PAEDIATRIC RESPIRATORY REVIEWS (2007) **8**, 287–291

ELSEVIER

Paediatric Respiratory Reviews

MINI-SYMPOSIUM: POLLUTANTS AND RESPIRATORY HEALTH IN CHILDREN

Effect of biomass smoke on pulmonary host defence mechanisms

Jonathan Grigg

Academic Unit of Paediatrics, Institute of Cell and Molecular Science, Queen Mary University London, London, UK

KEYWORDS
children;
lower respiratory tract infection;
biomass smoke;
indoor air pollution;
bacterial pneumonia

Summary In the developing world, the burning of biomass fuels in and around homes results in very high levels of inhalable particles and gases. Several epidemiological studies have reported an association between indoor air pollution from biomass smoke and increased vulnerability to lower respiratory tract infection in children. This review assesses whether a plausible mechanism for this association can be found in studies using animal models and airway cells.

Indoor air pollution from the burning of biomass fuels such as wood and dung is a major threat to children's health[1] as a result of increased vulnerability to bacterial pneumonia.[2] This review assesses whether indoor air pollution increases pulmonary infection in animal models, and increases the ability of bacteria or viruses to infect lung cells *in vitro*. Since few animal studies have used biomass smoke, data must be extrapolated from studies modelling the effect of either fossil-fuel emissions or cigarette smoke. The validity of this approach is debatable. On one hand, biomass smoke, fossil-fuel, and cigarette emissions all produce inhalable particles of elemental carbon (Fig. 1), carbon monoxide, nitrogen oxides (e.g. nitrogen dioxide), and hydrocarbons (Table 1).[3,4] On the other hand, the concentrations of inhalable particles and gases required to model exposure to biomass smoke, are well above levels required for modelling effects of fossil-fuel emissions. For example, indoor air levels of particles in biomass burning homes regularly exceed 1000 $\mu g/m^3$ (Table 1),[2] whereas the UK limit for inhalable particles (i.e. particles less than 10 microns in diameter) is a 24-hour value of up to 50 $\mu g/m^3$.[5] In addition, toxic compounds may be absorbed onto to the surface of carbon particles generated by biomass burning. For example, increased metal contamination of biomass particles increases their capacity to cause tissue damaging oxidant injury due to the formation of free-radicals (Fig. 2).[6]

ANIMAL MODELS: PARTICLES AND MIXTURE OF PARTICLES AND GASES

Animal models are particularly helpful in studying the effects of air pollution on host defence, since they assess the function of all the components working together *in vivo*. These include anatomical barrier function, mucociliary clearance, and effects of secretory immunoglobulin A (IgA), surfactant, opsonising IgG, complement, alveolar macrophages, plasma components, and vasoactive mediators.[1]

Pseudomonas aeruginosa is an opportunistic Gram-negative bacillus that causes pneumonia in vulnerable children.[7] Reed *et al.*[8] exposed rats to hard wood smoke at concentrations of particles ranging from 0 to 1000 $\mu g/m^3$ for 6 hours per day for 26 weeks, then intratracheally instilled *P. aeruginosa*; they found that wood smoke exposure did not increase the number of bacteria in the lung. In contrast, significantly increased levels of bacteria in lung tissue have been reported in mice exposed to diesel exhaust emissions (particle contents ranging up to 1000 $\mu g/m^3$ for 6 hours per day for 1 week).[9] In this model, mice exposed to diesel particles have visible loading of alveolar macrophages with

E-mail address: j.grigg@qmul.ac.uk

1526-0542/$ – see front matter © 2007 Elsevier Ltd. All rights reserved.
doi:10.1016/j.prrv.2007.07.010

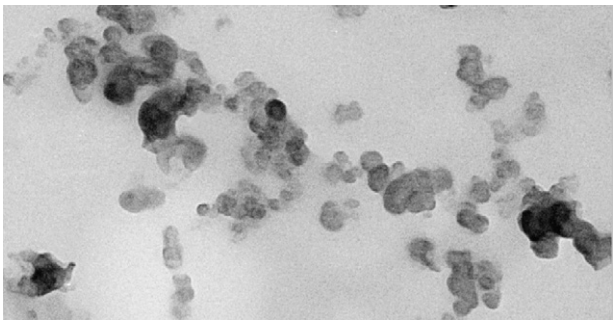

Figure 1 Aggregates of carbon particles from diesel exhaust emissions imaged by electron microscopy. Each aggregate is less then 10 microns in diameter, and consists of nanoparticles (<10 nm). Similar nano particle aggregates are present in smoke from biomass fuels.[4]

