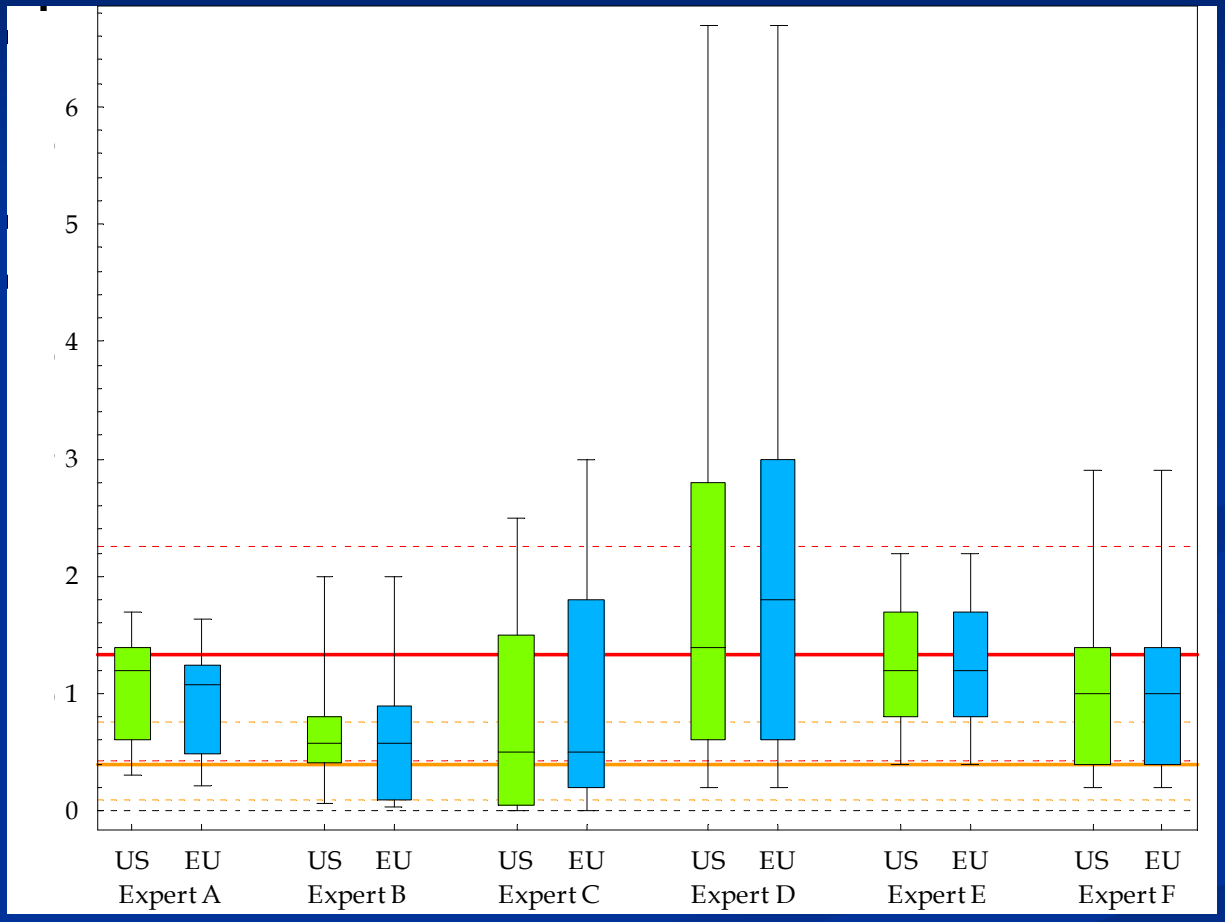
What is your estimate of the true, but unknown, percent change in the total annual, non-accidental mortality rate in the adult U.S. population resulting from a permanent 1 μg/m^3 reduction in long-term annual average $PM_{2.5}$ (from a population-weighted baseline concentration of 18 μg/m^3) throughout the U.S.? To express the uncertainty associated with the concentration-response relationship, please provide the 5th, 25th, 50th, 75th, and 95th percentiles of your estimate.

