Development and application of a spatially disaggregated exposure series in time series analyses of air pollution related health effects in Chennai, India

Kalpana Balakrishnan, [2]Bhaswati Ganguli, Santu Ghosh, Sankar Sambandam, Vijayalakshmi Thanasekaraan

[1] Dept of Environmental Health Engineering, Sri Ramachandra University, Chennai, India
[2] Dept. of Statistics, University of Calcutta, Kolkata, India

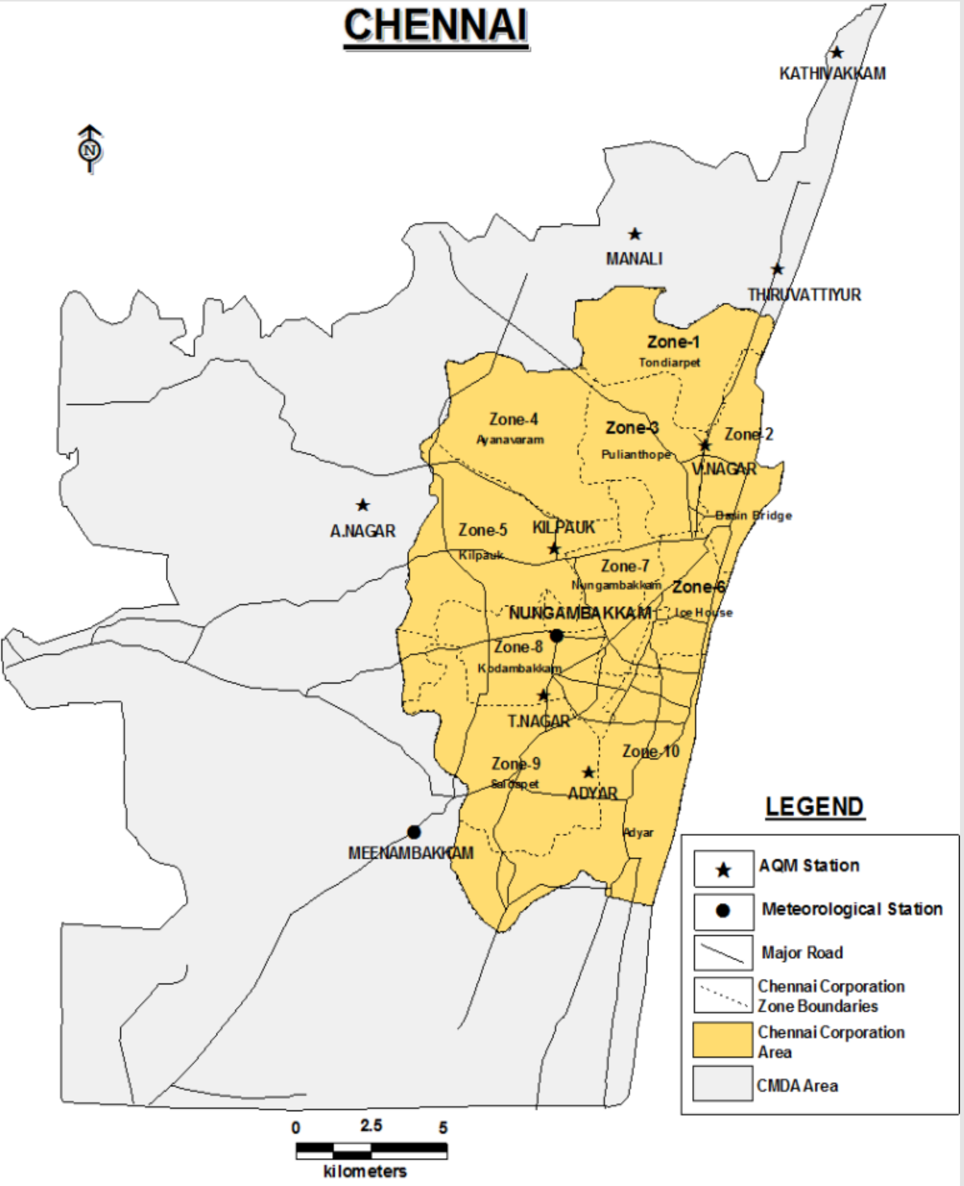
Introduction

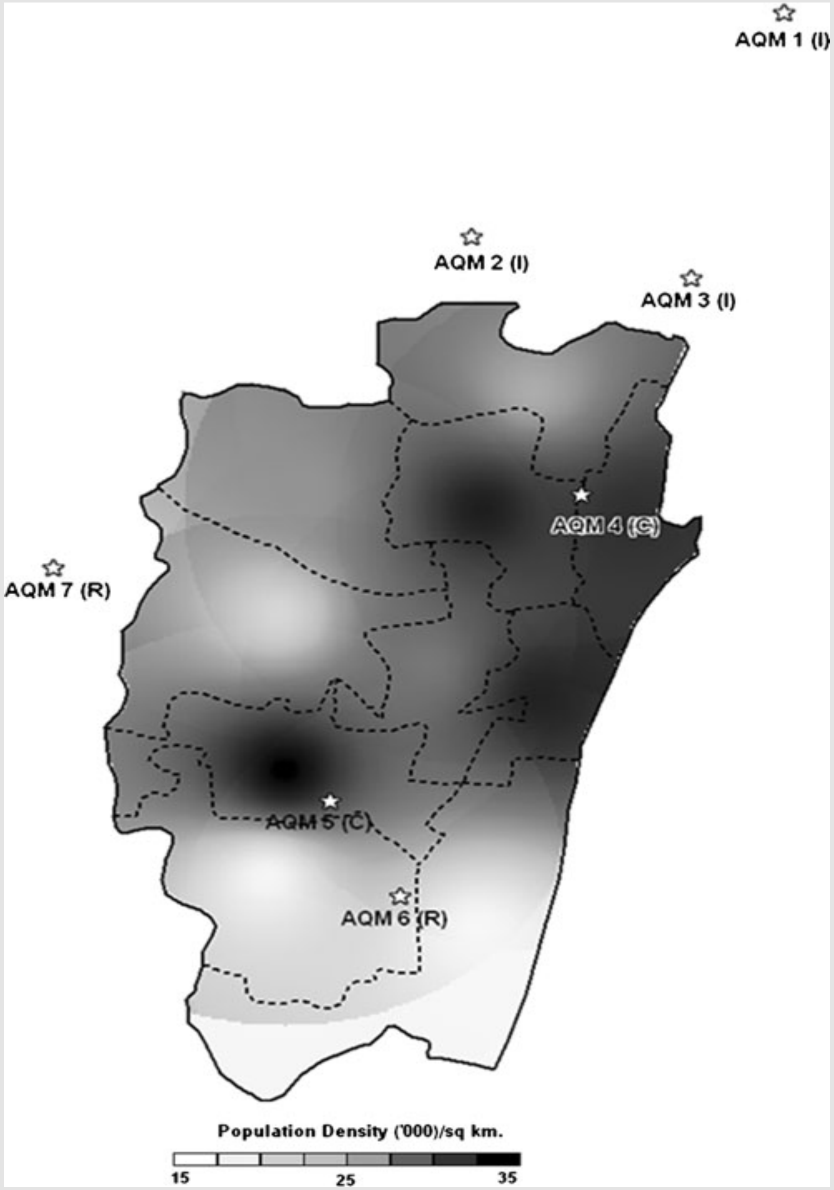
- The global burden of disease due to air pollution is concentrated in the rapidly developing counties of Asia, but a recent meta-analyses found that relatively few time series studies on short-term exposure to air pollution and mortality have been performed in these countries, including India. Time-series studies of the effects of short-term exposure on cardio-respiratory morbidity and mortality have provided high-quality scientific evidence for regulatory policies in Europe and North America and offer similar promise in India.

