The respiratory toxicity of coal fly ash

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The combustion of coal for the generation of electricity has many environmental implications. Coal fly ash (CFA; Figure 1) is a product of coal combustion, formed from the incombustible mineral matter contained within the coal. CFA is respirable (i.e. <2.5μm diameter) and known to be detrimental to human respiratory health upon exposure (Brown, 2011).

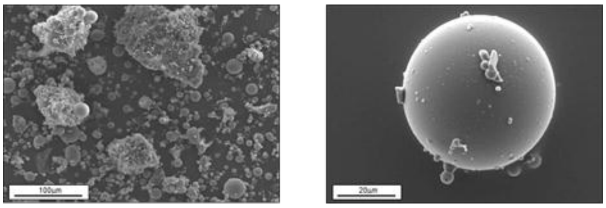

Figure 1. Scanning electron micrograph of CFA: Bulk (left|) and PM10 (right) fractions, respectively.

The aim of this study was to compare the relative respiratory toxicity of CFA samples obtained from three Chinese coal-burning power stations to CFA obtained from a UK coal-burning power station; both bulk and respirable PM_{10} samples were tested. In order to elucidate CFA toxicity, a multi-disciplinary approach was taken, thereby considering geochemical aspects of the fly ash as well as biochemical properties.

Geochemical analysis was used to determine the composition, morphology and solubility of metallic components. Total analysis, carried out using FLUXY ICP-MS, identified the bulk elements present, X-ray diffraction (XRD) identified crystalline phases present in the particles, and the overall morphology was evaluated by scanning electron microscopy (SEM).

Three *in vitro* biochemical techniques were used to elucidate the samples relative bioreactivity. The samples were tested on their capability to a) generate reactive oxygen species (ROS), using a DCFH assay, b) cause haemolysis of red blood cells (RBCs) via a haemolysis assay, and c) cause damage to plasmid DNA, by use of a plasmid scission assay (PSA).

The geochemical analysis showed the samples differ very little in composition between bulk and PM_{10} fractions and the overall solubility of metals was low (Figure 2). XRD identified the presence of mullite (Figure 3) in all samples with increased levels seen in one particular Chinese sample. SEM showed the particles to be spherical in shape and respirable in size, with 18% of the UK PM_{10} samples in the fine particle size range, able to reach the most distal regions of the respiratory system.

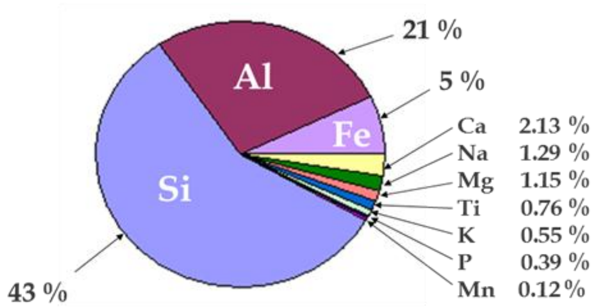

Figure 2. Elemental composition of a UK PM_{10} fly ash sample. The level of leachable metals is very low.

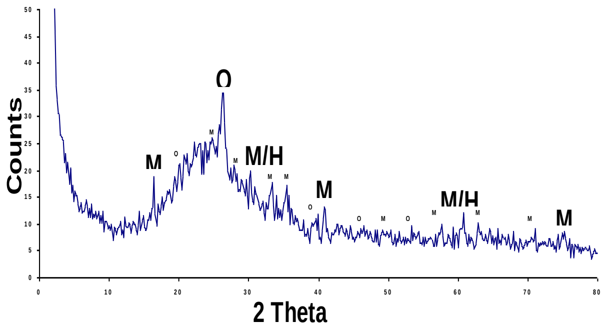

Figure 3. XRD showing mullite (M) and hematite (H).

The biochemical assays showed the Chinese samples to be more reactive, especially one PM_{10} sample, which gave 66% haemolysis for a 15mg dose and 49% damage to plasmid DNA. The relative toxicity of technogenic particles is often dependent on the bioavailability of metals, which generate ROS via Fenton-redox mechanisms. CFA metals appear tightly bound within the spheres, suggesting forms of crystalline silica may provide the platform for toxicity.

PM_{10} can remain airborne, travel long-distance and penetrate into the thoracic region of the lungs. CFA is known to contain toxic heavy metals, e.g. As, Hg, Pb, Cd, Se, which are associated with cancer and neurological problems. Fly ash is put into landfills and lagoons which can leach heavy metals, risking contamination of ground water and water supplies. Effective particulate removal technology and waste management is critical to removing any potential threat to human health.

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Brown, P. (2011), *Respiratory Toxicity of Coal Fly Ash*. PhD Thesis, Cardiff University, Wales, UK.