An analysis of the inhalable coal dust samples in Queensland

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ABSTRACT

Coal mining faces numerous health and safety challenges, with the generation of dust being a prominent issue throughout the development and mining processes. This paper provides an assessment of the levels of inhalable dust in Queensland underground coalmines to gauge the exposure of coalmine workers. It presents a thorough analysis of over 11 000 inhalable dust samples gathered by Resources Safety and Health Queensland between 2011 and 2021. The samples are analysed based on operation types and similar exposure groups over time, providing insights into exposure and exceedance levels. The findings reveal that the majority of samples were obtained during development production, underground maintenance, and longwall production. Significantly, the study highlights the prevalence of exceedances in specific areas, with longwall face, tailgate, and development production accounting for the highest rates – 36.9 per cent, 33.3 per cent, and 17.0 per cent, respectively. This emphasises the critical need for targeted interventions and safety measures in these specific operational aspects to mitigate risks and ensure the well-being of coalmine workers. The data and analyses presented in this paper contribute valuable insights for developing strategies aimed at minimising dust-related health hazards in the coal mining industry.

INTRODUCTION

Coal is a combustible sedimentary rock in black or brown formed at the strata called the coal seam. The primary constituents of coal are organic carbon compounds. The coal was discovered in the very early period in the history of Australia, dating back to the year 1797, by a survivor of the wreck of a vessel which had landed near NSW. Nowadays, Australia is one of the largest coal producers in the world.

Coal mining still has many challenges in terms of health and safety. There are many coalmine hazards, such as methane explosion and spontaneous combustion, and exposure to coal dust. Exposure to coal dust may result in diseases as Coal Workers' Pneumoconiosis (CWP). Dust is created by various production and development processes such as the cutting and transporting coal. The particle size range of coal dust can vary depending on factors such as the type of coal, the mining or processing methods, and the specific conditions under which the dust is generated. Generally, coal dust particles can range in size from a few microns to several hundred microns in diameter. The air quality within the underground coalmine as well as around the surface infrastructure has the potential to be impacted by the coal dust. The primary dust sources at the underground longwall panels and development sections are mechanical cutting drums on the shearers and continuous miner machines. The primary sources of coal dust at the surface operations are associated with handling, storing, and transporting coal. As before the coal been transported to the port and loaded on trains, coal dust comprises of the small proportion of the total dust that present in the air near the coalmines and the coal export terminals. The size of the coal dust ranges from submicron to 200 microns in diameter. In terms of size, there are currently two size fractions of coal dust sampled for measuring exposure: inhalable dust, and respirable dust. Inhalable dust refers to the particle that can be breathed into the nose or mouth and respirable dust refers to the dust that can be breathed into the respiratory system (Coal Services Pty Limited, 2016). Inhalable dust refers to particles with a median diameter of 100 µm, while respirable dust refers to particles less than 10 µm. Figure 1 shows the inhalable and respirable dust conventions.

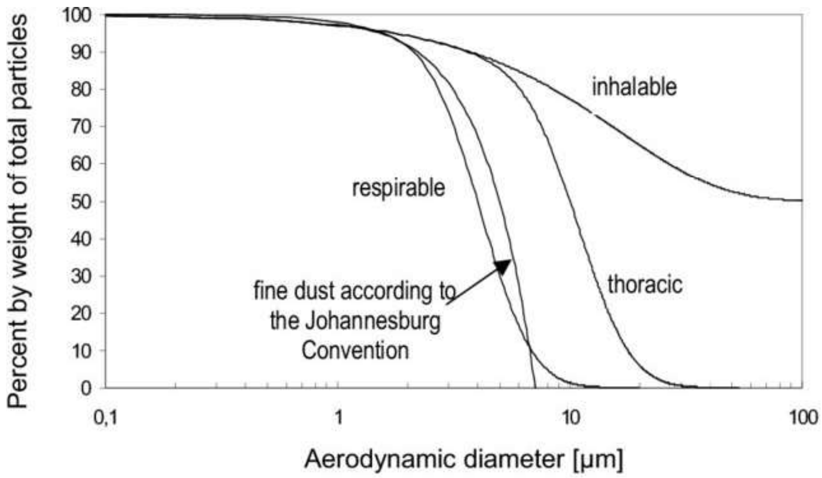

FIG 1 – Inhalable, thoracic and respirable conventions, in percent by weight of total airborne particles according to EN 481, and fine dust fraction according to the Johannesburg Convention (Parlar and Greim, 2005).