5% :_____ 25%:_____ 50% :_____ 75%:_____ 95%:_____

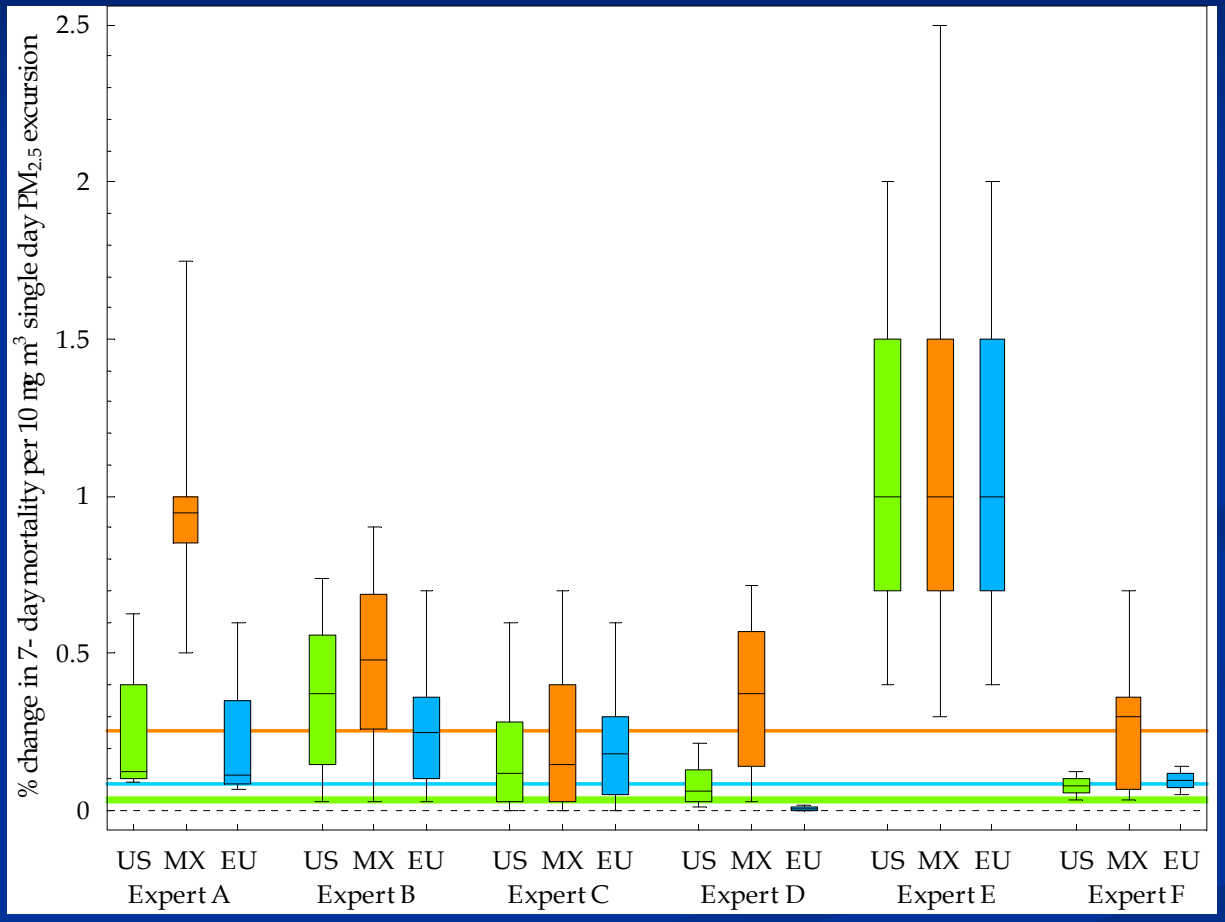
Linking Evidence & Answers

- What evidence suggests ***large values*** for this relationship?
  - What is the highest plausible value?
  - Tell us a little about your reasoning, the evidence, and theories that lead you to this value.
  - Can you tell us of scenarios that would yield higher results?
- What evidence or theory suggests ***small values***?
  - What is the lowest plausible value?
  - Tell us a little about your reasoning, the evidence, and theories that lead you to this value.
  - Can you tell us of scenarios that would yield lower results?