- We report the results from one of the first of such studies in metropolitan Chennai, India, conducted as part of a coordinated multi-city time-series initiative in India aimed at estimating the effect of short-term exposure to particulate matter ≤10 µm in aerodynamic diameter (PM10) on all-cause mortality . The studies in Indian cities (Chennai, Delhi and Ludhiana) were part of a larger multi-city initiative in Asia, coordinated by The Health Effects Institute (Boston, MA,USA) under their program f or Public health and Air Pollution in Asia (PAPA).

Data sources

- Air Quality Data
  - Data from 8 ambient air quality monitoring stations operated by TNPCB & CPCB in the greater Chennai area
  - The centers carry out monitoring approximately every third day resulting in approximately 90-100 observations per year per station
- Mortality Data
  - Chennai Corporation Daily all cause mortality
- Meteorological Data
  - Regional meteorological stations (city center, airport) ; Daily temperature, RH, Dew Point


CHENNAI
KATHIVAKKAM
MANALI
THIRUVATTIYUR
Zone-1
Tondiarpet
Zone-4
Ayanavaram
Zone-3
Pulianthope
Zone-2
V.NAGAR
Basin Bridge
A.NAGAR
Zone-5
KILPAUK
Kilpauk
Zone-7
Nungambakkam
Zone-6
NUNGAMBAKKAM
Ice House
Zone-8
Kodambakkam
T.NAGAR
Zone-9
Saidapet
ADYAR
Zone-10
Adyar
MEENAMBAKKAM
LEGEND
AQM Station
Meteorological Station
Major Road
Chennai Corporation Zone Boundaries
Chennai Corporation Area
CMDA Area
0
2.5
5
kilometers


AQM 1 (I)
AQM 2 (I)
AQM 3 (I)
AQM 4 (C)
AQM 7 (R)
AQM 5 (C)
AQM 6 (R)
Population Density ('000)/sq km.
15
25
35

Rationale for spatially disaggregated (Zonal) exposure series

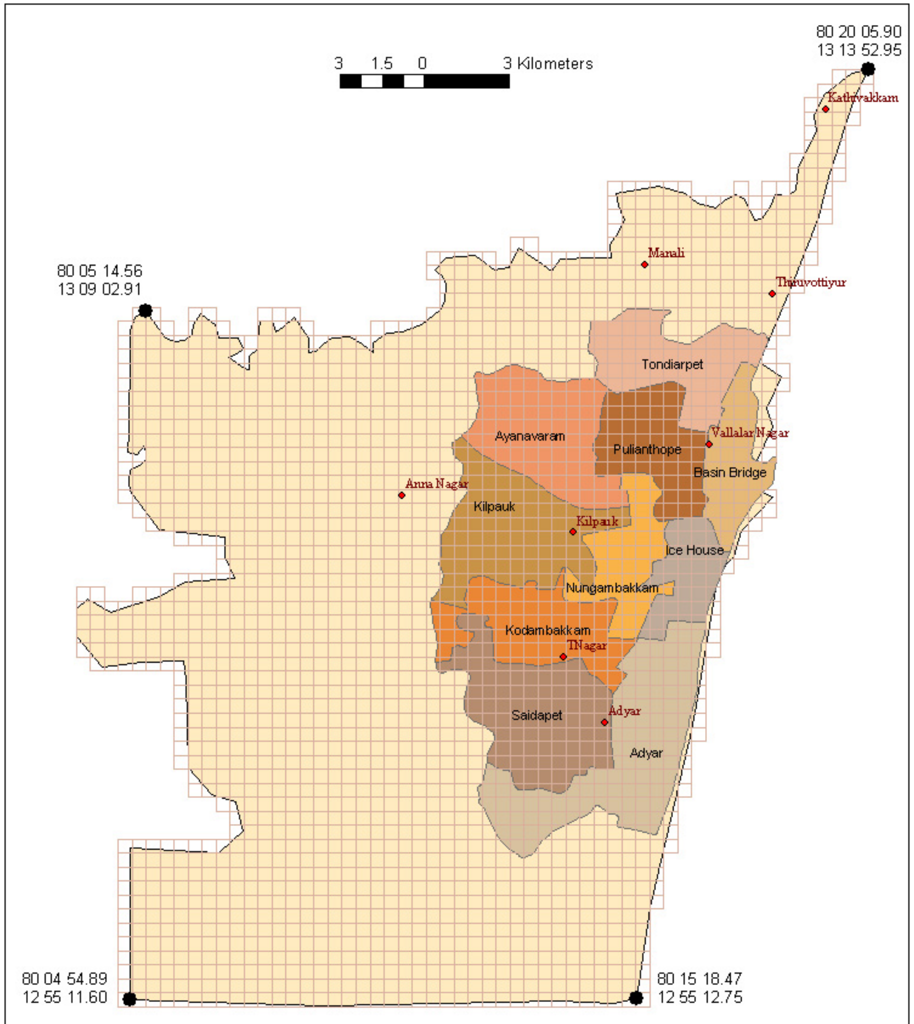
- A high percentage of **missing observations** and **low correlation** between daily readings recorded by various monitors precluded the use of the daily mean as a meaningful measure of average exposure.
- An analysis of variance comparing the between monitor variation to the within monitor variation found statistically significant differences in mean levels
- Small monitor foot prints and significant differences in source strengths have been shown to be likely responsible for such poor correlation
- A full blown geo-statistical analysis of the data could not be conducted as address information was available only for less than 30% of deaths.
- **Limited parallels could be found in standard approaches followed in earlier studies**

