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The Metal Content of Airborne Particles in Edinburgh: Application to Epidemiological Research

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Metals are putative causative agents in the association between ill health and exposure to airborne particles. We present preliminary results from an epidemiological study using exposure metrics of metal contained in PM10, PM2.5 and black smoke. A 1 yr monitoring and analysis campaign has been completed for 11 metals at 24 h sampling resolution. Empirical models of environmental determinants of metal concentration have been used to retrospectively extrapolate the pollutant time series. We are currently evaluating whether the use of metal concentration explains more of the variance in the population exposure–response relationship compared with the use of particle mass concentration alone.

Keywords: air pollution epidemiology; back trajectory analysis; metals

BACKGROUND AND OBJECTIVES

Metals have been proposed as causative agents for the well-documented association between inhaled exposure to ambient airborne particulate matter (expressed as mass concentration) and adverse respiratory and cardiovascular health outcomes. We are undertaking the first long-term study of the quantitative relationship between specified health outcomes and the variance in daily metal composition of coarse (δPM10), fine (δPM2.5) and black smoke (δ<PM4) measures of particulate matter in urban background air in the UK.

MATERIALS AND METHODS

Concurrent 24 h samples of PM10, PM2.5 (gravimetric measures, Zefluor filters) and black smoke (reflectance measure, Whatman no. 1 filters) were collected at an urban background site in Edinburgh between September 1999 and September 2000. Each filter was sequentially extracted with 18 M∧ deionized water followed by a 2.8:1 (v/v) HCl:HNO3 acid mixture. All extracts were analysed by inductively coupled plasma mass spectroscopy (ICP-MS) for Ti, V, Cr, Mn, Fe, Ni, Cu, Zn, As, Cd and Pb. The influence of air mass source region on metal content was studied using air mass back trajectory analyses. Metal enrichment factors were calculated for different geographical categories of trajectory. The time series of metal concentration were extended retrospectively to

1992 by applying the enrichment factors to historical PM10 and back trajectory data for Edinburgh Poisson log-linear regression models are currently being used to determine whether adjustment for specified metals explains a higher proportion of the variance in health outcome data than the gravimetric measure alone (Fig. 1).

RESULTS

Time series (duration 365 days) have been obtained for particle mass concentrations (⌠g particles/m3 air for PM10, PM2.5 and black smoke) and airborne metal concentrations (ng metal/m3 air and ng metal/⌠g particles for water extractable and total acid extractable metal content of each size fraction). Rigorous analytical protocols have enabled very low limits of detection in comparison with previously published work of this nature (see for example Fig. 2). There were considerable day-to-day variations in metal concentration (Fig. 2). This may have important implications for acute health outcomes. Air mass back trajectories were clustered according to source location and differences in metal content between source region were identified (Table 1). These data are currently being incorporated within our epidemiological time series analyses.

CONCLUSIONS

Detailed time series of metals in PM10, PM2.5 and black smoke have been measured in urban and rural areas in central Scotland. Rigorous analytical protocols have enabled very low limits of detection in our chemical analyses systems. The effect of air mass source region on the metal content of particles was quantified using a cluster analysis method. Empirical models of the environmental determinants of metal concentration have been developed to allow the metal concentration data to be applied to epidemiological analyses, which up until now have relied on total particle mass concentration.