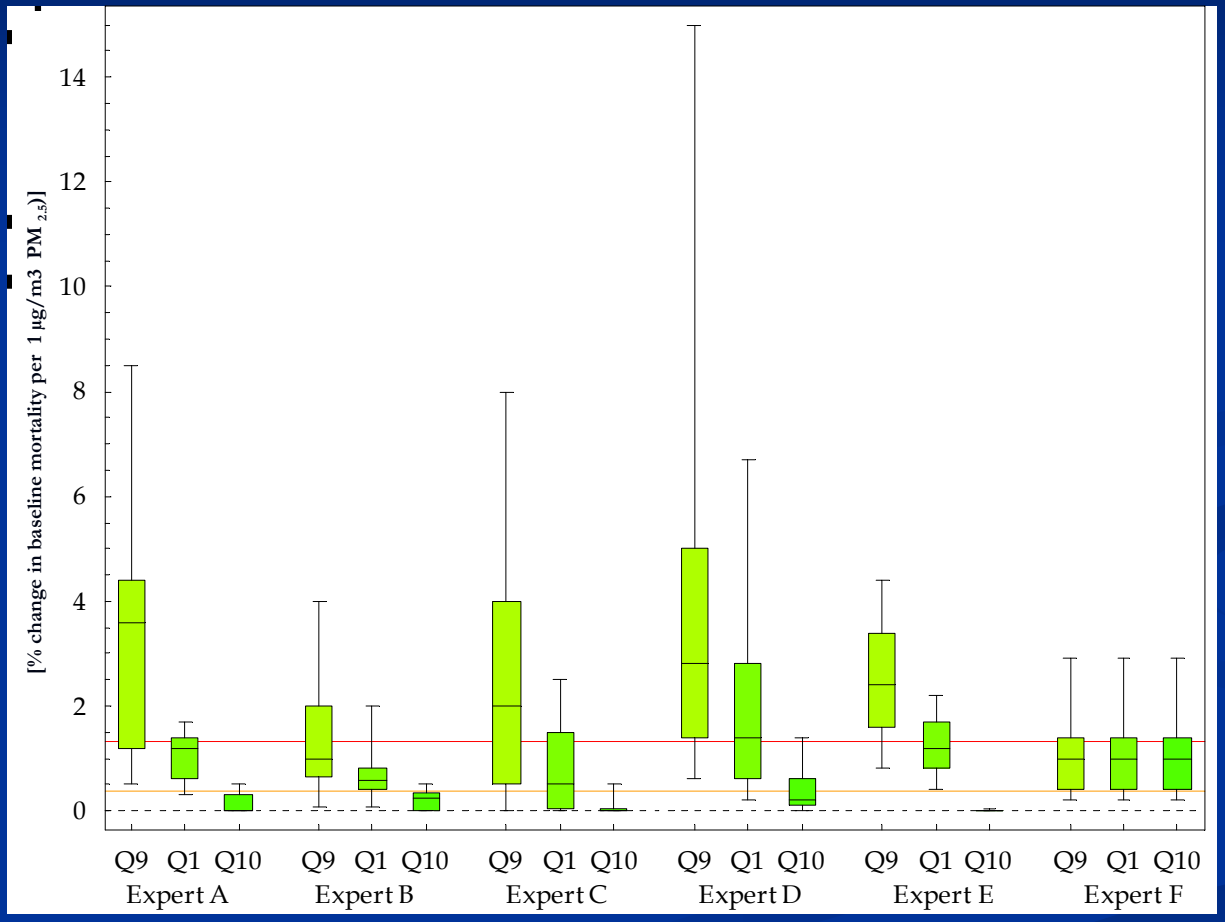
Mortality Impact of Permanent Decrease in $PM_{2.5}$ of 1 μg/m^3 in US (Green) or Europe (Blue)



Mortality Impact of Single Day Increase in $PM_{2.5}$ of 10 µg/m^3 in US (Green) or Europe (Blue)