The term inhalable dust applies to both non-toxic and toxic dusts. Inhalable dusts that are toxic have an exposure standard based upon the substance of concern. Where the toxic component of the dust is measured, this is satisfactory as long as the exposure standard for dusts not otherwise classified is not exceeded. Exposure standards for dusts are measured as inhalable dusts unless there is a notation specifying an alternate method, eg cotton dust, silica (Safe Work Australia, 2013a).

For dusts without specific exposure standards, it's recommended to maintain exposure below 10 mg/m^3 of inhalable dust (measured over an 8 hr period) if the substance is inherently low in toxicity and free from toxic impurities. However, if the particulate material contains other toxic substances that can cause physiological impairment at lower concentrations, then the exposure standard for the more toxic substance should be applied. For example, if a dust contains asbestos or crystalline silica, exposure should not exceed the appropriate value for those substances (Safe Work Australia, 2013b). Table 1 shows dust exposure standards set by different countries.

TABLE 1

Dust exposure standards by countries.

Country	Organisation	Inhalable dust limit	Comments
US	ACGIH	10 mg/m^3	American Conference of Governmental Industrial Hygienists (ACGIH), (1990).
Australia			Adapted from the ACGIH
	Safe Work Australia	10 mg/m^3	Safe Work Australia (2013a): Guidance on the Interpretation of Workplace Exposure Standards for Airborne Contaminants
	AIOH	5 mg/m^3	Australian Institute of Occupational Hygienists, Inc., (AIOH) (2016); Standards Australia (2009)
	NOHSC	10 mg/m^3	National Occupational Health and Safety Commission (NOHSC), 1995
UK	HSE	10 mg/m^3	Health and Safety Executive (HSE)
	COSHH	10 mg/m^3	Control of Substances Hazardous to Health Regulations (COSHH) (2002) Note that this concentration is not an exposure limit, but it triggers values for application of all the COSHH regulations to the dust.
	IOM	5 mg/m^3	IOM (Institute of Occupational Medicine) (2011)
Germany	MAK Commission	4 mg/m^3	MAK (maximale Arbeitsplatz-Konzentration) Commission is the German Commission for the Investigation of Health Hazards of Chemical Compounds in the Work Area (MAK Commission, 1983)

INHALABLE COAL DUST DATABASE

The Resources Safety and Health Queensland has provided a database of 11 791 Queensland coal dust monitoring data records collected between 2011 and 2021, with the aim of analysing the data to gain insights into coal dust levels in the region. The coal dust monitoring data is crucial in understanding the potential health risks posed to workers and their exposure levels in the coalmines.

Out of the total 11 791 coal dust monitoring data records, 10 610 (~90 per cent) were found to be usable for analysis. The remaining 1181 (~10 per cent) records were classified as non-usable or deemed to be invalid due to various reasons, which were grouped under the following 13 categories including: damage to filter/sample head, failed post flow, filter overloaded, flow fault, invalidated by lab, not reported, pump damaged, pump failure, pump not collected/returned, short run time, tubing detached, worker removed pump and other reasons.

Sample classification by operation type

The invalid samples have been excluded from the analysis. The remaining valid samples have been classified in to three categories based on what type of operations the samples came from, namely Underground, Surface and Coal Handling and Processing Plant (CHPP) and Run-of-mine (ROM). As seen from Figure 2 more than half of the data have been collected from the underground operations.