Zonal Model

- We therefore developed a zonal model which disaggregates exposures and mortality at the level of individual zones (Corporation zones) by
  - describing the concentration at non-sampled site within a zone by the concentration at nearest sampled site or by the average of the surrounding sites

  and
  - fitting a regression of zone specific mortality on average daily exposure within the same zone.

Zonal Model

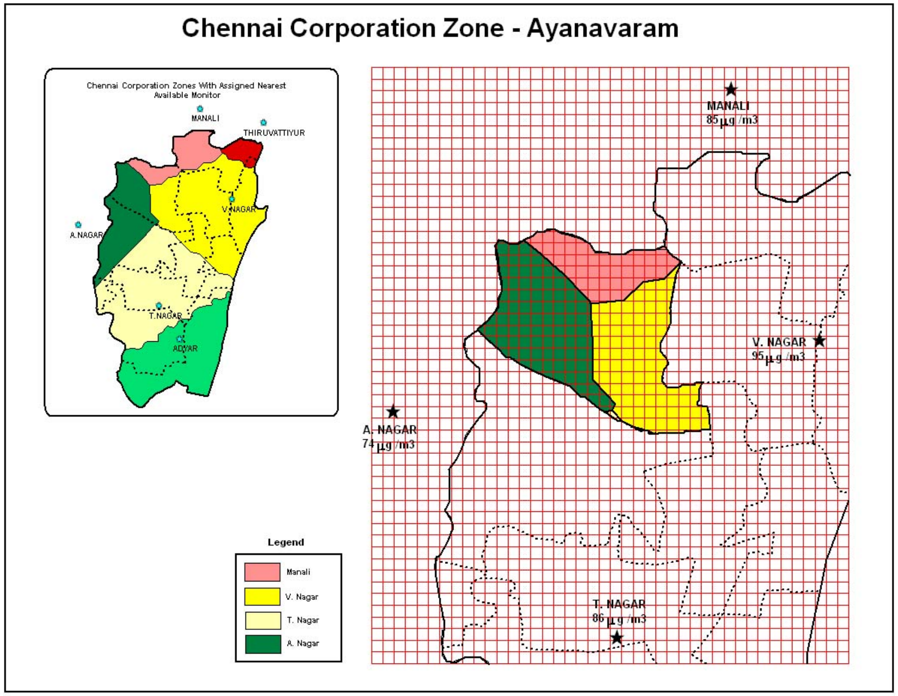


- We superimposed a fine grid of squares of size 0.5 sq.km. over the Chennai map.
- Each cell in the grid is sufficiently small so that all points within the cell have one single nearest monitor
- Assign to each grid cell the exposure recorded at the monitor nearest to its centroid
- For a fixed zone, i, PM_{it} is then measured as the simple average of the readings from all cells located in zone i on day t i.e. for a fixed zone i on a given day t,

$$PM_{it} = \frac{\sum_{k \in S_{it}} PM_{itk}}{N_{it}}$$

; S_{it} is the set of N_{it} grid cells with centroids located in zone i for which a valid exposure is available on day t

