Real-time measurement of total and solid particle fraction in underground mining environment with DC based sensors (MPEC+)

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In an underground mining environment, the primary particles from vehicles and off-road working machinery are an important pollution source affecting the air quality in an underground mine [1]. These volatile and non-volatile particles affect occupational health as well as economy of the mine because the ventilation demands substantial amount of energy. In addition, air quality is affected by mining activities such as blasting, crushing ore, and transporting ore from the mine. Moreover, non-volatile soot or metallic particles nanoparticles may originate from the diesel engines due to incomplete combustion or from the lubrication oil ash components entering the cylinders. Volatile nanoparticles can be formed during the expansion and dilution of the engine exhaust from the tailpipe to its surroundings due to e.g. sulfur, nitrogen, and hydrocarbon containing gaseous species. These engine originating nanoparticles exist mainly in the ultra-fine particle size range (UFP, diameter < 100 nm), and therefore, the number concentration is a metric that measures the concentration of UFP's. In addition, the volatility of UFP's is an indicator for particle origin and composition.

A system to determine real-time total particle and solid particle number concentrations (TPN and SPN) and fraction of SPN was developed from two diffusion charger based MPEC+ instruments (Dekati Ltd.) In this study, two MPEC+ devices were used as stationary measuring devices for TPN and SPN concentration in an underground mine, located nearby the city of Kemi at northern Finland. The structure of MPEC+ consists of an optional heated sampling line, water separator, evaporation chamber for volatile particle removal (VPR) with an integrated heated critical flow orifice, diffusion charging and diffusion collection based ePNC sensor [2] and a Faraday cage electrometer. The device also includes a three-way valve for automatic zero level measurements for long-term measurements. Typical DC-based instruments have particle size dependent response with linear relationship to Lung Deposited Surface Area (LDSA). In fact, DC-based sensors have previously been used in a mine for LDSA monitoring [3]. However, the particle size response of MPEC+ is close to a pure number concentration response due to the ePNC sensor being operated in reduced pressure conditions which affects both the diffusion charging and particle collection by diffusion [2]. In addition, MPEC+ has been shown to comply with the PN-PEMS requirements when the evaporation chamber is used for VPR in the size range of 23 – 200 nm [4]. In this study one MPEC+ was used in typical configuration with the evaporation chamber removing volatile particles and thus measuring SPN. The second MPEC+ was modified to operate without heating the evaporation chamber, in which case the measurement corresponds to TPN including both volatile and non-volatile particles.

Figure 1 shows the real-time number concentration of total and solid particles and the solid particle fraction at the maintenance level of the underground mine over one measurement day. The solid fraction varied on this day around 5% - 20%. Daily averages of solid and total particle number concentrations were found to be higher at the maintenance level compared to the location near a blasting site. At the maintenance level, the maximum daily concentration of TPN was ca. $4x10^5 cm^{-3}$ and the SPN ca. $1.5 x10^4$ cm^{-3}. The volatile particle fraction behaved oppositely, as the daily average fraction of solid particles was

in maximum 31 % near the blasting site and 12 % at the maintenance level. This results suggest that volatile particles were mainly produced by the traffic inside the underground mine.

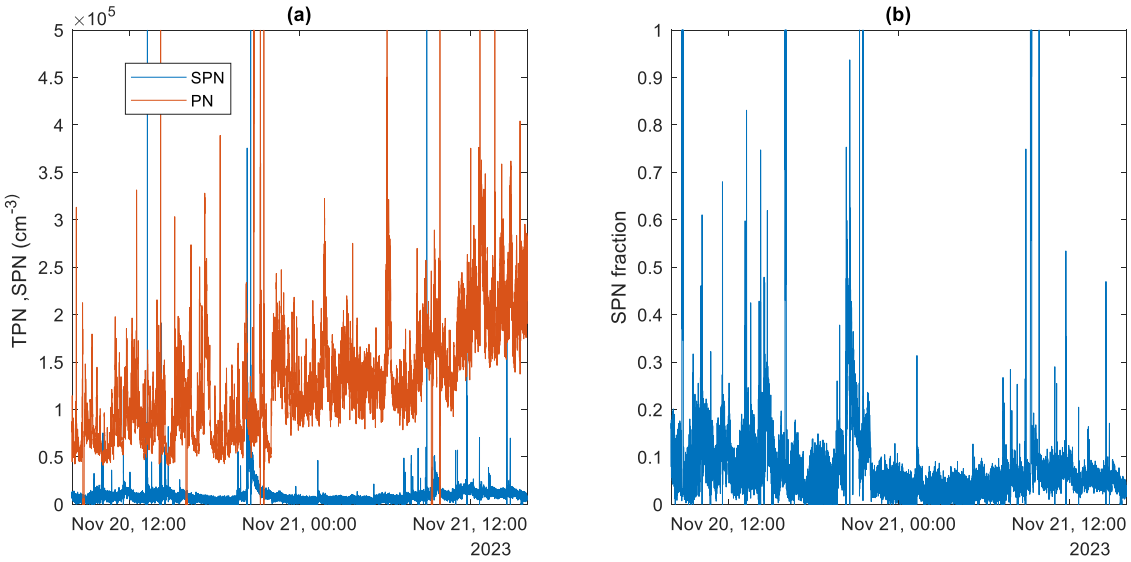

Figure 1. (a) Solid particle number concentration and total particle number concentration (b) solid particle fraction of total particle number concentration.

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