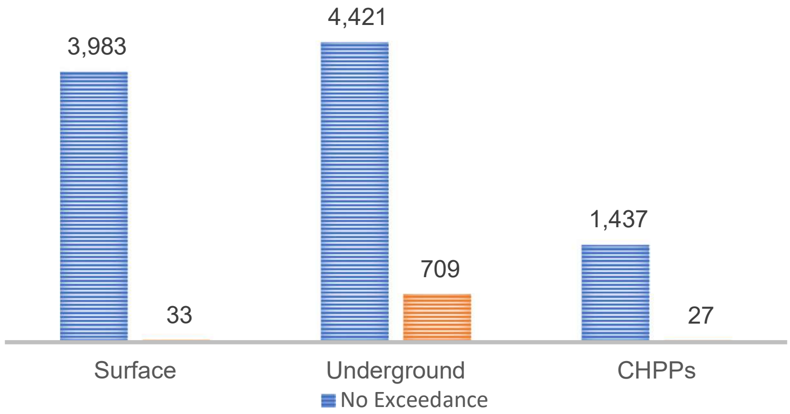

FIG 2 – Number of samples for each operation type.

Exposure to coal dust above threshold limits poses a significant health concern. Therefore, data have been analysed based on exceedances of these threshold limits. The Occupational Exposure Limit (OEL) of 10 mg/m³ is not constant and requires adjustment to account for work shifts that differ from the standard 8 hr workday. Exceedance analyses were performed using these adjusted exposure limits. All exceedance ratios were calculated using Equation 1. If the measured dust concentration is below the corrected exposure limit, the exceedance ratio is considered to be zero.

$$\text{Exceedance Percentage}=\frac{(\text{Measured Dust Concentration-Corrected Exposure Limit})}{\text{Corrected Exposure Limit}}*100 \tag{1}$$

Number of data with exceeding and non-exceeding the corrected exposure limits based on the mine type has been provided in Table 2.

TABLE 2

Numbers of exceeding and non-exceeding samples.

Mine Type	No Exceedance	Exceedance	Exceedance (%)	Total
Surface	3983	33	0.8	4016
Underground	4421	709	13.8	5130
CHPP and ROM	1437	27	1.8	1464
Overall	9841	769	7.2	10 610

As seen from Table 2, underground mines had the highest exceedance rate, approximately 13.8 per cent while surface mines had a very low number of exceedance cases (0.8 per cent). Overall, the rate of exceedance cases from all operations was 7.2 per cent.

Similar exposure group

Similar exposure group (SEG) codes are used to identify a group of workers who have the same general exposure to risks. This can include:

- similarity and frequency of the tasks performed
- types of materials and processes used to complete tasks or
- similarity of the way tasks are performed.

SEG codes were used to measure the average dust exposure levels and exceedance rate for each SEG. Figure 3 shows the distribution of exceedance percentage based on SEG codes for all underground mines. As seen from the figure, the highest rates of exceedances were recorded for longwall face, tailgate and development production; 36.9 per cent, 33.3 per cent and 17.0 per cent respectively. Figure 4 shows the number of samples collected and the number of exceedances per

SEG activities for underground mines. The highest number of samples were collected development production, underground maintenance and longwall production.

