Determination of quartz and its abundance in respirable airborne dust in both coal and metal mines in India

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Abstract

The WHO/ILO international program (1995) on the global elimination of silicosis, aiming inter alia at characterization of dust and its sources, monitoring and evaluation of the results for health risk, has put a premium on the determination of quartz in respirable airborne dust, which is known to cause irreversible lung diseases, such as silicosis and cancer. The work presented herein is a study of the quartz content in airborne respirable dust (ARD) generated in coal and metal mines (zinc and manganese) with a view to evaluate the health risk of miners as per mines regulations. Implementation of safety measures to reduce/eliminate risk to contract silicosis in any mine requires monitoring of the emission of quartz in various locations in addition to the ARD concentration for computation of Maximum Exposure Limit (MEL).

The direct on-filter method using an FTIR spectrometer has been adopted for the determination of quartz in ARD. Personal air samplers were used to collect ARD from different locations in mines on GLA-5000 PVC membrane filters. The air samplers were either attached with different workers engaged in the shift or placed in a position near to the dust generation source in the mines to collect suitable amount of dust for analysis. Each dust-loaded filter was then directly scanned by the spectrometer to give the spectrum of quartz, from which the proportion of quartz in the dust was determined from an estimation of the intensity of the doublet at 800 cm⁻¹ using standard procedure.

It has been found that the percentage of quartz in ARD of coal mines, especially in coking coal mines situated in Jharia coalfield, is less than 1% in almost all the workings, barring a few cases where it has exceeded this value. MEL for workers is, therefore, equal to 3 mg/m³ in almost all the working places sampled in coal mines. In contrast, for metal mines the situation is different. Quartz determined in ARD exceeds 5% in many workings. Further, the percentage of quartz is also found to vary from location to location inside the mine, which is a reflection of the compositional variation of the rock strata in different working zones of the mines. Monitoring of the emission of quartz is essential for identifying potentially dangerous silicosis-prone areas and working out strategies to mitigate health-related problems of the miners. It has been found that wet drilling and good ventilation systems help to effectively control dust problems at some locations, whereas rotation of workers may be needed in some places where it is difficult to suppress dust to a safe level.

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1. Introduction

The WHO/ILO international program aiming at the global reduction and eventual elimination of silicosis has put emphasis on the determination of characteristic of dust and its sources, problem recognition, monitoring and evaluation of result, available technical and personal measures to prevent or control the generation, release and dissemination of dust in the workplace, Wagner [1] and Fact Sheet No. 238, 2000 [2]. It is known that all production oriented mining operations such as cutting, breaking, crushing, drilling, grinding or abrasive blasting, contribute to fine dust generation. With increasing demand of coal to meet the shortfall in energy production, there is a concomitant increase of the concentration of respirable dust in work places. Also increased use of metals in industry has led to excavations of minerals and extraction of metals on a much larger scale than ever before. The situation demands increased mechanization in mining to match the growing demand, putting the workers at risk in workplaces due to generation of large amount of dust.

Mukherjee et al. [3], in their study on assessment of respirable dust and its free silica contents in nine Indian coal mines to evaluate the risk of coal worker’s pneumoconiosis, found that the dust levels in the face return air of both board and pillar (B&P) and Long Wall (LW) mining were above the permissible level recommended in India and that the compressor and driller operators were the major exposed groups in open cast mining. In conventional mining, they have shown drillers were the most affected group of workers as they worked very close to dust source. Inhalation of airborne respirable dust (ARD) generated at work places is known to cause irreversible diseases of the lung, such as cancer, classified by the International Agency for Research in Cancer [4], as a group(I) human lung carcinogen, and silicosis, recognized as the oldest and among the most serious occupational diseases. Bang et al. [5] studied national trends in silicosis mortality in the United States, 1981-2004, and showed that the mortality rate decreased from 1981-2004 due to various preventive actions taken like respiratory protection, posting of warning signs, record keeping or reporting of occupational illnesses. Despite the reduction in mortality rate, silica exposure remains ubiquitous and considerable progress has still to be made towards elimination of silicosis. Kulkarni [6] has described prevention and control of silicosis as a national challenge and pointed out the need for planning a national strategy to combat silicosis, especially in the unorganized sector. Lapp and Castranova [7] and Castranova and Vallyathan [8] have disclosed in their publications prevalence of lung diseases coal mines. Bhagia [9] has even reported non-occupational exposure to silica dust in the vicinity of slate pencil industry and observed that silica dust concentrations were much higher than the ambient air quality standards, posing a health risk to villagers nearby.

