[S4-4]

Electric charge on nano-aerosols – implications for lung deposition of inhaled carcinogens

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Introduction

The probability that inhaled aerosol particles will deposit and be retained in the lung, has been extensively investigated and is generally well expressed by the ICRP 66 lung model (1999). Figure 1 shows total deposition probability of inhaled aerosol particles in all compartments of the human lung according to the ICRP 66 model. Aerosols of a few nanometres in size deposit with essentially 100% efficiency and owing to their high diffusivity, these are likely to deposit in the mouth and throat, well before reaching the lung itself. As aerosol size increases, the probability of deposition in the lung reduces, reaching a minimum of 30% at around 0.2 µm or 200 nm. As aerosol size increases further, the deposition probability increases again and for the larger aerosols inertial deposition in the major airways becomes the dominant lung deposition mechanism.

Kim and Jaques (2000) have validated the ICRP 66 lung deposition model on 22 human volunteers. For 100 nm non-hygroscopic aerosols, total lung deposition on inhalation was around 25% only.

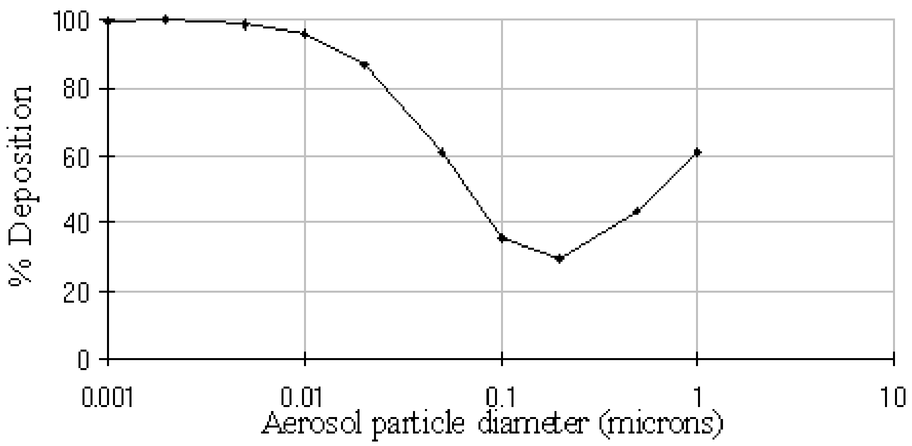

Figure 1: Total deposition probability of inhaled aerosol particles in all compartments of the human lung according to the ICRP 66 (1994) lung model.

However, the ICRP lung model takes no account of the electric charge state on aerosols, which could increase lung deposition by attractive mirror charge effects in the small airways and the lung alveoli. Indeed, aerosol charging has been investigated as a means of improving drug delivery to the lung (for example Melandri *et al*. 1983). In normal air, while a proportion of aerosols particles are naturally charged, in the size range up to 200 nm this is a small effect. Cohen *et al*. (1998) has shown that the addition of a single charge to 20 and 125 nm aerosols increase deposition in metal alloy casts of the human tracheobronchial tree by factors of 3.2 ± 0.3 and 2.3 ± 0.3 respectively. These findings are of particular importance because the number distribution of pollutant aerosols outdoors is dominated by those in the size range up to a few hundred nano-metres and evidence suggests that these may carry a significant proportion of the total mass of potentially carcinogenic poly-cyclic aromatic hydrocarbons (PAHs).

