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Enhancing operator enclosure air quality in tunnelling operations: addressing silica dust exposure and compliance through AS/ISO 23875

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ABSTRACT: Tunnelling operations pose many occupational health hazards, primarily due to exposure to airborne contaminants such as respirable crystalline silica (RCS). This exposure is linked to serious health conditions such as silicosis, chronic respiratory diseases, and increased mortality rates. This white paper explores the health risks associated with tunnelling operations and highlights the critical importance of effective air quality management. It discusses the role of AS/ISO 23875 in mitigating these hazards, outlining how its implementation can safeguard operator health by improving enclosure air quality, ensuring compliance, and reducing health risks for contractors and equipment suppliers.

1 INTRODUCTION

Tunnelling operations inherently generate fine particulate dust, much of which contains crystalline silica, a byproduct of drilling, blasting, and mechanical excavation of rock. Long-term exposure to this dust, even at low concentrations, can result in severe health conditions: silicosis, chronic obstructive pulmonary disease, lung cancer, and an increased risk of tuberculosis and kidney disease [1]. Despite advancements in machinery and ventilation, operator enclosures can still be vulnerable to contamination due to inadequate filtration systems, poor sealing, and a lack of ongoing air quality performance monitoring. Operator cabs, typically seen as passive protective spaces, require robust systems that needs to be validated on an ongoing basis to ensure their effectiveness in safeguarding operator health.

In response to the hazards posed by dust exposure, the international standard ISO 23875: Operator Enclosures – Air Quality Control Systems and Performance Testing was first developed by the ISO Technical Committee 82 – Mining in 2021 and was subsequently adopted in Australia in 2023.

The implementation of AS/ISO 23875 fosters a culture of safety and sustainability, leading to safer working environments, reduced health risks, and improved operational efficiency [2]. The standard provides a comprehensive, performance-based framework designed to ensure machine operators, particularly in dust-heavy environments such as tunnelling, are consistently protected from harmful airborne particles. AS/ISO 23875 prioritises system simplicity and clarity, making it applicable for both original equipment manufacturers (OEMs) and retrofit scenarios. The standard encourages stakeholder collaboration and places a strong emphasis on practical, field-based performance testing to ensure air quality systems perform effectively under actual operational conditions.

1.1 *System components*

The effective implementation of AS/ISO 23875 relies on the integration of multiple interdependent system components that function synergistically to maintain safe air quality within operator enclosures. The key elements include the performance and control of the HVAC system, which must reliably supply clean, conditioned air while effectively removing airborne contaminants. This is achieved through both intake and recirculation filtration systems, which play a critical role in capturing respirable dust particles such as crystalline silica.

Maintaining positive cabin pressure is essential to prevent the infiltration of contaminated air, and this is only effective when coupled with robust cabin seal integrity, ensuring that unfiltered air does not bypass the system. Real-time air quality monitoring is also a vital component, providing continuous assessment of internal cabin conditions and enabling immediate intervention if parameters deviate from established safety thresholds. The combined functionality of these components is essential for protecting worker health in high-risk environments such as tunnelling operations.

2 CASE STUDY

AS/ISO 23875 requires field-based performance validation to verify that the components are functioning correctly. Performance metrics such as carbon dioxide (CO_2) concentration, pressure differential, dust ingress rates, and airflow capacity are used to assess the overall effectiveness of the air quality control system. These tests are conducted on-site to ensure that the systems operate effectively in real-world conditions, as opposed to controlled lab environments.

A case study is presented to illustrate the critical role of air exchange combined with high-efficiency intake and recirculation air filtration and continuous cab pressurization, in significantly reducing particulate decay times [3].

A drill rig working in an open-pit gold mine was retrofitted to the requirements specified in AS/ISO 23875. The tested machine operated under challenging environmental conditions, including temperatures as low as −29°C with strong winds with a three-machine drilling configuration producing substantial quantities of visible airborne dust. With three operators present, the cab door was opened over thirty times, as was typical for the working shift.