It requires implementation of safety measures at work places to avoid/reduce the risk of imbibing silicosis by workers. With a view to protecting miners’ health and provide safe and healthy work place environment, maximum exposure limit (MEL) to dust is determined. But MEL prescribed by any country depends on the quartz content of dust. There are at present two important methods used for the determination of quartz, FTIR and XRD. The FTIR method is widely used for the determination of quartz in respirable fraction of dust due to its lower limit of detection, economy, and accuracy, MDHS 101 [10]. The aim of the present work is to communicate the results of a study undertaken to determine quartz and its abundance in ARD generated in both selected coal and metal (zinc and manganese) mines and discuss its importance in assessing the health risk of miners as per the MEL prescribed in the country, DGMS (Tech.) (S&T) Circular No.01 [11].
2. Materials and method

Various mines, viz. coal mines located in Jharia coalfield, zinc mines in Rajasthan and Orissa, and manganese mines in Maharashtra and Madhya Pradesh, were selected for the present study. The objective of sampling was to know: 1) The quantity of respirable dust generated in the mines and 2) The quartz content of the generated dust. The data of the two different experiments are required for assessment of health risk.

The sampling of airborne dust was carried out by personal sampler AFC-123 (Casella London), whose flow rate was maintained at 1.9 l/min. Collection was done on a pre-weighed GLA-5000 PVC membrane filter of 37mm diameter and 5µm pore size. The amount of dust collected on each filter was determined from the weight of filter before and after the collection. The volume of air sampled was calculated from the time of sampling. The concentration of dust (in mg/m³) was determined by dividing the amount of dust (in mg/m³) by the volume of air sampled (in mg/m³). The data on dust collected from different mines, viz. coal, zinc and manganese, are tabulated in Table 1, Table 2 and Table 3, respectively.

The dust loaded on the filter was put directly into the sample compartment of an FT-IR (Model 1760X, Perkin-Elmer) for direct on-filter analysis, MDHS 101 [10] and Foster et. al. [12]. The quartz doublet peaks was obtained at 800 and 780 cm⁻¹, which is shown in A and B of Fig. A and B, for zinc and manganese mines, respectively. The peak height of the 800 cm⁻¹ band was measured with respect to a baseline drawn, as shown in Fig.2 for a sample of zinc mine dust. For each sample the peak height measured was translated to concentration of quartz from the calibration curve of peak height vs. concentration of standard quartz (Sikron F600, HSE standard quartz).

The health risk at different sites of the mines selected was determined by prescribed regulations for India. The same exercise was done with USA regulations in order to compare the health risks only due to existing regulations in the two countries for the same quantity of dust and quartz level. The risks are labeled as Low for compliance with regulation, High exceeding compliance limit and Very High (V.H.) exceeding twice the limit and Very Very High (V.V.H.) exceeding thrice or above the MEL. The risk levels as assessed are not as per any regulation, but labeled as such to demarcate zones inside the mines as silicosis-prone.

Table 1. Concentration of dust and quartz content in dust at different locations in coal mines and assessment of health risk due to dust