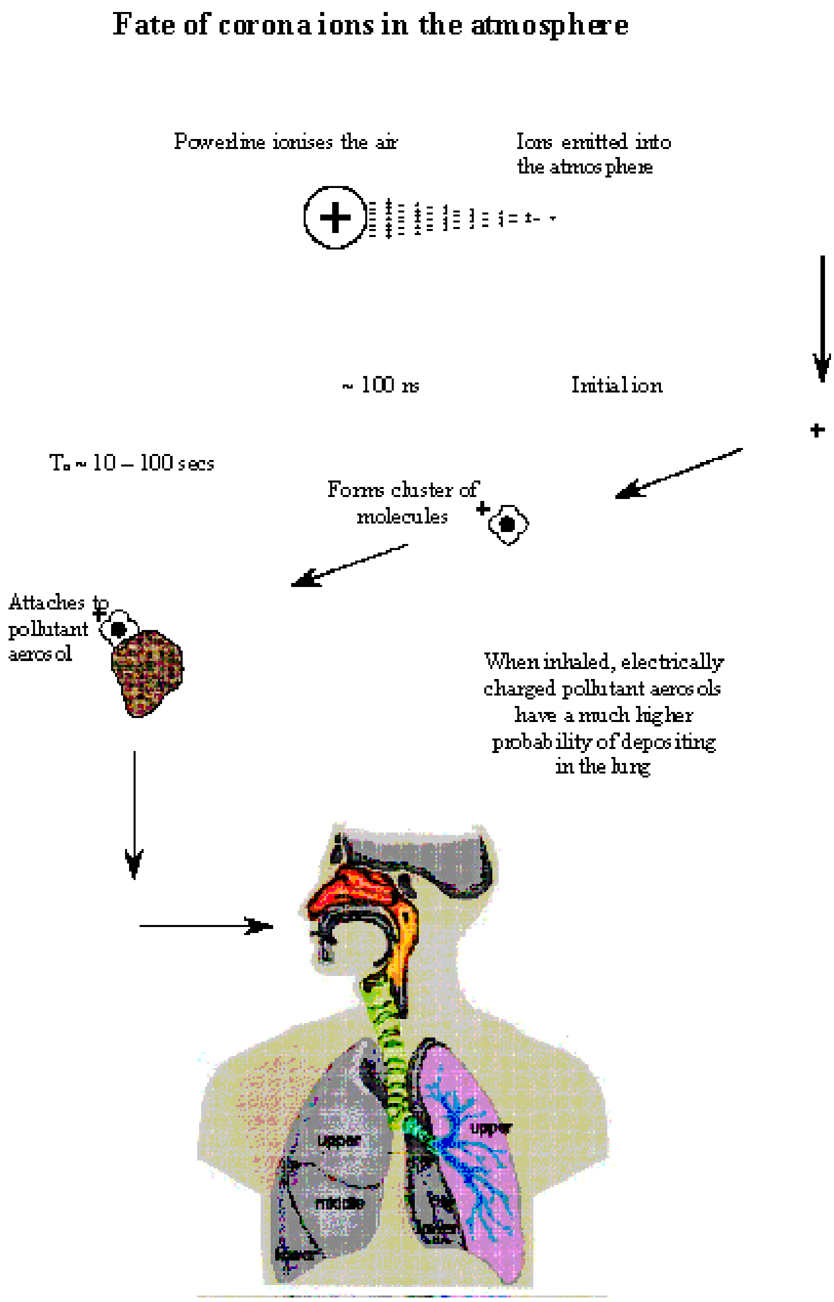

Figure 2: Possible scenario of how corona ions emitted from high voltage powerlines may increase increased lung deposition of inhaled pollutant aerosols.

This talk will describe situations where pollutant aerosol particles, particularly those in the nano-size regime, may become artificially charged and this may act to increase the uptake of air pollution via increased lung deposition on inhalation.

High voltage powerlines

We first addressed the question of aerosol electric charge state in relation to corona ion emission from high voltage powerlines (figure 2). Such powerlines can and frequently do emit corona ions, electrons and molecular ions of oxygen and nitrogen, which are emitted into the atmosphere. On a very short time scale, ~100 ns, these nucleate small ions around 1 nm in size. On a time scale of 10 to 100 seconds, the latter attach themselves to particles of air pollution at a rate governed by the small ion and aerosol number densities and the ion-aerosol attachment coefficient (Hoppel & Frick 1986). When inhaled, previously uncharged aerosols and those with added charge are considered more likely to deposit in the lung. An important phenomenon concerning powerline corona ion emission is its non-equilibrium steady state nature. Efficient separation of positive and negative small ions occurs, resulting in the observation of unipolar space charge extending large distances from powerlines, up to several kilometres in some cases, before becoming charge neutralised. A risk assessment of the possible increased number of air pollution associated illnesses in populations living near powerlines was published in Henshaw (2002).

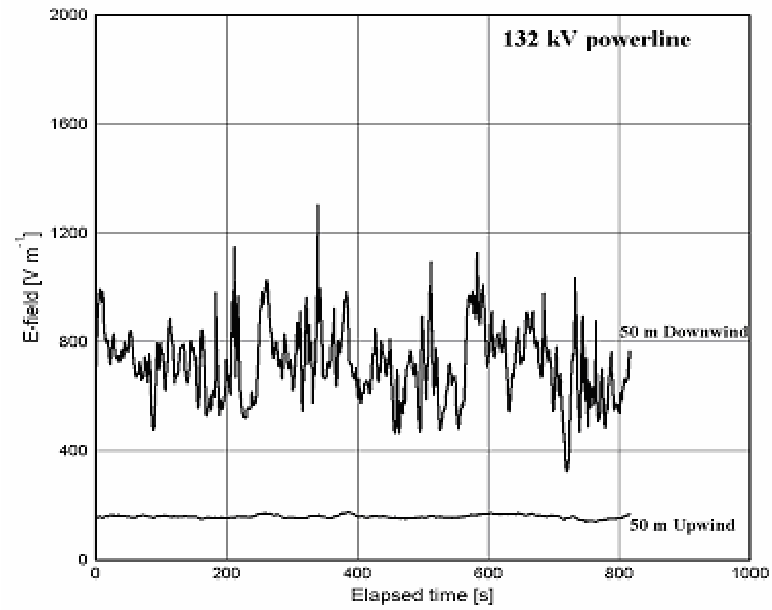

Figure 3: Contemporaneous measurements of the Earth's DC field at one metre height 50 m upwind and 50 m downwind of a 132 kV powerline at Rangeworthy, South Gloucestershire on 19th October 1999. The perturbed field downwind, is indicative of positive corona ion emission carried downwind of the line.