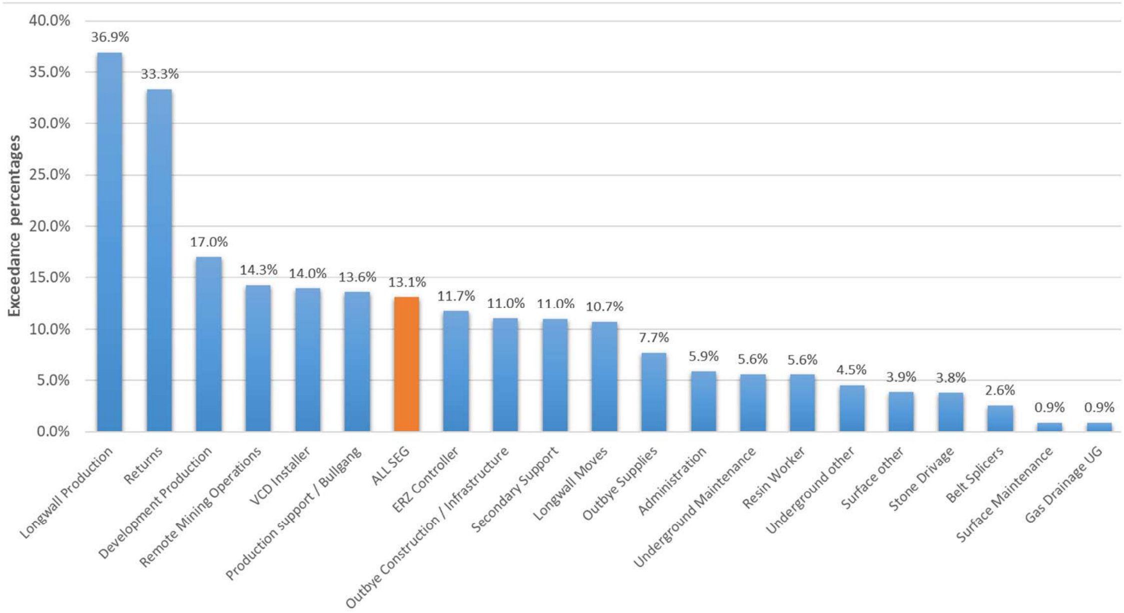

FIG 3 – Percentage of exceedances based on SEG codes in underground mines (overall percentage of all SEGs are shown with orange bar).

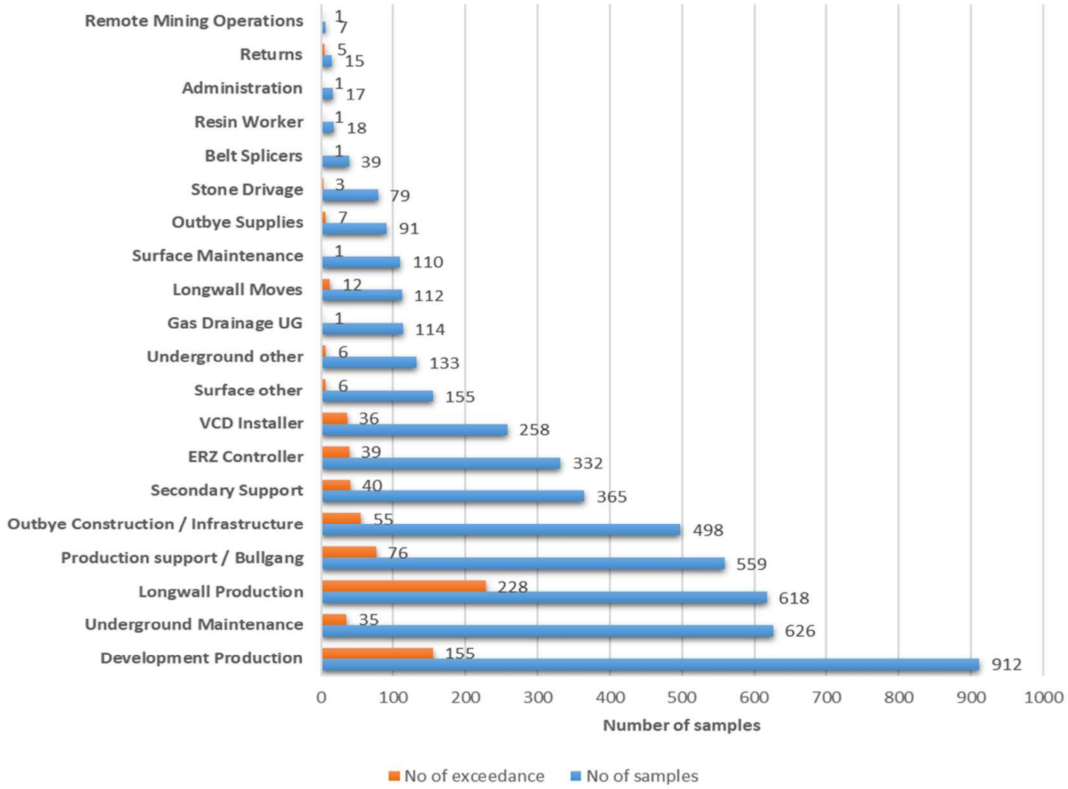

FIG 4 – Number of samples collected and number of exceedances per SEG activities for underground mines.