Zonal Model



$$\log(E(\text{Mortality}_{it})) = \alpha_{0i} + \beta_1 \text{PM}_{i(t-1)} + f_1(t) + f_2(\text{temp}_t) + f_3(\text{rh}_t)$$

for all i^{th} zone on day t

- Days when data from all monitors representing a zone are available, the average zone exposure is adequately weighted by the proportion of grids close to particular monitors.
- Days when none of the grids in a zone have a value available were excluded from the analysis
- When some monitors are missing, we ignored all cells assigned to the missing monitor and instead used the average over all grid cells for which the reading at the nearest monitor has been recorded

Summary Descriptives

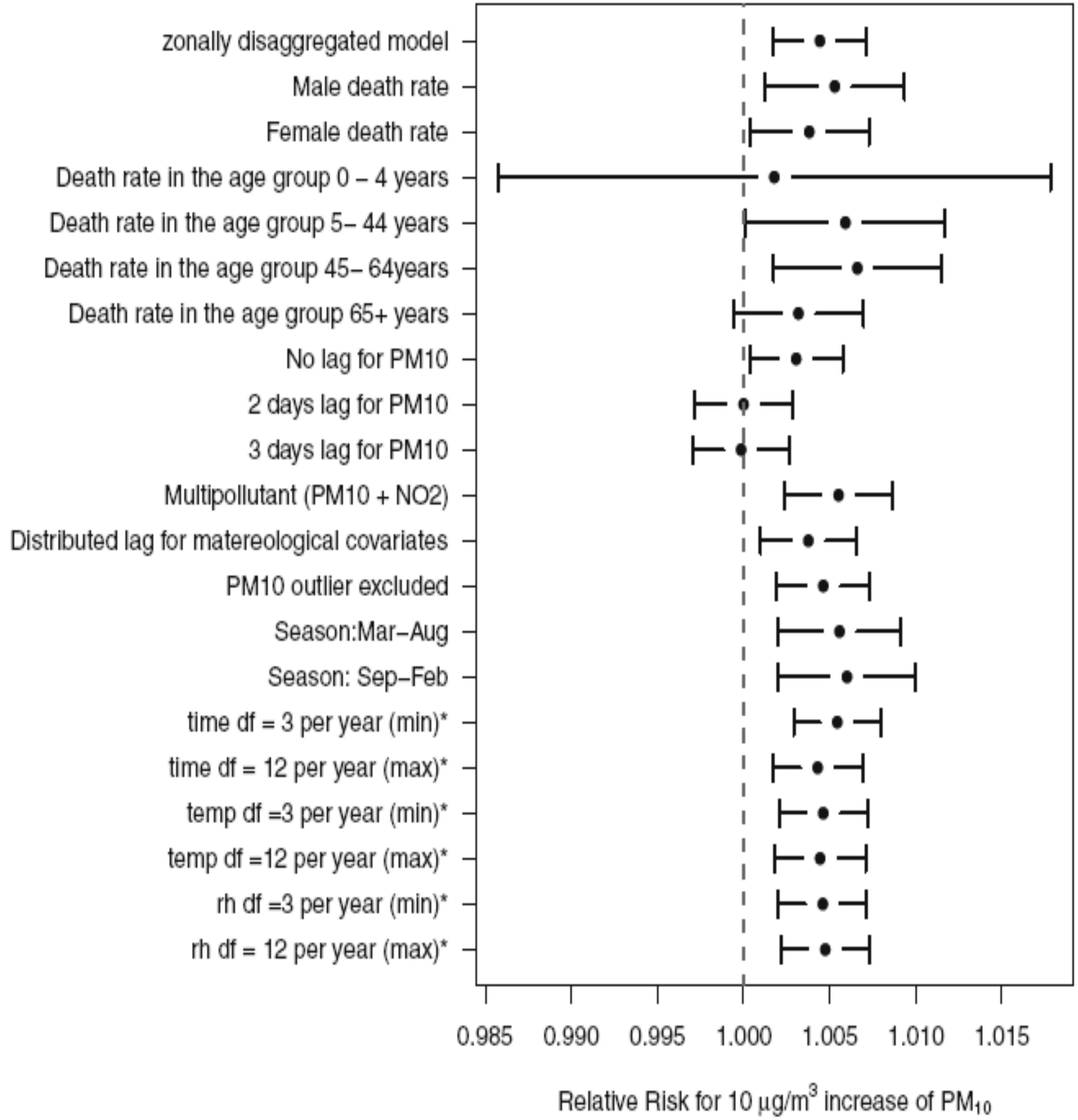
Variables	N	Mean	Median	Standard deviation	Quartile deviation	Minimum	Maximum
Daily mortality	1096	97	96	17	10	61	229
PM_{10} ($\mu g/m^3$)							
Industrial(I)							
AQM 1 (Manali)	280	108.02	107.55	27.48	18.81	39.6	218
AQM2 (Thiruvottiyur)	288	95.86	94.3	26.02	17.31	35.9	183
AQM 3 (Kathivakkam)	293	90.67	89.9	25.45	18	35	195.8
Commercial ©)							
AQM 4 (V.Nagar)	360	110.7	101	47.23	23.40	32	417
AQM 5 (T.Nagar)	365	48.2	38	32.26	18.1	10.9	366
Residential ®)							
AQM 6 (Adyar)	357	87.66	81	54.69	32	12	307
AQM 7 (A.Nagar)	376	71.73	67	33.42	16.37	15	317
Temperature (°C)	1096	29.77	30.1	3.06	2.24	23	40
Relative humidity (%)	1096	75.2	76	10.77	6.5	44	98
Dew point (°C)	1096	23.49	23.4	2.85	1.65	15.5	38.8
Wind speed (km/hour)	1096	8.76	8.2	5.82	5.2	0	25