To determine small ion and charged aerosol densities near powerlines, state-of-the-art high resolution spectrometers, based on mobility measurements, have been developed in the Bristol laboratory capable of obtaining a size spectrum in around 10 minutes in outdoor air (Fews *et al*. 2004a). Figure 5 shows measurements taken near the 400 kV powerline at Lower Godney.

Charged aerosols, vehicle exhausts and stir fry cooking

We are also investigating whether charged aerosols are emitted from vehicle exhausts and from the process of stir fry cooking. In both of these situations adverse health effects have been reported which may in part relate to exposure to PAHs contained on nano-aerosols. The initial observations indicate that charged nano-aerosols may be associated with diesel exhausts but not with the process of stir fry cooking. Further details are given in Fews *et al*. 2004b.

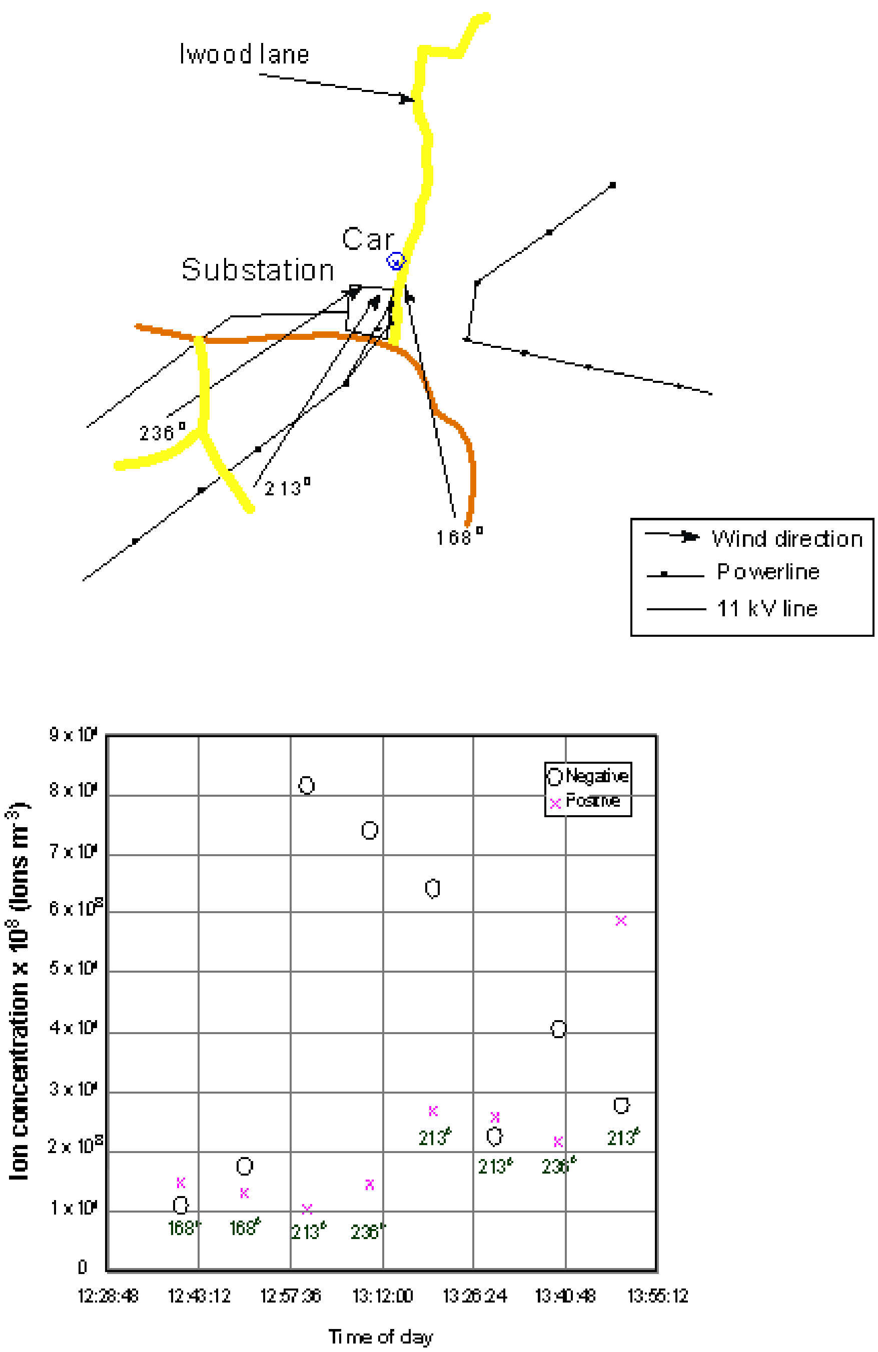

Figure 4: Short term variation in the number density of corona ions with wind direction near an electricity substation at Iwood lane, North Somerset on 28th November 2002.