The Box-Whisker plot of the exceedance ratio for various underground coalmine SEGs is presented in Figure 5. This figure illustrates that the distribution of inhalable dust concentrations across different SEGs is not uniform and varies with different mining activities. The median inhalable dust measurement for the production support/bullgang SEG was the highest among all SEGs. Figure 6 displays the total number of samples, exceedance cases, and exceedance percentages of underground cases on an annual basis. The graph clearly indicates that, although the number of samples collected has been slightly increasing over time, the number of exceedance cases has decreased. After rising from 12 per cent in 2011 to 21 per cent in 2013, the exceedance rate has dropped to 10 per cent by 2021.

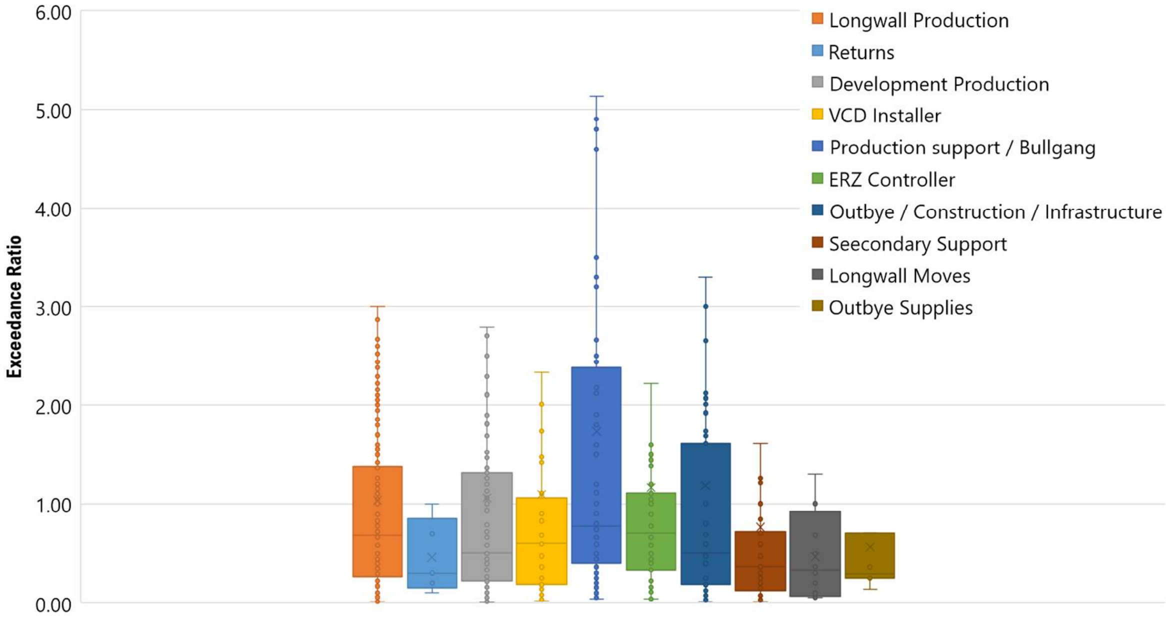

FIG 5 – Box-Whisker plots of the exceedance ratios for some underground coalmines SEGs.

