Assessing personal exposures

Jonathan Grigg

Professor of Paediatric Respiratory and Environmental Health

Barts and the London School of Medicine

Carbon containing particulate matter (PM) is an important mediator of the adverse health effects of air pollution in children. Several large epidemiological studies have shown that black carbon PM, is associated with health effects from fossil-fuel and biomass emissions – with some suggestion that it may also be the driver of health effects associated with exposure of children to environmental tobacco smoke (ETS). Most of these studies have indirectly assessed individual exposure - using either distance of the home to the nearest main road in urban areas – or time spent near to a cooking fire in low-income rural settings, or the uniform “background” level of PM across an urban area. For example, in a cohort of over 4,000 preschool children living in Leicester (UK), we found an association between modelled annual exposure to PM from traffic pollution at the home address and prevalence of cough without a cold (probably post-viral bronchitis) and wheeze (preschool viral-wheeze) 1. Since modelled exposure captures only a fraction of total exposure, an ability to measure personal exposure to PM would be a major advance. However, the equipment required to measure personal exposure of children to black carbon PM has, to date, been both expensive and cumbersome.

Over the last 5 years, we have been assessing a new approach to measuring the internal dose of black carbon PM. We use the capacity of airway macrophages to remove and retain material inhaled into the lower airways. The airway macrophage (AM) resides on the surface of the airway. AM are most numerous in the alveoli – but they also sit just below the mucus layer of the larger airways. They do not present in the upper airway – so phagocytosed material seen within AM must be acquired below the vocal chords. Using this technique we first addressed the question - what type of PM penetrate into the lungs of young children? Using bronchoalveolar lavage done when children were undergoing elective surgery – we showed that AMs from children as young as 3 months of age contained aggregates of nanoparticles of carbon – with a morphology typical of fossil fuel emissions 2. A more practical method of sampling AMs from children is to use induced sputum. During sputum induction, children breath hypertonic saline then cough up lower airway cells for processing. Using image analysis of digital AM images, we were able to assess the surface area of black carbon within each AM, and calculate the mean level of loading from 50 separate cells. Figure 1 shows a typical induced sputum slide (x 40). Under x 100 magnification, areas of carbon may be readily identified and measured (Figure 2). In 2004, a landmark epidemiological study of school-age children performed in different communities in Southern California found that exposure to higher background (i.e. city-wide) levels of black carbon was associated with reduced growth of lung function 3. We therefore hypothesised that by using internal PM dose, we would be able to detect an association between AM carbon (i.e. reflecting variations in PM exposure within a community) and school-age children’s lung function. Indeed, we found an inverse association between AM carbon and lung function in healthy children living in Leicester (UK) 4. Subsequently, other groups have reported associations between AM carbon and markers of cardiovascular disease in adults 5.
Are we able to sue the AM carbon/internal dose technique in children exposed to PM in low-income countries? In a pilot study in Gondar, Ethiopia, we found much higher levels of carbon in mothers and children’s AM compared with AM from women and children living in the UK. In collaboration with a group in Malawi – we have also found an association between reported fuel use in the home and AM carbon. In this study, adults using wood for cooking had higher AM carbon loading compared with those using cleaner fuels. To date, no study has assessed the association between AM carbon and lung function in children living in biomass/solid fuel emission rich environments.

Recently, a portable monitor for black carbon (external dose) has been developed – which may enable some aspects of personal exposure in young children to be estimated- especially in those who cannot perform induced sputum (e.g. children less than 7 years of age). We are currently assessing the association between AM carbon (as a long term marker of PM exposure) and short-term (24 h) measured black carbon exposure assessed over a “typical” day in adult cyclists and walkers living in London. Additional studies are in progress assessing the association between AM carbon and external black carbon PM dose in children – where induced sputum is being performed in local schools (Figure 3).

Is a focus on black carbon PM appropriate? Certainly AMs contain black carbon – but what about the effect of black carbon PM on other cells that defend the lung against bacterial infection? To answer this question we have modelled the reported association between black carbon PM (especially biomass PM) and vulnerability of bronchial epithelial cells to pneumococcal pneumonia. Using PM from Leicester and Accra – we found that PM from both urban environments increase the adhesion of pneumococci to lung airway lining cells.

In summary, we now have the tools to measure both “internal” and “external” personal exposure of children to black carbon PM. This will result in more accurate assessment of the effects of PM from all combustion sources on children’s respiratory health.

References

**Figure 1** Preparation of an induced sputum sample (x40). The majority of cells are airway macrophages (AM). The amount of carbon AM from this subject (a walker) is low.

**Figure 2** An AM imaged under oil (x100) showing spots of black carbon in its cytoplasm
Figure 3 Performing sputum induction in a classroom. The boy is breathing hypertonic saline, prior to coughing up lower airway cells.