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SAFETY ENGINEERING & MANAGEMENT –
SCIENCE, INDUSTRY, EDUCATION (SEM-SIE 2023)

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PERSONAL EXPOSURE TO RESPIRABLE DUST IN EXTRACTIVE INDUSTRIES IN WESTERN BALKAN COUNTRIES

Abstract: *Despite the various advancements made in recent years, workers in the extractive industries continue to face the potential hazard of exposure to detrimental particulate matter. Also, despite the significant economic contribution of the extractive industries to the Western Balkan region, there is a lack of data pertaining to the level of personal dust exposure experienced by people employed in these industries. This study shows the findings of a personal exposure sampling program that was carried out in five distinct enterprises located in Macedonia, Serbia, and Albania. The respirable personal dust levels observed at metal mining sites displayed a wide range of values, ranging from 0.12 to 1.78 mg/m^3. The dust exposure experienced by workers in the industrial mineral processing sector has a similar range, from 0.04 to 4.71 mg/m^3. The measured values at the locations where metal processing occurs were determined to be the most minimal on record, falling within the range of 0.03 to 1.36 mg/m^3. This study provides empirical evidence that showcases the ongoing prevalence of elevated levels of respirable dust exposure among workers employed in the extractive industry in Western Balkan countries. The results emphasize the ongoing necessity for the adoption of efficient monitoring and control measures in order to mitigate dust exposure among employees in extractive sectors.*

Keywords: respirable dust, personal exposure, sampling, monitoring, extractive industry

INTRODUCTION

According to the United Nations Conference on Trade and Development (UNCTAD), the extractive industry encompasses a range of activities aimed at extracting raw materials from earth's crust, including metals, minerals, and aggregates. These commodities are subsequently processed and utilized by consumers. Those industrial activities usually include a wide range of different processes that involve primary processing of metallic ores, fuels, building materials, ceramics, detergents, electronics, filtration, glass, medications and medical devices, paints, paper and plastics, and many more industrial and domestic products.

Despite the advancements in safety legislation, technology, and awareness, workers in extractive industries continue to face the potential hazard of being exposed to dangerous dust particles. Contemporary extractive industries encompass a diverse array of processes, which encompass activities such as mining or quarrying, drilling and blasting, crushing, and the subsequent processing of raw materials. Each of these actions has the potential to generate dust, particularly in the absence of adequate dust management methods.

Wide range of materials, including silica-containing minerals, coal, metals, and even organic materials pose its unique health risks when airborne, and workers can be exposed to a mix of dust types, increasing the complexity of managing health risks. Utilization of robust machinery and equipment adds to the problem, due to high potential to emit significant quantities of respirable dust particles into the atmosphere. High-volume operations frequently result in elevated levels of dust formation, particularly in enclosed environments.

The term *dust* is commonly described as particles that are suspended in the air, typically within a size range of 1 to 100 µm (World Health Organization, 1999). Portion of a dust cloud that is capable of being inhaled through the nose or mouth and frequently gets caught in the upper respiratory tract is referred to as inhalable particulates (World Health Organization, 1999), and it is usually correlated with respiratory ailments, including asthma, tracheitis, pneumonia, and allergic rhinitis (Rumchev et al., 2023).

Finer particles that possess dimensions small enough to be effectively absorbed into the pulmonary system, or 50% cut-point of 4 µm, are defined as respirable dust (International Organization for Standardization, 1995). Respirable dust particles possess dimensions that allow them to evade the inherent protective systems of the respiratory system, such as those present in the nasal and throat regions, hence facilitating their penetration into the lower regions of the lungs. The inhalation of those particles can have varying effects on respiratory health, including chronic bronchitis, silicosis, tuberculosis, emphysema, renal failure, and cancer (Cecala et al., 2021).

Given the abundance of information available, regulatory bodies, industrial associations, and the scientific community in developed nations have acknowledged the crucial importance of monitoring occupational exposure to respirable dust. A substantial body of scientific data (Duarte et al., 2022), along with specialized databases such as IMA-DMP (Zillaot et al., 2017) and CONTAM (Rumchev et al., 2023), which collect representative occupational exposure data from various workplaces in extractive industries, is utilized to assess current levels of exposure and track exposure patterns over time.

However, although the extractive industries are vital part of all Western Balkan economies, a search of relevant research databases, including Web of Knowledge (Current Contents and Web of Science), Scopus, SAGE journals, American Chemical Society, Directory of Open Access Journals (DOAJ), Elsevier (Science Direct), Emerald, IEEE Xplore, and PubMed did not return any entries reporting personal exposure to respirable dust in Western Balkan countries. Even one of the largest occupational exposure databases, the IMA – DMP, which contains almost 30,000 personal exposure records from 160 different worksites owned by 35 industrial mineral companies in 23 countries across Europe, does not contain any record from a Western Balkan country with the exception of 18 records reported from a site in Bosnia and Herzegovina.