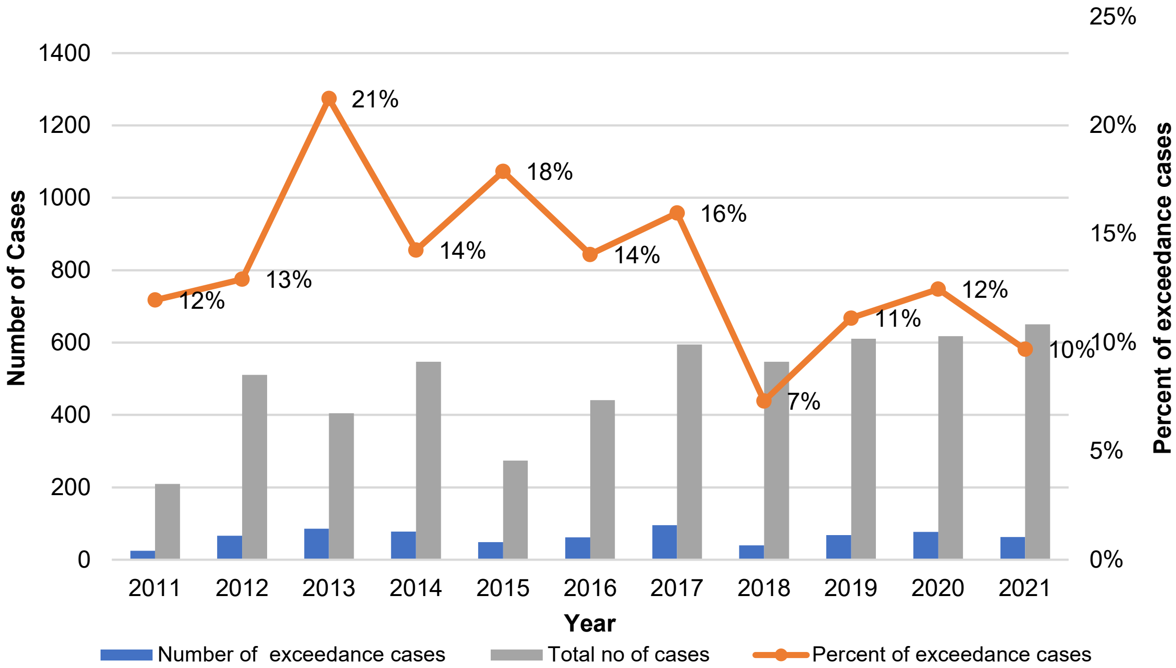

FIG 6 – Total, exceedance, and exceedance percentage of underground cases on annual bases.

Figures 7 and 8 show the average and the maximum measured inhalable dust concentrations for underground coalmines on annual basis, respectively.

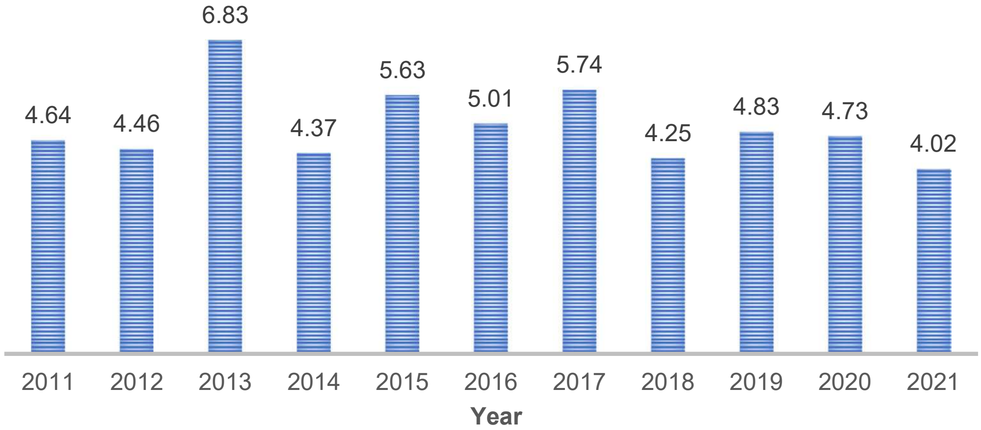

FIG 7 – Average measured inhalable dust concentrations in mg/m³ for underground mines on annual basis.