Figure 1 demonstrates the results of the particulate monitor which was located inside the drill rig cabin. The monitor measured PM_{10} concentrations each minute of operation. Figure 1 shows many elevated spikes in dust concentrations, which corresponded to the door being opened and closed. PM_{10} concentrations reached 1708 μg/m³ and reduced to <22 μg/m³ within 3 minutes. Throughout the test, continuous cab pressurisation was maintained at 200 Pa and the rapid air exchange effectively reduced these dust concentrations, maintaining an average PM_{10} concentration within the cab below 10 μg/m³ over the period of 2 hours

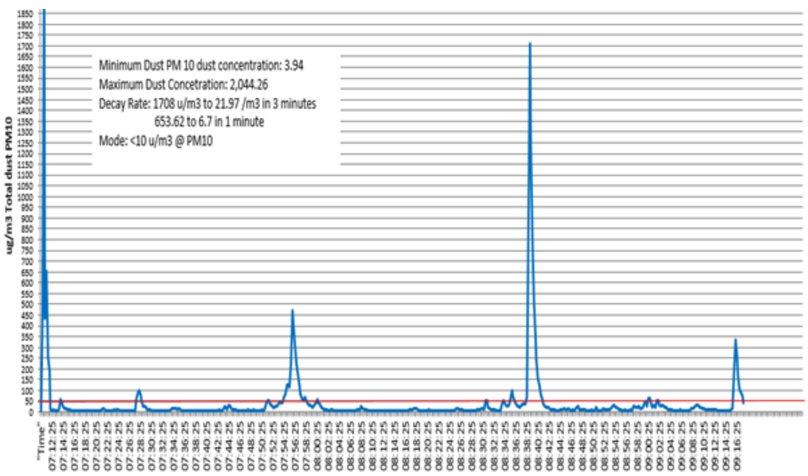

Figure 1. Particulate matter PM_{10} concentrations in operator cab during multi-machine drilling operations showing peak exposures and rapid decay following the operator leaving and reentering the drill cab.

To evaluate the effectiveness of the installed system, multi-day testing was performed using both static (area) and personal monitoring for RCS. Both personal and static samples were collected on the same day, with area samples situated in the air space within the cabin, and personal samples collected from drill operators. NIOSH test method 7500 was used for sampling and analysis for a total test time of approximately 9.5 hours, which reflected the drill operator's duration of exposure. Sampling took place over 6 different days between March 10, 2015 and October 20, 2015.

Figure 2 presents the results obtained during the multi-day testing. On average, personal exposure to RCS concentrations decreased by 87% when the system was installed, compared to when it was not. In-cabin concentrations, based on static sampling, were reduced by 56% under the same conditions.

A Wilcoxon rank sum test confirmed a statistically significant difference in RCS concentrations between conditions with and without the system installed, with lower concentrations observed when the system was in use.

This real-world example highlights how the performance requirements specified by AS/ISO 23875 can be effectively met in typical drilling operations, underscoring the practical value and applicability of the AS/ISO 23875 performance tests. Despite the harsh environmental conditions, the engineering controls specified by AS/ISO 23875 were able to effectively maintain good air quality within the enclosure.

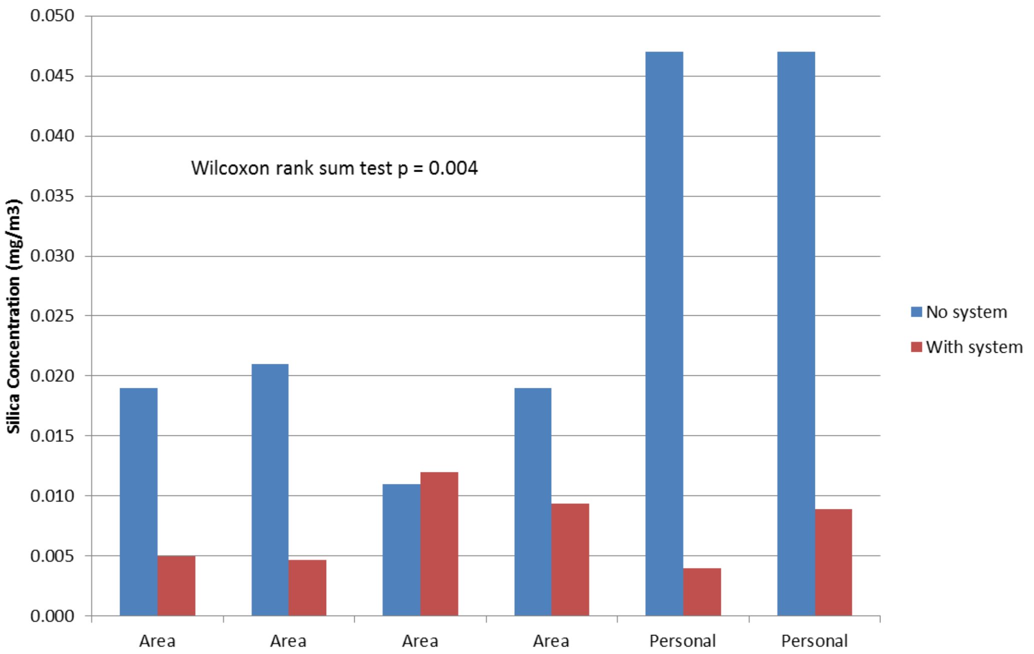

Figure 2. RCS concentrations (in milligrams per cubic meter) with and without a ISO 23875 system installed.