| S. No. | Identification No. | Concentration of dust (mg/m³) | % quartz In dust | MEL (mg/m³) In India | Assessment of health risk (India) | MEL (mg/m³) In U.S.A | Assessment of health risk U.S.A |
|--------|-------------------|------------------------------|----------------|----------------------|----------------------------------|----------------------|----------------------------------|
| 1      | Coal/Mine-1/Dust/loc-1 | 1.36                         | 0.4            | 3.0                  | Low                             | 2.0                  | Low                              |
| 2      | Coal/Mine-1/Dust/loc-2 | 1.58                         | 0.2            | 3.0                  | Low                             | 2.0                  | Low                              |
| 3      | Coal/Mine-1/Dust/loc-3 | 1.07                         | 0.8            | 3.0                  | Low                             | 2.0                  | Low                              |
| 4      | Coal/Mine-1/Dust/loc-4 | 1.42                         | 0.8            | 3.0                  | Low                             | 2.0                  | Low                              |
| 5      | Coal/Mine-1/Dust/loc-5 | 10.0                         | 0.5            | 3.0                  | V.V.H                           | 2.0                  | V.V.H                            |
| 6      | Coal/Mine-1/Dust/loc-6 | 0.87                         | 0.2            | 3.0                  | Low                             | 2.0                  | Low                              |
| 7      | Coal/Mine-1/Dust/loc-7 | 5.00                         | 0.4            | 3.0                  | V.V.H                           | 2.0                  | V.V.H                            |
| 8      | Coal/Mine-2/Dust/loc-1 | 0.96                         | trace          | 3.0                  | Low                             | 2.0                  | Low                              |
| 9      | Coal/Mine-2/Dust/loc-2 | 1.38                         | trace          | 3.0                  | Low                             | 2.0                  | Low                              |
| S. No. | Identification No. | Concentration of dust (mg/m³) | % quartz In dust | MEL (mg/m³) In India | Assessment of health risk (India) | MEL (mg/m³) In USA | Assessment of health risk U.S.A |
|-------|--------------------|-------------------------------|-----------------|-----------------------|-----------------------------------|-------------------|----------------------------------|
| 1     | Zn/Mine-1/Dust/Loc-1 | 2.12                          | trace           | 3.00                  | Low                               | 2.00              | high                             |
| 2     | Zn/Mine-1/Dust/Loc-2 | 2.04                          | 9.0             | 1.67                  | High                              | 0.91              | V.H                              |
| 3     | Zn/mine-1/Dust/Loc-3 | 1.81                          | 24.0            | 0.63                  | V.H.                             | 0.38              | V.V.H.                           |
| 4     | Zn/Mine-2/Dust/Loc-1 | 7.85                          | 11.1            | 1.35                  | V.V.H.                           | 0.76              | V.V.H.                           |
| 5     | Zn/Mine-2/Dust/Loc-2 | 2.61                          | 10.3            | 1.46                  | High                              | 0.81              | V.H                              |
| 6     | Zn/Mine-2/Dust/Loc-3 | 0.63                          | 12.5            | 1.20                  | Low                               | 0.69              | Low                              |
| 7     | Zn/Mine-2/Dust/Loc-4 | 1.61                          | 7.8             | 1.92                  | Low                               | 1.02              | high                             |
| 8     | Zn/Mine-2/Dust/Loc-5 | 1.00                          | 20.4            | 0.74                  | High                              | 0.45              | V.H                              |
| 9     | Zn/Mine-3/Dust/Loc-1 | 0.56                          | 3.3             | 3.00                  | Low                               | 1.89              | Low                              |
| 10    | Zn/Mine-3/Dust/Loc-2 | 0.86                          | 0.8             | 3.00                  | Low                               | 3.57              | Low                              |
| 11    | Zn/Mine-4/Dust/Loc-1 | 0.89                          | 12.5            | 1.20                  | Low                               | 0.69              | high                             |
| 12    | Zn/Mine-4/Dust/Loc-2 | 1.11                          | 16.2            | 0.93                  | High                              | 0.55              | V.H                              |
| 13    | Zn/Mine-4/Dust/Loc-3 | 1.03                          | 23.2            | 0.65                  | High                              | 0.40              | V.H                              |
| 14    | Zn/Mine-4/Dust/Loc-4 | 10.14                         | 18.5            | 0.81                  | V.V.H.                           | 0.49              | V.V.H.                           |
| 15    | Zn/Mine-4/Dust/Loc-5 | 0.22                          | trace           | 3.00                  | Low                               | 2.00              | Low                              |
| 16    | Zn/Mine-4/Dust/Loc-6 | 0.22                          | trace           | 3.00                  | Low                               | 2.00              | Low                              |
| 17    | Zn/Mine-5/Dust/Loc-1 | 13.57                         | 60              | 0.25                  | V.V.H.                           | 0.16              | V.V.H.                           |
| 18    | Zn/Mine-5/Dust/Loc-2 | 3.42                          | 54.6            | 0.26                  | V.V.H.                           | 0.18              | V.V.H.                           |