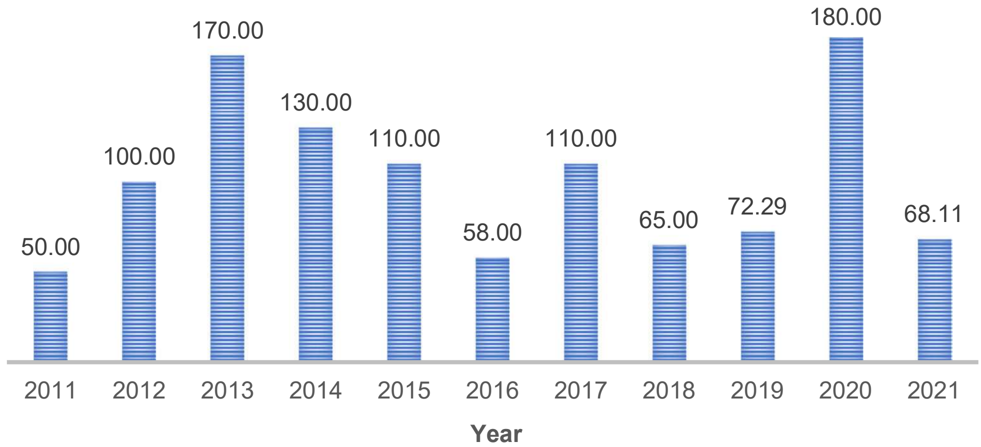

FIG 8 – Maximum measured inhalable dust concentrations in mg/m³ for underground mines on annual basis.

As seen from Figures 7 and 8, there was no specific trend between the maximum and average inhalable dust concentration on year by year bases. The average readings seem to be below the threshold limit while the maximum readings were recorded well above the limit. The underground inhalable dust concentrations show log-normal distribution with positive skewness. The frequency of readings above the threshold limit was less than 0.12, as seen in Figure 9.

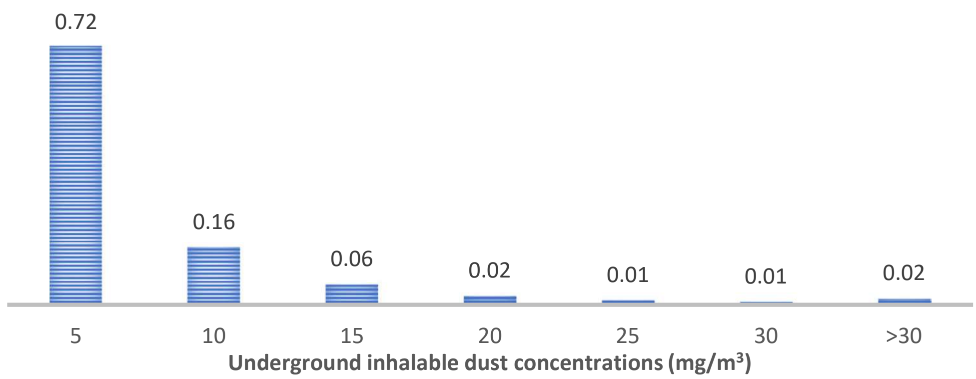

FIG 9 – Relative frequency distribution of inhalable dust concentrations in underground mines.

Personal protection equipment use during dust surveys

The inhalable dust database had a record of weather the coalmine workers were wearing personal protection equipment (PPE) or not during the surveys and whether the PPE was worn for the whole or partial part of the shift. PPE included: P1 half face disposable mask, P2 full face non-disposable mask, P2 half face disposable mask, P2 full face non-disposable mask, P3 full face non-disposable mask and Powered Air Purifying Respirators (PAPR) and half face.

Out of 5408 total cases, no PPE was used in 1003 surveys, and PPE was used for the partial or full duration of the shift in 2614 cases. In 1791 cases, there was no record of whether PPE was used. Among the 709 exceedance cases, there were 299 instances (42 per cent) with no report, 27 instances (4 per cent) where no PPE was worn, and 383 instances (54 per cent) where PPE was worn for the partial or full duration of the shift, as shown in Figures 10 and 11.