N, Total no. of days for which data are available during the study period

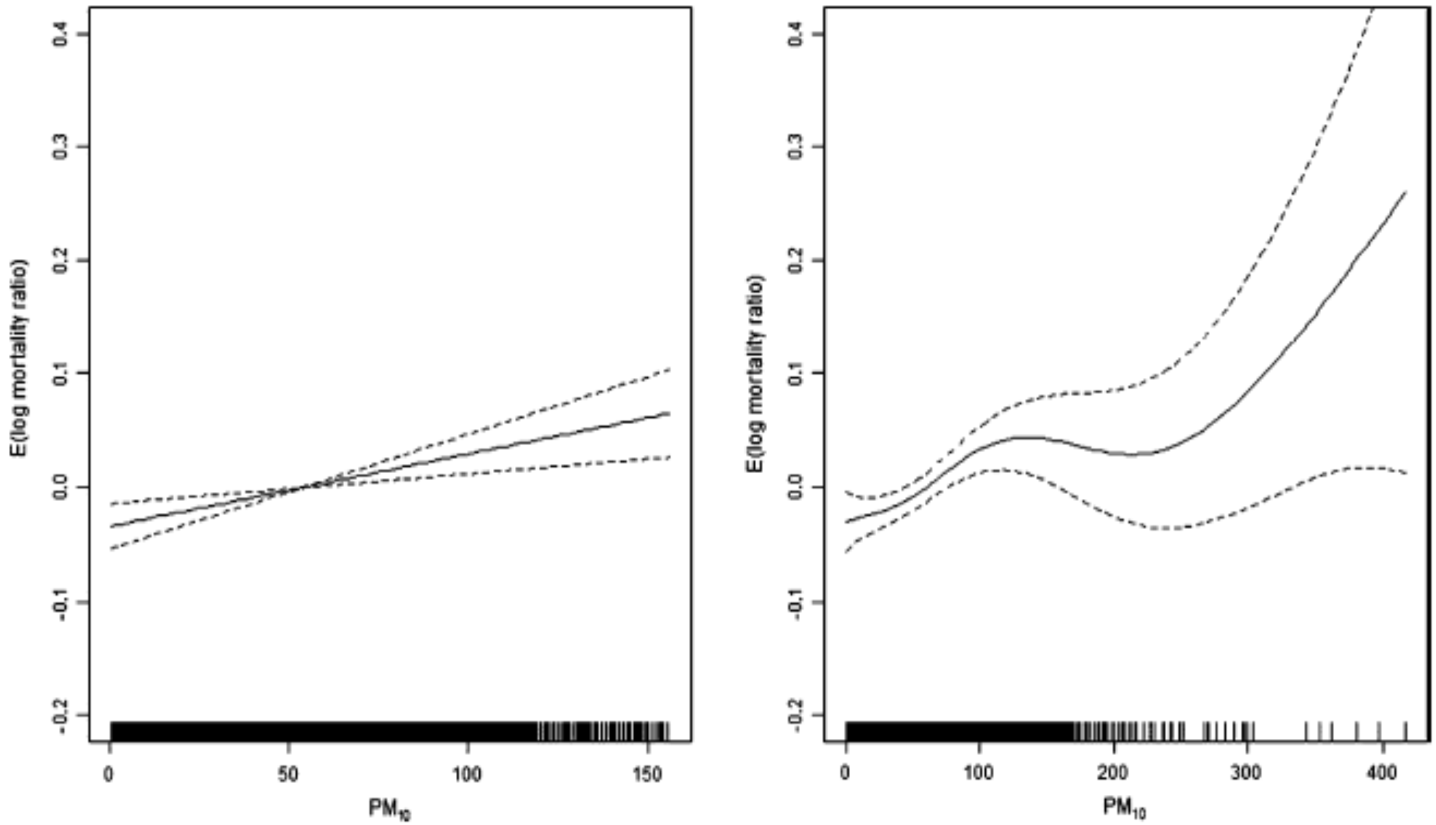
Model Results

- The core model that used the zonal exposure series estimated a log mortality ratio of 0.00044 [95% confidence interval (CI)0.00017–0.00071; relative risk (RR) 1.0044 (95% CI 1.002–1.007)]. This corresponds to a 0.44% (95% CI0.17–0.71%) increase in mortality per 10 µg/m3 increase in PM10 exposure . The core model used 8, 6 and 5 degrees of freedom per year to adjust for confounding by time, temperature and relative humidity, respectively. The model explained 50% of the total deviance and had an estimated over-dispersion parameter of 1.24, the lowest amongst all other alternative models fitted to the data.

Model results (Sensitivity Analyses)



Dose-Response Relationships



Implications for future studies

- Issues such as missing measurements and small monitor footprints (which result in available air quality data being inadequate to readily represent population exposure) are likely to be encountered in many other Indian cities as well as perhaps in other developing countries. Until investments in infra-structure allow the design of more sophisticated monitoring mechanisms, the methods developed in this study may therefore allow data currently being collected only to be used for baseline assessments in situations where similar data challenges prevail.
- This analysis supports the inference that relative effects are likely to be similar across regions of the world that vary markedly in levels of PM10, but that insufficient attention to the nature of local datasets and the application of models that do not adequately address exposure misclassification prevalent in these settings may provide inconsistent results.

Implications for future studies

- With routinely collected information becoming more accessible, including electronic data on daily PM10, SO2 and NO2 concentrations across 341 CPCB stations in 125 cities/towns and mortality/ morbidity data from many municipalities and hospitals, multi-city/multi-pollutant studies of short-term health effects are becoming increasingly feasible

- While evidence for long-term effects of air pollution is limited in Asian studies, the comparability of results obtained through time-series studies on short-term effects obtained in India to other countries and regions would increase confidence in using the much more robust evidence on long-term effects provided by Western cohort studies

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