Therefore, this research attempts to clarify the methods of personal exposure sampling while examining the personal exposure data collected from several sampling campaigns carried out in extractive industry sites throughout several Western Balkan countries.

MATERIALS AND METHODS

Personal exposure monitoring, alternatively referred to as personal sampling or personal air monitoring, is a technique employed to evaluate an individual's exposure to potentially harmful substances, including but not limited to dust, gases, or biological agents, within occupational or other settings. This approach involves determining the levels of contaminants present in the ambient air that an individual is exposed to throughout their designated work shift or a predetermined duration.

Exposure monitoring generally encompasses a series of sequential procedures, commencing with the positioning of sampling devices, followed by the collection of samples, subsequent analysis of the collected samples, and ultimately the interpretation of the obtained data.

A sampling device, such as a wearable monitor or a pump equipped with an air sampling device, is positioned within the breathing zone, which refers to the region surrounding the nose and mouth of the worker. The device is responsible for monitoring and/or collecting air samples for the duration of the work shift, thereby offering a precise depiction of the contaminants to which the worker is exposed during their occupational tasks. The findings are analysed in order to evaluate the level of exposure experienced by the worker. Subsequently, a comparison is made between these findings and the established occupational exposure limits (OELs) or regulatory requirements in order to ascertain whether the degree of exposure experienced by the worker is above the acceptable thresholds.

In recent times, advancements in personal sampling pumps, sensor technology, and battery technology have facilitated the exploration of individual exposure to diverse environmental toxins beyond the scope of cumulative particle or gas sampling (Koehler & Peters, 2015).

Typically, personal size-selective samplers are the most commonly employed approach for assessing individual exposure to different dust fractions. Size-selective samplers typically employ a cyclone or impactor mechanism to exclude particles that exceed a specific size threshold, subsequently capturing smaller particles onto a filter medium.

There are many size-selective samplers available to gather particles in accordance with respirable or inhalable conventions. Inhalable samplers commonly consist of devices equipped with a mouth-like entrance, such as the IOM sampler, or perforated curved surface inlets, such as the Button Aerosol Sampler from SKC Inc. Respirable samplers commonly utilize a cyclone intake, such as the Dorr Oliver and Higgins Dewell cyclones, to eliminate larger particles (with a 50 % cut-point of 4 μm). Subsequently, a filter is employed to capture the smaller particles that are capable of entering deep in the lungs (Koehler & Peters, 2015). For determining the size distribution of a particulate exposure, personal cascade impactors are also available. Cascade impactors are composed of a series of successive impactors that are arranged in a decreasing order of cutoff sizes, such as Sioutas (SKC Inc.) or 290 Series (Tisch Environmental) personal cascade impactors. Particles that exceed the predetermined size level are deposited onto impaction substrates, while particles smaller than the minimum cutoff size are captured by a filter. The size distribution of the aerosol can be determined by analysing specific substrates (Misra et al., 2002).

The most widely used direct-reading instruments are light-scattering monitors. The operation of these monitors is based on the idea of light scattering, wherein a light source is used to illuminate airborne particles, and sensors are employed to detect the resulting scattered light. Through the examination of the dispersed light patterns, these monitors have the capability to offer instantaneous information regarding the concentration and size distribution of particles present in the air. The utilization of personal, belt-mounted light scattering devices enables valuable real time data, allowing professionals to take more informed decisions. Examples of such devices include the SidePak and DustTrak monitors (TSI Inc.), Personal DataRam (Thermo Scientific), and Aeroqual Series 200 (Aeroqual).

Occupational exposure limits (OELs) refer to the quantities of specific chemicals or substances present in the immediate breathing vicinity of workers, which are considered safe and should not result in negative health consequences or excessive discomfort for the majority of individuals.

Regulatory authorities at both the European Union (EU) and national levels establish these limitations, considering the existing information and up-to-date data regarding the potential dangers associated with a particular substance. These limitations primarily focus on evaluating the substance's carcinogenicity, mutagenicity, toxicity to reproduction, repeated dose toxicity, and short-term exposure effects.

