The Chemical Nature of PM_{10} and $PM_{2.5}$ in Cork City Centre: Links to Source and Toxicity

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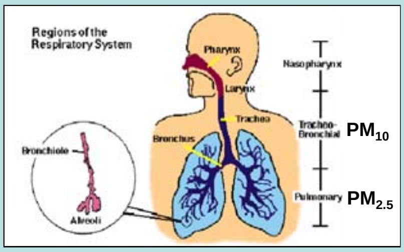
Introduction

Numerous studies worldwide have highlighted the detrimental effects of airborne particulate matter (PM) on human health. A UK government committee reported short term air pollution episodes are responsible for between 12,000 and 24,000 premature deaths in the UK each year. The sources of airborne PM are fairly well understood but the mechanism by which they exert their toxic effect remains unclear. However, the toxicity of airborne PM is known to be dependant on two factors; size and chemical composition. Generally the smaller the particle the further it will penetrate the lung so the greater the toxicity, leading to the classification of PM_{10} (particulate matter with a diameter less than 10 μm) and $PM_{2.5}$ (less than 2.5 μm). Metal ions have been found to be linked to lung injury and polyaromatic hydrocarbons (PAHs) have been found to exert toxic effects on animal models and the carcinogenic and/or mutagenic properties have been found to have a marked effect on lung tissue. This area is also of great importance to Irish Environmental Science. Hence this project is sponsored by the EU Marie Curie (Transfer of Knowledge) programme and the EPA Doctoral Fellowship Scheme.



Aims

Samples of $PM_{10-2.5}$ and $PM_{2.5}$ are to be collected using a dichotomous Partisol sampler and a high volume cascade impactor in Cork city centre (Old Station Road) and at a background urban site (Heatherton Park). The samples will undergo chemical analysis for metal ions using ICP-OES, PAHs using GC-MS, inorganic ions by ion chromatography, carbon content by reflectometry and elemental species by x-ray fluorescence. The use of this detailed chemical data is twofold; firstly it is to be used to produce a computer model of the origin and distribution of the PM_{10} in Cork and secondly it is to be used to find links with toxicological endpoints.

Methodology

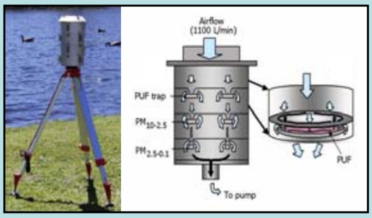


Fig 1. The three stage high volume cascade impactor, collecting $PM_{10-2.5}$ and $PM_{2.5}$ onto polyurethane foam.

The two types of collector employed in this study are the high volume cascade impactor (HVCI) and the dichotomous Partisol sampler. Both can separate PM_{10} into the coarse ($PM_{10-2.5}$) and fine ($PM_{2.5}$) fractions.

The HVCI (Fig 1) runs at a high flow rate of 1100 l min^{-1} and uses polyurethane foam as the inert collection substrate. Therefore a high weight of PM can be collected in a short period of time, providing an excess of sample for chemical analyses and sufficient weight for toxicological studies, which can require weights in the mg range.

The Partisol sampler (Fig 2) operates at a much lower flow rate of 16.7 l min^{-1} and collects between 50-500 μg per day. This is sufficient for limited chemical analyses but the PTFE collection filters are very flat providing an excellent substrate for electron microscopy, reflectometry and x-ray flourescence.

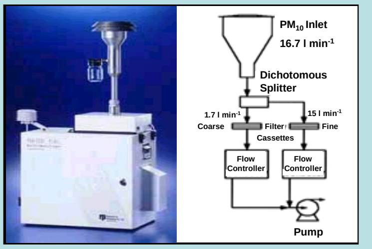


Fig 2. The Partisol sampler with the dichotomous splitter for the collection of $PM_{10-2.5}$ and $PM_{2.5}$ on PTFE filters.

Initial Results

ICP-OES analysis of PTFE filters from the City Centre (Old Station Road) and the background urban (Heatherton Park) sites reported that lead levels were significantly higher in the City Centre during both November (Fig 3) and December (Fig 4) 2003.

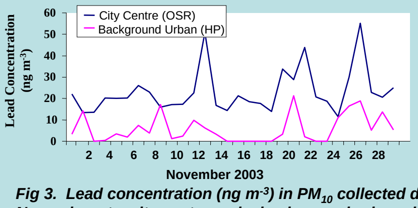


Fig 3. Lead concentration (ng m^{-3}) in PM_{10} collected during November at a city centre and a background urban site.

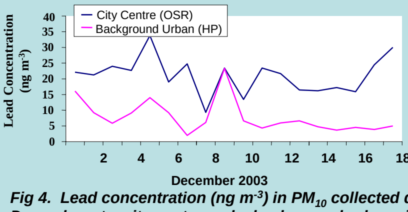


Fig 4. Lead concentration (ng m^{-3}) in PM_{10} collected during December at a city centre and a background urban site.

Example Study – Linking Chemical Analysis to Toxicological Data

The following is an example of a study that compares chemical data to toxicology. The study involved airborne particulate samples collected in London between 1955 and 1952 (blue points) and in 2001 (red point).

The samples were analysed for both the total (digestion in nitric acid) and water soluble metal content using inductively coupled plasma mass spectrometry (ICP-MS). Identical samples were tested for toxicity using an *in vitro* DNA scission assay and a TD_{20} value (toxic dose causing 20% damage to the DNA) was determined for each sample.

No correlation could be found between the total metal content and toxicity (Fig 5) but a link was present with the soluble metal content. Increased concentrations of soluble metals caused a increased toxicity in the sample (Fig 6) with the metals iron, copper, lead and vanadium being the major players (data not shown).

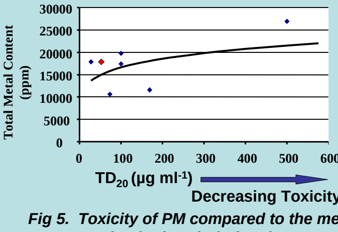


Fig 5. Toxicity of PM compared to the metal concentration in the whole fraction.

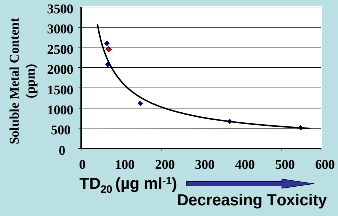


Fig 6. Toxicity of PM compared to the metal concentration in the water soluble fraction.

Summary

Initial findings suggest a higher concentration of lead in the city centre compared to the background urban site, which may be indicative of the higher vehicular activity in the centre. This type of information will be critical for the modelling of the source and distribution of the numerous pollutants present in the ambient air. As in the example study (Figs 5 & 6) differences in chemical composition will also be investigated to determine if certain pollutants lead to greater *in vitro* toxicity.

The ultimate aim of this study is to bring together the three facets of chemical analysis, toxicology and computer modelling to determine the toxic components within the ambient air of Cork and map them to specific sources.