Table 2. Concentration of dust and quartz content in dust at different locations in zinc mines and assessment of health due to dust
| S. No | Identification No. | Concentration of dust (mg/m³) | % quartz In dust | MEL (mg/m³) In India | Assessment of health risk (India) | MEL (mg/m³) In U.S.A | Assessment of health risk (U.S.A) |
|-------|--------------------|-----------------------------|-----------------|---------------------|-----------------------------|---------------------|-----------------------------|
| 1     | Mn/Mine-1/Dust/loc-1 | 4.12                        | 8.6             | 1.74                | V.V.H                       | 0.94                | V.V.H                       |
| 2     | Mn/Mine-1/Dust/loc-2 | 2.25                        | 7.1             | 2.11                | high                        | 1.09                | V.H                         |
| 3     | Mn/Mine-1/Dust/loc-3 | 7.71                        | 55.4            | 0.27                | V.V.H                       | 0.17                | V.V.H                       |
| 4     | Mn/Mine-1/Dust/loc-4 | 1.51                        | 37.0            | 0.41                | V.H                         | 0.25                | V.V.H                       |
| 5     | Mn/Mine-2/Dust/loc-1 | 1.15                        | trace           | 3.00                | low                         | 2.00                | low                         |
| 6     | Mn/Mine-2/Dust/loc-2 | 0.68                        | 24.3            | 0.62                | high                        | 0.38                | high                        |
| 7     | Mn/Mine-2/Dust/loc-3 | 0.14                        | trace           | 3.00                | low                         | 2.00                | low                         |
| 8     | Mn/Mine-2/Dust/loc-4 | 0.14                        | trace           | 3.00                | low                         | 2.00                | low                         |
| 9     | Mn/Mine-3/Dust/loc-1 | 0.37                        | 33.6            | 0.45                | Low                         | 0.28                | high                        |
| 10    | Mn/Mine-3/Dust/loc-2 | 0.29                        | trace           | 3.00                | low                         | 2.00                | low                         |
| 11    | Mn/Mine-3/Dust/loc-3 | 0.61                        | trace           | 3.00                | low                         | 2.00                | low                         |
| 12    | Mn/Mine-3/Dust/loc-4 | 1.73                        | 62.3            | 0.24                | V.V.H                       | 0.15                | V.V.H                       |
| 13    | Mn/Mine-3/Dust/loc-5 | 0.20                        | trace           | 3.00                | low                         | 2.00                | low                         |
| 14    | Mn/Mine-4/Dust/loc-1 | 1.32                        | 16.3            | 0.92                | V.H                         | 0.54                | V.H                         |
| 15    | Mn/Mine-4/Dust/loc-2 | 0.20                        | trace           | 3.00                | low                         | 2.00                | low                         |
| 16    | Mn/Mine-4/Dust/loc-3 | 0.19                        | 41.1            | 0.36                | low                         | 0.23                | low                         |
| 17    | Mn/Mine-4/Dust/loc-4 | 2.76                        | 9.7             | 1.55                | high                        | 0.85                | V.V.H                       |
| 18    | Mn/Mine-4/Dust/loc-5 | 0.35                        | trace           | 3.00                | low                         | 2.00                | low                         |
| 19    | Mn/Mine-5/Dust/loc-1 | 4.19                        | 3.8             | 3.00                | high                        | 1.72                | V.V.H                       |

