5th Working & Indoor Aerosols Conference
18-20 April 2018 - Cassino, Italy

Separation and chemical analysis of underground coal mine PM_{10} and $PM_{2.5}$: a contribution to the new ROCD project

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Keywords: Coal; Dust; $PM_{2.5}$ and PM_{10}; underground mining

ABSTRACT – Coal dust exposure is a potential respiratory health hazard in underground mining and is therefore strongly regulated in most parts of the world. Despite this, over the last 15 years, some countries have seen a resurgence in coal mine dust lung disease [1]. As part of the new ROCD (Reducing risks from Occupational exposure to Coal Dust) project, we will identify the main metallic elements of concern in PM_{10} and $PM_{2.5}$ in different locations and operations in underground coal mines in Poland and Slovenia. Here we present some background to the ROCD project and outline a new approach to the physicochemical characterization of coal mine PM.

1. INTRODUCTION and OBJECTIVES

With increasing pressure and temperature, buried organic matter is progressively transformed to lignite and then through sub-bituminous and bituminous coals to anthracite. This transition, and increase in rank, results in a progressively higher proportion of carbon and increased hardness and energy content creating products which, when mined, produce different types of dust [2]. Dust from high-rank coal, for example, is associated with a higher risk of respiratory diseases [3].

Coal miners may be regularly exposed to coal dust as well as other types of emissions (e.g. diesel exhaust particulate) in their work environment. The resulting (variable) mixtures of particle types are frequently grouped together as “coal mine dust”, however the proportions of particle types should be determined in order to fully assess potential mine dust toxicity and to design mitigation strategies. The smaller particle size fractions (PM_{10} and especially $PM_{2.5}$) are capable of penetrating deep into the lungs where they may cause significant long-term injury, potentially leading to coal workers’ pneumoconiosis (CWP) and other lung-related pathologies [1].

A specific objective of this part of the ROCD project is to investigate the chemistry of different coal mine particle size fractions ($PM_{2.5}$ and PM_{10}). In order to achieve this a variety of chemical analysis techniques will be applied to PM collected from a range of active underground coal mines in Poland and Slovenia, using the methodology summarised below.

2. METHODOLOGY

2.1 Sampling

Around two hundred collector plate-deposition coal dust samples from mines in Poland and Slovenia are being collected and sent for analysis at the IDAEA-CSIC research centre. A new protocol for PM_{10} and $PM_{2.5}$ separation from the dust has been developed using a specially designed particle size separation device (**Figure 1**). This comprises a rotating 17 cm diameter methacrylate cylinder which is attached at one end to a filter sampling head through which air is drawn by a pump. The cylinder is continuously rotated to resuspend PM which is then collected on a 0.60 µm pore size polycarbonate filter, at an air flow rate of 25 $l \cdot min^{-1}$ or 5 $l \cdot min^{-1}$ to collect PM_{10} and $PM_{2.5}$, respectively.

Figure 1. Equipment for separation of $PM_{2.5}$ and PM_{10}.

2.2 ICP-MS, ICP-AES, DRX and SEM analysis

Once the $PM_{2.5}$ and PM_{10} samples have been collected, they will be chemically analysed by ICP-MS and ICP-AES. In addition, samples will be studied by X-Ray Diffraction (XRD) in order to elucidate their mineralogy. Scanning electron microscopy with energy dispersive X-ray analysis (SEM-EDS) will enable the physicochemical characterization of each sample. Samples are also being separated with a precision cascade impactor to allow comparisons between the chemistry of seven different size range fractions (0-30 µm).

3. RESULTS AND DISCUSSION: THE ROCD PROJECT

The recently initiated ROCD project is working towards a comprehensive assessment of the levels, composition and toxicity of dust (including $PM_{2.5}$) from different mines and mining scenarios to generate a predictive model for coal dust hazards. In this context, the study herein, which is based in IDAEA Barcelona, is in the process of producing the largest publicly available database of inhalable coal dust chemistry. The efficiency of the new protocol to separate coal mine $PM_{2.5}$ and PM_{10} has been tested on a sample of lignite-type dust from an underground mine in Slovenia using a Malvern Mastersizer 2000. From the results in **Figure 2**, which shows the volume distribution of particle sizes in the $PM_{2.5}$ and PM_{10} fractions, 57 % of particles in the PM_{10} fraction are < 10 µm in diameter, and 65% of particles in the $PM_{2.5}$ are < 2.5 µm in diameter.

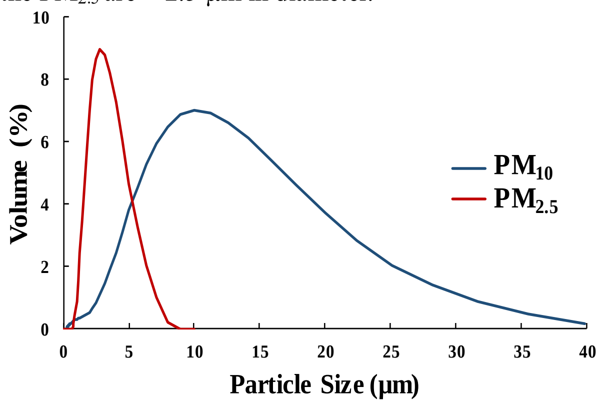

Figure 2. Distribution of the particle sizes in the samples after separating the PM_{10} and $PM_{2.5}$ fractions.

Further results from the physicochemical characterisation of the mine dust samples in this initial stage of the ROCD project will be presented at the Aerosols 2018 conference.

4. CONCLUSIONS

After several decades of substantial improvement in coal mine air quality there has been a downturn in recent years in some countries, leading to increased lung disease in coal miners.

The reasons for this deterioration in mine working conditions are as yet unclear, but likely relate to changing work practices and mining targets producing more and/or different types of ambient dusts in the mines.

Under the wing of the European ROCD project, a new study has been initiated aimed at the detailed physicochemical characterization of PM_{10} and $PM_{2.5}$ in underground mines. This study has necessitated the research and development of a protocol designed to separate PM_{10} and $PM_{2.5}$ particle size fractions from mine dust.

The PM extraction protocol has been verified using a Malvern Mastersizer 2000, and a detailed work programme is currently underway to produce the largest publicly available database on inhalable coal dust chemistry and mineralogy.

5. ACKNOWLEDGEMENTS

This work was supported by the 'Reducing risks from Occupational exposure to Coal Dust" (ROCD) project from the European Commission Research Fund for Coal and Steel; Grant Agreement Number - 754205 - ROCD - RFCS-2016. Thanks to all partners in the ROCD project for their assistance in this study, see partner list at: http://emps.exeter.ac.uk/csm/rocd/ .

6. REFERENCES

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