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Portable AI-Assisted System for Real-Time Dust Exposure Monitoring in Working and Occupational Environments

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Summary:
Despite improved workplace exposure limits regulations, many workers remain at risk from airborne particulate matter with lasting health effects. To address this, we developed a portable device that measures dust concentration, identifies chemical composition, and calculates individual exposure in real time. The system combines sensor-based measurements with an AI model trained to classify particulate types, offering a compact, efficient tool for occupational exposure assessment. This approach enhances early detection of hazardous conditions and supports more responsive workplace safety management.

Keywords: respirable fraction, personal exposure, dust identification, trained model, portable sensor

Background, Motivation an Objective

Recent studies in toxicology and regular updates of regulation policy allows to reduce risks of personal exposure to widely used or new hazardous materials. However, more than 1 billion workers are exposed to dangerous substances and factors, like chemicals, fumes, vapors and airborne particulate matter, with long-term impacts on health and quality of life [1]. Majority of the rules are based on average 8-hour total weight average (TWA) permissible exposure limit (PEL), which requires, by definition, a long term monitoring and averaging of data. In case of particulate matter exposure, the collection time and further chemical analysis could take from few hours to few days, and short term exposure limits (STELs) or peaks are not detected and evaluates for adequate protection of workers. To address this, we have developed a portable device capable of measuring dust concentration, identifying the chemical nature of dust particles, and calculating individual exposure in real time.

Description of the New Method

Method is based on few following facts. The granulometric signature of particulate matter generated by same tool but on different materials (wood, plastics, concrete, metal, etc.) is different. The different tool or activity (drilling, polishing, cutting, etc.) produce different granulometric distribution, as well [2, 3]. The individual worker with his personal tool is near to the source. Sensor collection head is near to respiratory tract, so it corresponds to inhaled air.

The system integrates multiparameter sensor-based measurements with an AI model trained to classify particulate types. Data used for model training consist real time measurement and previously collected data completed by chemical analysis according to regulation policy. Its allow to create a database with different sources/tool/material combination and select most probable sources according to working environment.

During operation sensor collect and transfer to server data in almost real time, with 10 seconds interval. Then data are evaluated by server based trained model to calculate dust concentration of respirable or thoracic fraction of dust, identifies chemical composition according to saved database and calculates individual exposure to hazardous substance, like hard wood, crystalline silica, black carbon, oil droplets, etc.

Results

In the development stage multiple candidates of low cost particle counter are tested. In-vitro conditions were realized in 250L test bench, where sensors are placed and exposed by commercially available powders samples: alumina, carbon black, graphite, moondust, quartz in ranges from 1 to 50 mg/m^3. Following data treatment with principal component analysis and linear discriminant analysis were used to identify most promising low cost particle counter (see Fig. 1) The 2 dimensional linear discriminant analysis is showed for finally selected sensor.

In industrialization phase the capacity for measurement of respirable fraction were evaluated. As reference instrument a device called CIP-10 were used [4]. Multiple simultaneous test (see Fig 2) shows very good correlation between

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approved dust collection device with developed sensor based on particle counter.

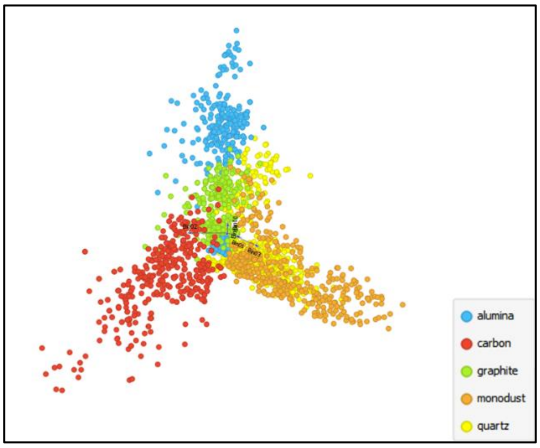

Fig. 1. LDA visualization of discrimination capacity of low cost particle counter

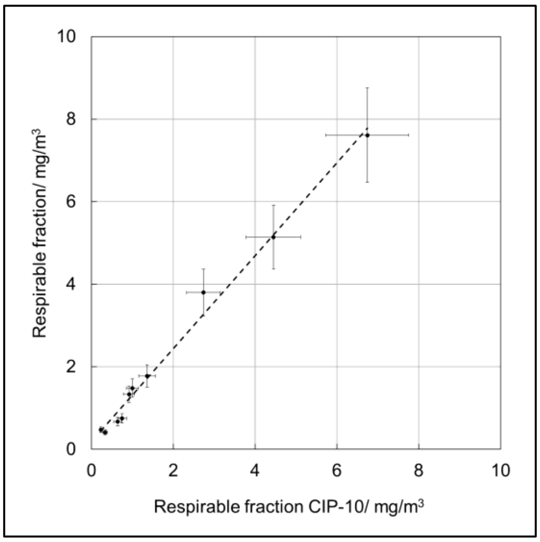

Fig. 2. Graph of respirable fraction collected by CIP-10 vs respirable fraction measured by sensor in 10 different campaign.

Final device, (see Fig.3), has two main parts: sensor head and data collection and treatment module with battery for more than 10h of autonomous work. Sensor head could be easily replaced by new one or different, according to working condition and particulate type.

Fig. 3. Sensor used by worker consist A – sensor head, B – electronic board with battery.

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