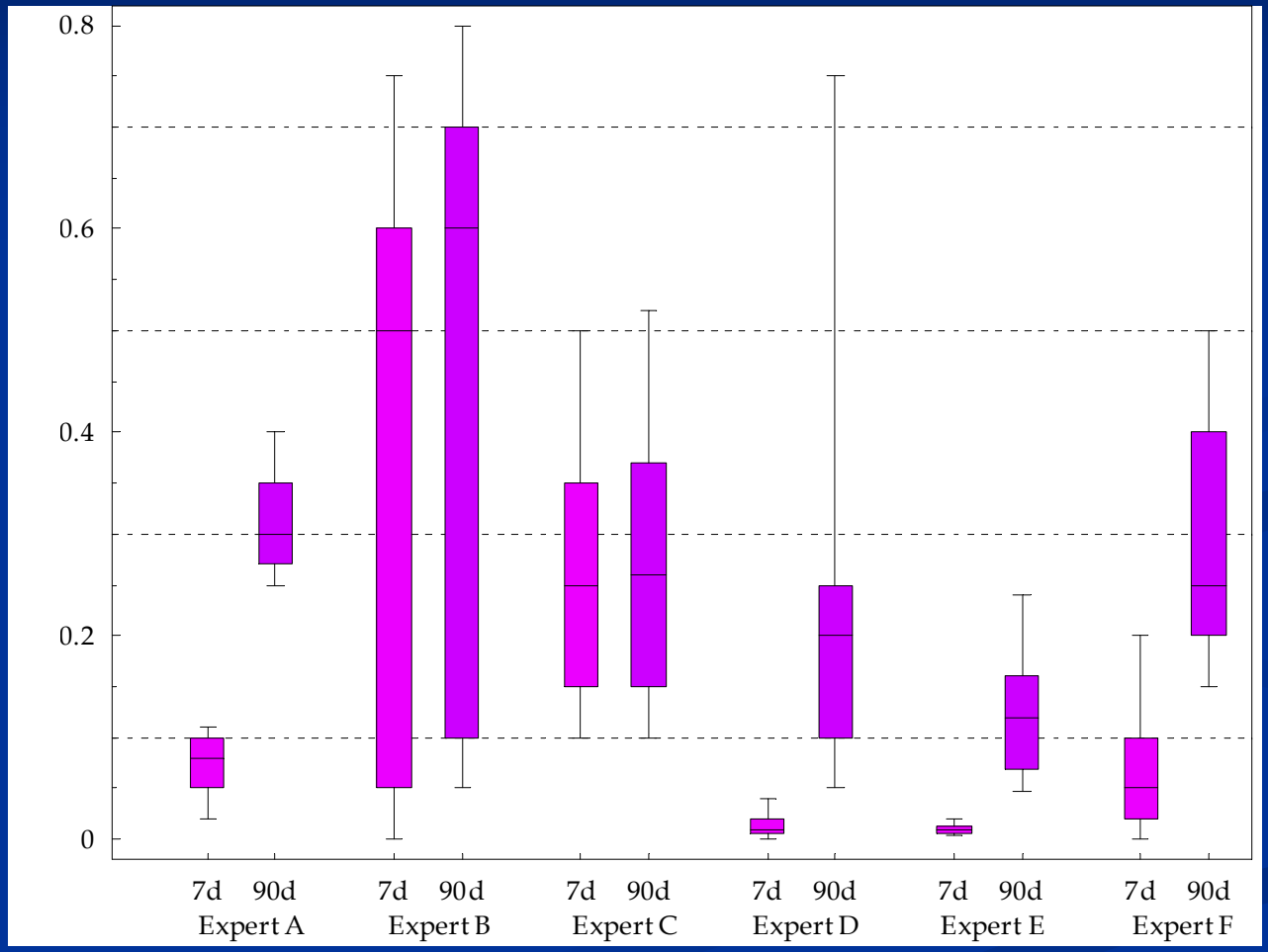


Differential Toxicity of PM Constituents -- Most Toxic (Q9) and Least Toxic (Q10)



Timing of PM Mortality Impacts –

Fraction of Effect Realized within 1 Week / 3 Months



What Experts Know About PM

- **Mortality impacts of PM exposure are relatively well understood.**
  - … but uncertainty is larger than indicated by statistical confidence intervals from studies (not surprisingly)
- **Some constituents are more toxic than others – however there is uncertainty and disagreement about which and how much.**
  - …these experts believe that combustion related particles are more toxic than other particles
- **The mortality impacts manifest themselves over time -- but again there is relatively large uncertainty and substantial disagreement about the time course of expression.**
  - … but most experts believe that while a substantial part of the effect is expressed within 3 months of exposure, only a small fraction occurs within the 1st week..