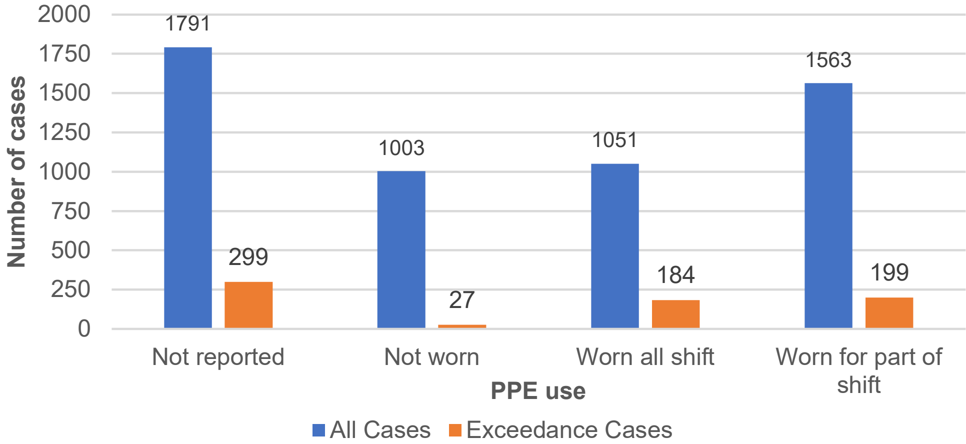

FIG 10 – Number of cases related to PPE use during the survey for all and exceedance cases.

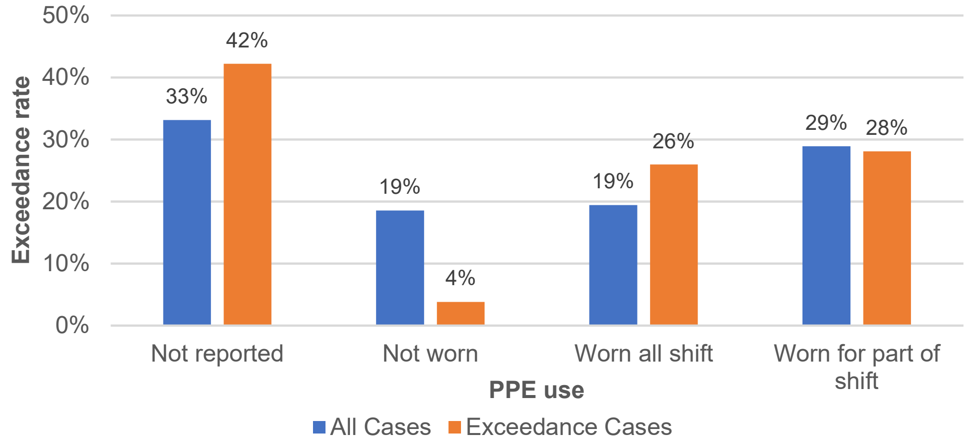

FIG 11 – Percentage of cases related to PPE use during the survey for all and exceedance cases.

CONCLUSIONS

This study analysed a data set comprising 11 791 inhalable dust monitoring records collected by Queensland Resources Safety and Health between 2011 and 2021. The aim was to assess the inhalable coal dust levels to which underground coalmine workers in Queensland were exposed. Of these records, 10 610 (90 per cent) were analysed, while 1181 (10 per cent) were deemed unusable for various reasons. The analysis focused on understanding exposure levels across different mine types (Underground, Surface, CHPP, and ROM) and SEGs.

Exceedance analysis was conducted to assess coal dust exposure levels above threshold limits. Corrected exposure limits were used based on working conditions. Results indicated that underground mines had the highest exceedance rate (13.8 per cent), while surface mines had a minimal rate (0.8 per cent). Overall, the exceedance rate across all operations was 7.2 per cent. SEG-based analysis revealed specific activities, like longwall face and tailgate, had higher exceedance rates (36.9 per cent and 33.3 per cent respectively). Over time, the analysis showed a decrease in exceedance cases, dropping from 21 per cent in 2013 to 10 per cent in 2021, despite a slight increase in the number of samples. However, the distribution of inhalable dust concentration varied across different SEGs, indicating non-uniform exposure levels.

Analysis of PPE use during surveys indicated that in 42 per cent of exceedance cases, there was no report, and in 54 per cent of cases, PPE was worn partially or for the whole shift. This data underscores the importance of monitoring PPE compliance and effectiveness in mitigating exposure risks.

The analysis highlights significant variations in coal dust exposure across different mine types, activities, and specific mines. While there's a positive trend showing a decrease in exceedance cases over the years, it's imperative to continue monitoring and enforcing safety protocols, including proper PPE usage, to ensure the well-being of coalmine workers in Queensland.

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