The majority of Western Balkan countries follow the European Council Directive 98/24/EC of 7 April 1998 on the protection of the health and safety of workers from the risks related to chemical agents at work (and subsequent amendments establishing lists of indicative occupational exposure limit values adopted to date), that determine the permissible levels of exposure to respirable dust, with a limit of 4 mg/m^3 over an 8-hour time-weighted average (Directive 98/24/EC). The standards set forth by the American Conference of Governmental Industrial Hygienists propose that airborne concentrations of respirable dust should be maintained at levels below 3 mg/m^3. Australia has also implemented exposure limits that align with these recommendations.

Personal exposure measurements

This study describes the findings of a personal exposure sampling program that was undertaken in five distinct enterprises located in Macedonia, Serbia, and Albania. These companies were characterized as metal mining, metal processing, and industrial minerals production sites. A total of 155 personal samples of respirable dust, each collected over an 8-hour shift, were obtained over the course of the past 2 years.

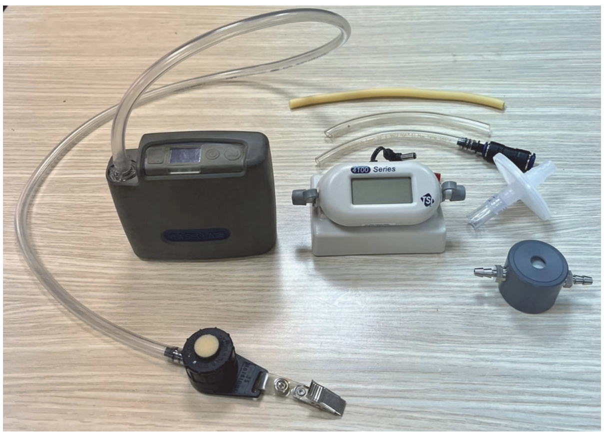

Figure 1. *Personal dust sampling set*

Sampling of respirable dust was performed according to a modified version of MDHS 14/4, which is a standard method for sampling and gravimetric analysis of respirable, thoracic, and inhalable aerosols (Health and Safety Executive, 2014) using an IOM 'multidust' dual-fraction respirable sampler (inhalable and respirable fraction) with 25-mm PVC membrane filters (GLA 5000 -PVC with 5 µm pore size, SKC Inc.) connected to a constant flow (2.0 l min−1) sampling pump (APEX 2, Casella). The quantification of the amount of dust deposited on the filters was performed using a gravimetric method.

Before sampling, all filters were individually identified and conditioned at a temperature of 20°C and a relative humidity of 50% in a climate chamber (ICH 110, Memmert, Germany) for a minimum of 24 hours. The filters were weighed twice, with a reconditioning interval of at least 12 hours between each weighing, in order to verify the stabilization of their mass. Two blank filters were designated for each batch to be used as weighing room blanks. Sampled filters after exposure were returned to the weighing room and conditioned in a controlled temperature and humidity chamber for more than 24 hours. Subsequently, the filters were weighed. The same conditions were applied to the field blanks. The weighing procedure was conducted using the Radwag MYA5.3Y.F micro balance, which is equipped with electronic control and has a resolution of 1 µg. The balance was situated in a controlled environment with regulated temperature and humidity, and an antistatic ionizer was employed to enhance accuracy. Mass concentration of respirable dust was calculated as the difference in mass between the exposed and the unexposed filter, divided by the sampled volume of air, determined as the flow rate multiplied by the sampling time. Measurement results are expressed as mg/m^3, where the volume of air is that under ambient conditions near the inlet during the sampling.

RESULTS AND DISCUSSION

The respirable personal dust levels observed at metal mining sites varied between 0.12 and 1.78 mg/m^3, with a geometric mean of 0.52 mg/m^3. It is worth noting that all recorded levels were found to be within the European Occupational Exposure Limits (OELs) of 4 mg/m^3.

The personal exposures of workers at industrial mineral processing sites demonstrate a lower respirable dust exposure, with values ranging from 0.04 to 4.71 mg/m^3 (geometric mean of 0.43 mg/m^3). However, it is worth noting that two of the samples exceeded the European Occupational Exposure Limits (OELs) of 4 mg/m^3.

The metal processing sites exhibited the lowest recorded values, which ranged from 0.03 to 1.36 mg/m^3 (with a geometric mean of 0.18 mg/m^3). It is noteworthy that all recorded values were found to be below the European Occupational Exposure Limits (OEL) of 4 mg/m^3.

Table 1. *Personal exposure to respirable dust fraction (time weighted average, 8-h working shift) in mg/m³*

Site classification	n	GM	MIN	MAX	STD
Mining metals	39	0.52	0.18	1.78	0.38
Metals processing	69	0.18	0.03	1.36	0.31
Industrial Minerals	47	0.43	0.04	4.72	1.17

The dust exposure levels observed in metal mining locations were consistent with the values reported in existing literature. The geometric mean values derived from a dataset of 8561 entries in the Australian CONTAM database were reported as 0.26 mg/m^3 (Rumchev et al., 2023).