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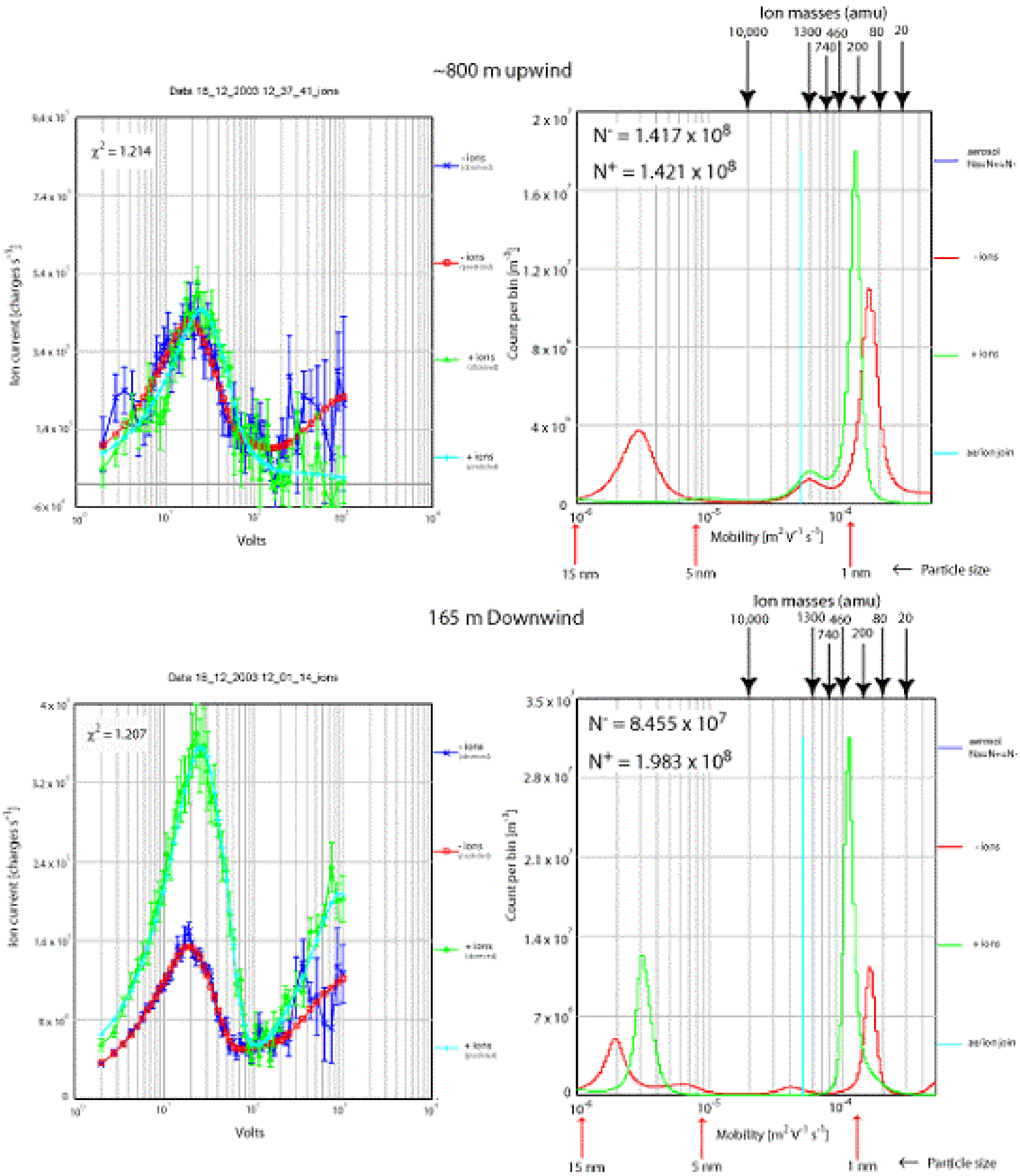

Figure 5: Contemporaneous ion and charged aerosol spectra 800 m upwind and 165 m downwind of a 400 kV powerline at Lower Godney, Somerset on 18th December 2003. The plots on the left show the voltage vs ion current scan data and on the right the deconvolved spectra. Compared with upwind, the downwind spectra show an excess of positive ions up to ~1 nm as well as evidence of an excess of charged aerosols between 5 and 15 nm.