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

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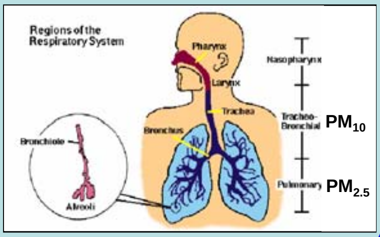
Introduction

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

- Collection of $PM_{10-2.5}$ and $PM_{2.5}$ in Cork city
- "Total" chemical analysis method development to determine the total chemical composition
- All data retrieved from the total chemical analysis will be used in the production of a *Computer Model* to help determine the origin & distribution of PM in Cork
- Determination of biochemical toxicological effects of airborne particulate components

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.

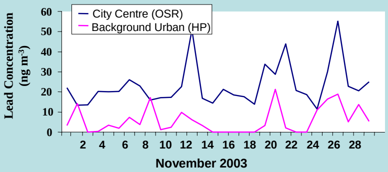


Fig 3. Lead concentration (ng m^{-3}) in PM_{10} collected during November at a city centre and a background urban site.

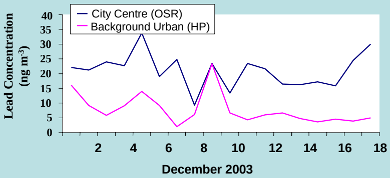


Fig 4. Lead concentration (ng m^{-3}) in PM_{10} collected during December at a city centre and a background urban site.

Example Study – Linking Chemical Analysis to Toxicological Data

- An example of a study that compares chemical data to toxicology. The study involved PM collected in London between 1955 and 1952 (blue points) and in 2001 (red point).
- Samples were analysed for both the total (digestion in nitric acid) and water soluble metal content using (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 Fe, Cu, Pb and V being the major players

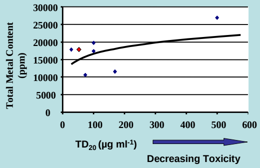


Fig 5. Toxicity of PM compared to the metal concentration in the whole fraction.

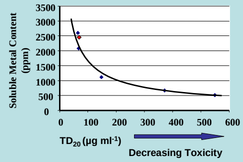


Fig 6. Toxicity of PM compared to the metal concentration in the water soluble fraction.

Experimental

Field Measurement:

Samples are collected using two types of samplers, the high volume cascade impactor (Fig 1) and the dichotomous Partisol sampler (Fig 2). Both can monitor for the coarse ($PM_{10-2.5}$) and fine ($PM_{2.5}$) fractions.

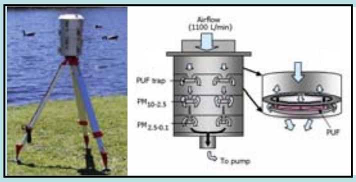


Fig 1. The three stage high volume cascade impactor, collecting $PM_{10-2.5}$ and $PM_{2.5}$ onto polyurethane foam.

- High flow rate of 1100 l min^{-1}
- Uses polyurethane foam an inert collection substrate
- 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

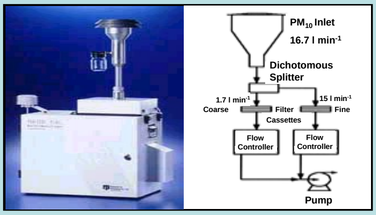


Fig 2. The Partisol sampler with the dichotomous splitter for the collection of $PM_{10-2.5}$ and $PM_{2.5}$ on PTFE filters.

- Flow rate of 16.7 l min^{-1}
- PTFE (47 mm) collection filters
- Filters are flat providing an excellent substrate for electron microscopy, reflectometry and x-ray flourescence.

Total Chemical Analysis:

Metal Content	PAHs	Inorganic ions	Carbon content	Elemental Species
ICP-OES	*GC-MS*	*Ion Chromatography*	*Reflectrometry*	*XRF*

"Source Apportionment Computer Modelling" programme

Source categories within the Source Apportionment Model

1) Primary anthropogenic particles *e.g* black smoke, PAHs

2) Secondary anthropogenic particles *e.g* SO_4^{2-}, NO_3^- and NH_4^+

3) Re-suspended dusts (*e.g* Ca &Fe)

4) Marine aerosols *e.g* sodium chloride

Biochemical Toxicology

- Investigation into the effects of chemical mixtures (based on the results from the chemical analysis) on cultured cells
- Dose response relationships determined.

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.