The Experts' Answers

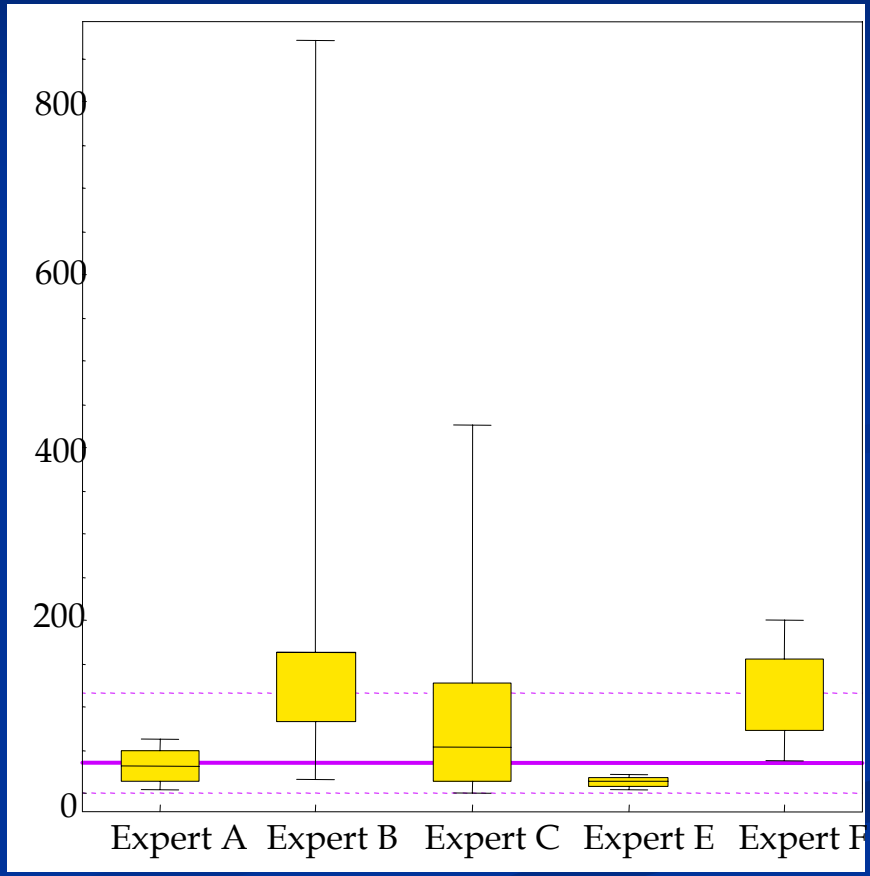
Deaths Attributable to Exposure to Smoke from the Kuwait Oil Fires

Expert *	5%	50%	95%	Approach
E	6	13	21	TS
A	4	32	63	TS
C	<1	54	426	C
F	37	110	210	C
B	16	164	872	C
D	575	2874	11496	C

- Experts are listed in order of their median estimate of risk.
- Letter identifications are randomly assigned to experts.

Health Impact of The Fires

- Kuwait's Basic Estimate of Risk
  - ~ 35 Deaths (ACS Study)
  - 0 (not causal) to 120 Deaths (Six Cities)
- Expert Judgments
  - Best Estimates 13, 32, 54, 110, 164, 2874
- ***Pooled Expert Judgments (50%, IQR)***
  - ***Equal Weights (82 deaths; 18 to 400)***
  - ***Performance Weights (35 deaths; 16 to 54)***



Conclusions / Question

- Kuwait's Estimate of 35 Deaths Not Arbitrary.
- Experts Place Very Little Weight on NO DEATHS
- Reasonable Confidence Intervals for True Number of Deaths – A Few/A Few Hundred
- Most Deaths NOT Within Days of Exposure => Not Observable Epidemiologically