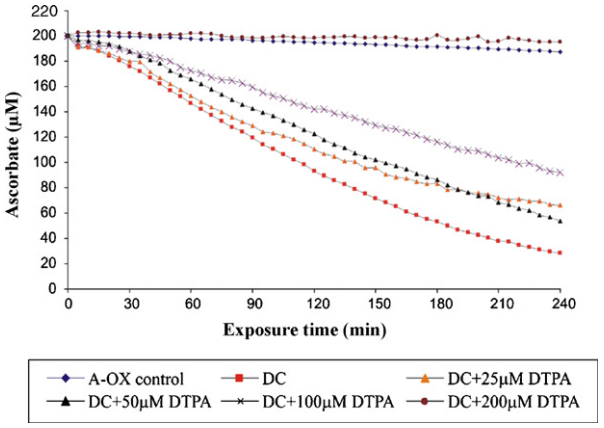

Figure 2 Depletion of the lung-lining fluid antioxidant, ascorbate, when incubated with dung cake smoke particles (50 μg/ml). Without added particles, there is minimal loss of ascorbate over time (top curve, A-OX control). Incubation with biomass smoke particles (bottom curve, DC), result in depletion of most of the ascorbate solution within 4 hours. The curve is shifted upwards (towards the control) by co-incubation with increasing concentrations of the metal chelator DTPA (DC+DTPA). This suggests that pro-oxidative capacity of dung smoke particles is due to their metal content.

particulate matter, increased pulmonary neutrophils, and decreased number of ciliated cells in the proximal and distal airways during the infection.[9] A similar pattern of delayed clearance of *P. aeruginosa* occurs in mice exposed to cigarette smoke for 5 days a week for 8 weeks.[10]

Listeria monocytogenes has the capacity to evade antibacterial pulmonary defences and grow within alveolar macrophages. *Listeria* is used, not because it is a common pathogen in children, but because it is a well-established model for the study of lung immunity.[11] In rats, inhalation of aerosolised diesel exhaust particles (DEP; 20 mg/m^3 for 4 hours a day for 5 days) followed by infection, increases lung *Listeria* levels for up to 7 days.[12] This DEP-induced impairment of pulmonary immunity is not permanent, as by 10 days, all DEP-exposed animals were still alive and *Listeria* levels were very low to absent (i.e clearance is delayed but is ineffective).[12] One possible mechanism for the delayed clearance of *Listeria* is that the alveolar macrophages in DEP-exposed animals release more interleukin-10, a cytokine which tends to prolong survival of *Listeria*.[12] In rats, a similar patter of delayed lung clearance of *Listeria* can be induced by a single intratracheal instillation of diesel exhaust particles (5 mg/kg).[13] In this model, DEP-exposed alveolar macrophages are less able to generate reactive oxygen species, a mediator of intracellular microbial killing. In contrast, instillation of pure carbon black (i.e. particles without absorbed compounds) does not affect clearance of *Listeria* – suggesting that vulnerability is modulated by compounds on the surface of the diesel particle core, rather than the carbon core itself.[13]

Staphylococcus aureus causes life-threatening pneumonia in the developing world.[14] Few animal studies have examined the effect of biomass smoke, or carbon particles, on *Staphylococcal* killing in the lung. However, a dose-dependent increase in lung concentrations of *S. aureus* occurs after inhalation of wood smoke for 1 hour per day for 4 days.[15] This adverse effect of wood smoke on pulmonary immunity occurs within 3 hours and persists for up to 5 days.[15]

Streptococcus pneumoniae is the major cause of mortality from pneumonia in children in the developed world.[16] To date, no animal study has modelled the interaction between biomass smoke and pneumococcal infection.

Table 1 Summary of the major pollutants emitted form the burning of biomass fuels

Compound	Examples	Source	Indoor levels*
Inorganic gases	Carbon monoxide	Incomplete combustion of organic material	1.59–263 μg/m^3
	Nitrogen dioxide	High temperature oxidation of nitrogen in air	2.0–263 μg/m^3
Hydrocarbons	Benzene	Incomplete combustion of organic material	
Aldehydes	Acrolein	Incomplete combustion of organic material	
	Formaldehyde	Incomplete combustion of organic material	87–1718 μg/m^3
Particles	Inhalable carbonaceous-based particles (particulate matter <10 microns; PM_{10})	Condensation of combustion gases; Incomplete combustion of organic material; entrainment of vegetation and ash fragments	25–34,700 μg/m^3
Polycyclic aromatic hydrocarbons	Benzo[a]pyrene	Condensation of combustion gases; incomplete combustion of organic material	Not available

Adapted from Brauer (1998).[34] *From the exposure database of Professor Kirk Smith.[35]