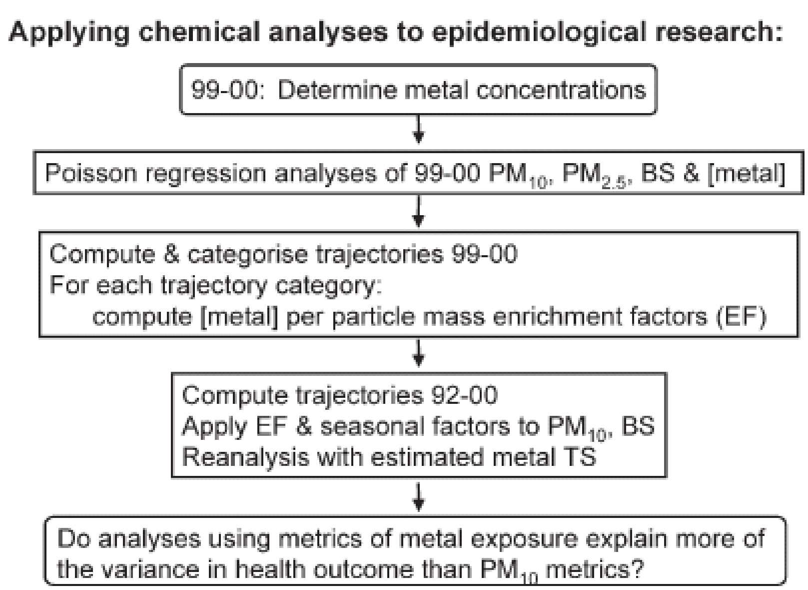

Fig. 1. Conceptual overview of the project to apply chemical exposure data to epidemiological time series analyses of population health outcome. The prior hypothesis was that metal enrichment factors (EF) would be significantly different for some air mass

back trajectory groupings because EF should depend on source region, but should be independent of dispersal processes.

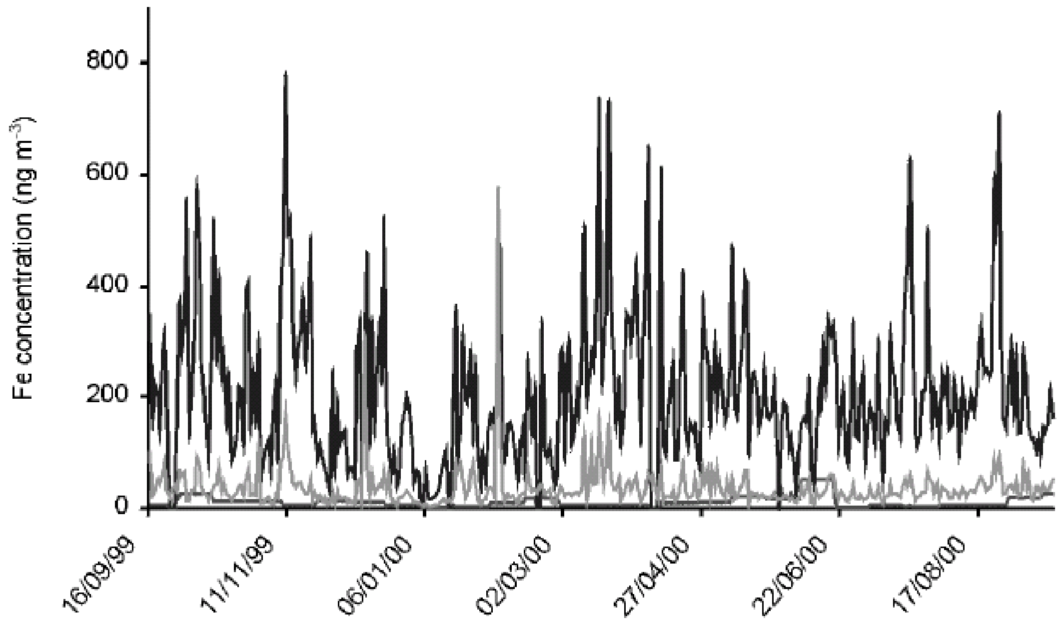

Fig. 2. Example time series of metal concentration. Three hundred and sixty-five daily measurements are illustrated for PM10 (upper time series), PM2.5 (middle time series) and limit of detection for analysis (lower time series).

	Acid	Aqueous	Total
^{49}Ti	0.002	0.07	0.002
^{51}V	<0.001	<0.001	<0.001
^{52}Cr	0.06	0.017	0.12
^{55}Mn	<0.001	<0.001	<0.001
^{57}Fe	<0.001	0.012	<0.001
^{60}Ni	0.24	<0.001	0.31
^{65}Cu	<0.001	0.014	<0.001
^{66}Zn	0.23	0.10	0.26
^{75}As	<0.001	0.003	0.004
^{111}Cd	0.009	0.036	0.009

Table 1. Results of Kruskal–Wallis tests to identify the presence of differences in metal enrichment factors between eight trajectory groupings identified by cluster analysis Data are *P* values (values <0.05 indicate the presence of difference in EF for each isotope at the 95% confidence level).

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