3 DISCUSSION

Tunnel construction can present challenges for managing RCS exposure, particularly among heavy equipment operators who spend extended periods inside enclosed cabins. The workplace exposure standard (WES) for respirable crystalline silica (RCS) is 0.05 mg/m³, based on an eight-hour time-weighted average. In tunnel construction, heavy plant operators such as those who operate excavators, dozers, articulated haul trucks, and drill rigs spend a significant amount of time inside enclosed cabins. These workers often complete extended shifts of up to twelve hours, requiring the WES to be adjusted to lower levels, such as approximately 0.03 mg/m³, to account for the longer exposure period.

Air monitoring for RCS is routinely undertaken in tunnel construction projects. Since 1 September 2024, notification to the WHS Regulator has been mandatory for any results that exceed the adjusted WES. Analysis of reported exceedances in New South Wales indicates that more than half originate from the tunnelling sector [4], with a proportion associated with operators of heavy plant and machinery [5][6]. In circumstances where RCS concentrations exceed the WES, respiratory protective equipment is typically used. However, reliance on personal protective equipment alone is not a sustainable solution, given that it represents the final and least effective layer of the hierarchy of controls.

Engineering interventions, such as the installation of AS/ISO 23875 compliant systems, offer a more effective means of protecting workers by reducing airborne contaminant levels within operator cabins. By significantly lowering personal exposure levels, these systems help reduce dependence on respiratory protection, decrease the incidence of regulatory exceedances, and enhance overall worker safety outcomes.

Effective implementation of AS/ISO 23875 requires a structured program of training and education that reaches all levels of an organisation. The International Society of Environmental Engineers (ISEEE) supports adoption by developing technical resources and training materials designed for operators, maintenance personnel, supervisors, safety professionals, and senior management. Training initiatives, such as the "Application of ISO 23875 in Operator Cab Air Filtration, Pressurization, and Certification," provide practical guidance on achieving and maintaining compliance. Through comprehensive education and broad engagement, tunnelling operations can embed air quality management practices into daily operations and foster a strong culture of occupational health and safety.

Beyond the health benefits, the adoption of AS/ISO 23875 offers economic advantages. Efficient operation of HVAC and filtration systems reduces maintenance costs and extends equipment lifespan. Improved system performance also enhances machine reliability and uptime, minimising costly production interruptions. Furthermore, reducing reliance on respiratory protection leads to better health outcomes, supporting workforce stability and productivity. Compliance with internationally recognised standards strengthens a company's reputation and improves its competitiveness in attracting and retaining skilled workers in a tight labour market.

In the context of increasing litigation related to occupational dust exposure, the ability to better protect workers is crucial. Adoption of AS/ISO 23875 provides a robust framework for documenting system performance, establishing continuous air quality monitoring, and evidencing preventative measures to protect worker health. This strengthens compliance efforts while reinforcing an organization's commitment to safeguarding employees.

The tunnelling industry has started to adopt AS/ISO 23875 compliant cabins across several projects in Australia. To further enhance understanding of the practical benefits of AS/ISO 23875 in tunnelling environments, additional case studies are being sought. Tunnelling contractors and project teams are invited to participate in future trials. Contributions from industry participants will help build a broader evidence base, support ongoing improvements in air quality management, and drive better health outcomes for workers across the sector.

4 CONCLUSIONS

Tunnelling remains a high-risk industry, with exposure to RCS being a risk that must be proactively managed. AS/ISO 23875 presents a practical, flexible, and effective standard that ensures operator enclosures meet the highest air quality standards. By adopting this standard, tunnelling stakeholders can shift to a proactive approach, ensuring ongoing and long-term protection for operators. The widespread adoption of this standard will help the tunnelling industry offer a safer, healthier, and more sustainable future for both its workforce and the broader tunnelling sector.

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