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Genotoxicity, inflammation and physico-chemical properties of fine particle samples from an incineration energy plant and urban air

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Abstract

Airborne particulate matter (PM) was sampled by use of an electrostatic sampler in an oven hall and a receiving hall in a waste-incineration energy plant, and from urban air in a heavy-traffic street and from background air in Copenhagen. PM was sampled for 1–2 weeks, four samples at each site. The samples were extracted and examined for mutagenicity in *Salmonella typhimurium* strains TA98, YG1041 and YG5161, for content of inorganic elements and for the presence of eight polycyclic aromatic hydrocarbons. The induction of *IL-6* and *IL-8* mRNA expression and the presence of DNA damage – tested by the comet assay – were determined after 24-h incubations with human A549 lung epithelial cells.

The $PM_{2.5}$ concentration was about twofold greater in the oven hall than in the receiving hall. The particle size distribution in the receiving hall was similar to that in street air (maximum mode at about 25 nm), but the distribution was completely different in the oven hall (maximum mode at about 150 nm). Also chemically, the samples from the oven hall were highly different from the other samples.

PM extracts from the receiving hall, street and background air were more mutagenic than the PM extracts from the oven hall. PM from all four sites caused similar levels of DNA damage in A549 cells; only the oven hall samples gave results that were statistically significantly different from those obtained with street-air samples.

The receiving hall and the urban air samples were similarly inflammatory (relative *IL-8* mRNA expression), whereas the oven hall did not cause a statistically significant increase in *IL-8* mRNA expression. A principal component analysis separated the oven hall and the receiving hall by the first principal component. These two sites were separated from street and background air with the second principal component. Several clusters of constituents were identified. One cluster consisted of all the polycyclic aromatic hydrocarbons (PAH), several groups of metals and one group of the biological endpoints (DNA damage, *IL-6* and *IL-8* mRNA expression). The PAH and the inorganic content of the air in the receiving hall may be due to vehicle emissions and suspended waste particles. The inorganic content in the street and background air may have been influenced by break wear, road emissions and long-range transport. The results from a partial least-square regression analysis predicted that both PAHs and a group of metals including

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Fe and Mn contributed to *IL-6* and *IL-8* induction. Only Mn and Sr were predicted to influence DNA damage statistically significantly. Among the PAHs only chrysene had influence on DNA damage.

The PM from the oven hall was markedly different from the PM at other locations in particle size distribution, chemical composition and the resulting biological effects when A549 cells were incubated with the PM. These characteristics and observations in the oven hall indicated that the PM source was oven exhaust, which was well combusted.

Keywords: Urban air; Incineration energy plant; Genotoxicity; Inflammation; Chemical composition; Particle size distribution

1. Introduction

Urban particulate air pollution has a major impact on the quality of life and human health [1,2]. Especially, there is concern over suspended fine and ultrafine particulate matter in urban areas, to which traffic contributes as a major source. Even though the problem has been intensively studied in the last decade, scientists are still struggling to understand the mechanisms behind the adverse health affects of modern urban particulate air pollution. However, it is not only in urban areas that people are exposed to particulate air pollution. In some occupational environments, the exposure levels are much higher than in urban air and the composition will be very different.

Incineration plants in industrialised countries are of great importance since waste is being generated in ever-increasing amounts and new waste-recycling facilities are being built. In Denmark, a total of 13.3 millions tonnes of waste was produced in 2004, of which 65% was recycled in 32 incineration recycling plants. In the period 1994–2004 the total amount of waste increased by 20% [3]. Exposures to bio-aerosols, dust concentrations and volatile and odorous compounds have been investigated [4–6]. Bacterial mutagenicity of samples from municipal and hospital-waste combustion emissions [7] and from the emission gas inside a municipal waste incinerator [8] has been investigated. Pani et al. [9] investigated the mutagenic activity of airborne particulates (total particulate matter and the respirable fraction) collected inside the working area of a municipal incinerator. However, not much attention has been focused on particle-size distributions and the *in vitro* toxicity of airborne fine particulate matter at incineration plant facilities.

The toxicity of urban particulate matter has been investigated in many *in vitro* studies (e.g. [10–14]). The aim of this study was to gain knowledge about fine particle concentrations, particle-size distributions, chemistry and *in vitro* toxicity at two sites in a waste-incineration recycling energy plant and compare the results with those obtained with samples collected in urban street and background air.

2. Materials and methods

2.1. Sampling sites

Samples were collected at four sites, which are described in Table 1. Four samples were collected from each site.

2.2. Particle collection and sample preparation

Particles were collected with a newly developed sampler that collects fine particulate matter [15]. Briefly, the sampler is based on a commercial electrostatic office-air cleaner with an air velocity of 175 $m^3 h^{-1}$. The collection efficiency window varies from 25 to 70% between 30 nm and 2.5 μm, with a maximum (60–70%) between 0.2 and 0.8 μm. Particle recovery tests showed that the recovery rate in the aqueous solution was >98%, varying between 98.2 and 99.8 for the four different sites. For dry particulate matter, testing of NIST SRM 2975 showed that the recovery rate was >80%; details of the particle-extraction method are given in Ref. [15].

2.3. $PM_{2.5}$ measurements and particle size distribution

At the two sites in the incineration plant we determined $PM_{2.5}$ concentrations during 7–10 days, with a sampling time of 2–3 days, using a Triplex cyclone (BGI, MA, USA), 37-mm Teflon filters (Millipore, Denmark, cat. 0*: FALP03700) and a pump (Aircon 2, Gilian, IL, USA) with an airflow of 1.5 l/min. $PM_{2.5}$ levels were not determined in street air and background air.

The particle-size distributions at the incineration plant were unknown and, therefore, we determined the distributions at both sites in the size range 0.0098–10 μm with a SMPS (Model 5.400, Grimm, Germany) and an Aerosol Particle Sizer (APS-3321; TSI Inc., USA) during 3–4 days during the same period in which particle samples were collected. The distributions were compared with distributions from the urban street site, which were determined with the same instruments during 15 days in October–November 2004.

2.4. Particle chemistry

2.4.1. Metal analysis

Elements were determined with ICP-MS (PE Elan 6100DRC ICP-MS with PE auto-sampler AS-91, Perkin-Elmer, Hvidovre, Denmark) at the Geological Survey of