The values obtained from metal processing and industrial minerals were also found to be consistent with those reported in the academic literature. For instance, Klasson et al. (2016) reported values of 0.048 ± 1.6 mg/m^3 for the Swedish hard metal industry.

The exposure data collected from industrial mineral sites exhibited similarities, with the geometric mean exposure to respirable dust reported in the IMA-DMP database for the year 2016 being 0.12 mg/m^3.

CONCLUSIONS

This study provided evidence that workers employed in the extractive industry in Western Balkan countries continue to encounter elevated levels of respirable dust exposure. The results emphasized the ongoing necessity of implementing efficient monitoring and control measures to mitigate dust exposure among workers in extractive sectors.

In order to address the potential hazards linked to individual dust exposure, it is imperative for workers to utilize suitable personal protective equipment, such as dust masks or respirators.

Additionally, employers should establish and enforce efficient dust management systems.

It is also imperative that workers receive proper education regarding the potential risks associated with dust exposure, as well as regarding the necessity of adhering to safety protocols in order to safeguard their well-being.

REFERENCES

Cecala, A. B., O'Brien, A. D., Schall, J., Colinet, J. F., Franta, R. J., Schultz, M. J., Haas, E. J., Robinson, J. E., Patts, J., Holen, B. M., Stein, R., Weber, J., Strebel, M., Wilson, L., & Ellis, M. (2019). *Dust Control Handbook for Industrial Minerals Mining and Processing* (2nd ed.). Centers for Disease Control and Prevention; National Institute for Occupational Safety and Health. https://www.cdc.gov/niosh/mining/userfiles/works/pdfs/2019-124.pdf

Directive 98/24/EC. *On the protection of the health and safety of workers from the risks related to chemical agents at work.* European Parliament and Council. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:01998L0024-20190726

Duarte, J., Castelo Branco, J., Rodrigues, F., Vaz, M., & Santos Baptista, J. (2022). Occupational Exposure to Mineral Dust in Mining and Earthmoving Works: A Scoping Review. *Safety, 8*(1), 9. MDPI AG. http://dx.doi.org/10.3390/safety8010009

International Organization for Standardization. (1995). *Air Quality – Particle size fraction definitions for health-related sampling* (ISO Standard No. 7708).

Koehler, K. A., & Peters, T. M. (2015). New Methods for Personal Exposure Monitoring for Airborne Particles. *Curr Environ Health Rep, 2*(4), 399-411. https://doi.org/10.1007/s40572-015-0070-z

Klasson, M., Bryngelsson, I. L., Pettersson, C., Husby, B., Arvidsson, H., & Westberg, H. (2016). Occupational Exposure to Cobalt and Tungsten in the Swedish Hard Metal Industry: Air Concentrations of Particle Mass, Number, and Surface Area. *The annals of occupational hygiene, 60*(6), 684–699. https://doi.org/10.1093/annhyg/mew023

Misra, C., Singh, M., Si, S., & Hall, P. (2002). Development and evaluation of a personal cascade impactor sampler (PCIS). *Journal of Aerosol Science, 33*, 1027-1047. https://doi.org/10.1016/S0021-8502(02)00055-1

Health and Safety Executive. (2014). MDHS 14/4 – General methods for sampling and gravimetric analysis of respirable, thoracic and inhalable aerosols.

Rumchev, K., Van Hoang, D., Lee, A. H. (2023). Exposure to dust and respiratory health among Australian miners. *International Archives of Occupational and Environmental Health, 96*(3), 355-363. https://doi.org/10.1007/s00420-022-01922-z

World Health Organization. (1999). *Hazard prevention and control in the work environment: airborne dust*. Occupational and Environmental Health Team. https://iris.who.int/handle/10665/66147

Zilaout, H., Vlaanderen, J., Houba, R., & Kromhout, H. (2017). 15 years of monitoring occupational exposure to respirable dust and quartz within the European industrial minerals sector. *International Journal of Hygiene and Environmental Health, 220*. https://doi.org/10.1016/j.ijheh.2017.03.010

Zilaout, H., Houba, R., & Kromhout, H. (2020). Temporal trends in respirable dust and respirable quartz concentrations within the European industrial minerals sector over a 15-year period (2002-2016). *Occupational and environmental medicine, 77*(4), 268–275. https://doi.org/10.1136/oemed-2019-106074