Table 3. Concentration of dust and quartz content in dust at different locations in manganese mines and assessment of health risk due to dust
| No. | Location                | Ti (mg/kg) | Fe (mg/kg) | Correlation Coefficient | V.H Percentage | V.V.H Percentage |
|-----|-------------------------|------------|------------|--------------------------|----------------|------------------|
| 20  | Mn/Mine-5/Dust/loc-2    | 7.58       | 12.1       | 1.24                     | V.V.H          | 0.70             |
| 21  | Mn/Mine-5/Dust/loc-3    | 0.72       | 13.3       | 1.13                     | Low            | 0.65             |
| 22  | Mn/Mine-5/Dust/loc-4    | 1.96       | 6.3        | 2.40                     | Low            | 1.20             |
| 23  | Mn/Mine-6/Dust/loc-1    | 9.90       | trace      | 3.00                     | V.V.H          | 2.00             |
| 24  | Mn/Mine-6/Dust/loc-2    | 5.70       | 44.8       | 0.33                     | V.V.H          | 0.20             |
| 25  | Mn/Mine-7/Dust/loc-1    | 4.92       | trace      | 3.00                     | High           | 2.00             |
| 26  | Mn/Mine-7/Dust/loc-2    | 0.14       | trace      | 3.00                     | Low            | 2.00             |
| 27  | Mn/Mine-7/Dust/loc-3    | 1.09       | trace      | 3.00                     | Low            | 2.00             |
| 28  | Mn/Mine-7/Dust/loc-4    | 1.29       | 10.0       | 1.50                     | Low            | 0.83             |
| 29  | Mn/Mine-8/Dust/loc-1    | 0.57       | trace      | 3.00                     | Low            | 2.00             |
| 30  | Mn/Mine-8/Dust/loc-2    | 0.80       | 11.1       | 1.30                     | Low            | 0.76             |
| 31  | Mn/Mine-8/Dust/loc-3    | 3.13       | 8.3        | 1.81                     | V.H            | 0.97             |
| 32  | Mn/Mine-8/Dust/loc-4    | 0.44       | trace      | 3.00                     | Low            | 2.00             |
| 33  | Mn/Mine-9/Dust/loc-1    | 0.40       | trace      | 3.00                     | Low            | 2.00             |
| 34  | Mn/Mine-9/Dust/loc-2    | 0.81       | 9.2        | 1.63                     | Low            | 0.89             |
| 35  | Mn/Mine-10/Dust/loc-1   | 0.15       | trace      | 3.00                     | Low            | 2.00             |
| 36  | Mn/Mine-10/Dust/loc-2   | 0.56       | 16.8       | 0.89                     | Low            | 0.53             |
| 37  | Mn/Mine-10/Dust/loc-3   | 0.82       | 15.7       | 0.96                     | Low            | 0.56             |
| 38  | Mn/Mine-10/Dust/loc-4   | 1.84       | 4.7        | 3.20                     | Low            | 1.49             |
| 39  | Mn/Mine-10/Dust/loc-5   | 3.31       | 29.7       | 0.51                     | V.V.H          | 0.31             |
| 40  | Mn/Mine-10/Dust/loc-6   | 6.00       | 14.8       | 1.01                     | V.V.H          | 0.59             |
| 41  | Mn/Mine-11/Dust/loc-1   | 0.37       | 1.6        | 3.00                     | Low            | 2.00             |
| 42  | Mn/Mine-11/Dust/loc-2   | 0.93       | 14.5       | 1.03                     | Low            | 0.60             |
| 43  | Mn/Mine-11/Dust/loc-3   | 1.32       | 12.5       | 1.20                     | High           | 0.69             |
| 44  | Mn/Mine-11/Dust/loc-4   | 6.19       | 12.0       | 1.25                     | V.V.H          | 0.70             |
| 45  | Mn/Mine-12/Dust/loc-1   | 1.34       | 11.6       | 1.30                     | High           | 0.73             |
| 46  | Mn/Mine-12/Dust/loc-2   | 2.26       | 7.7        | 1.94                     | High           | 1.02             |
| 47  | Mn/Mine-12/Dust/loc-3   | 1.80       | 11.6       | 1.29                     | High           | 0.73             |
| 48  | Mn/Mine-12/Dust/loc-4   | 0.73       | 4.2        | 3.00                     | Low            | 1.61             |
| 49  | Mn/Mine-12/Dust/loc-5   | 0.91       | 6.3        | 2.38                     | Low            | 1.20             |
| 50  | Mn/Mine-12/Dust/loc-6   | 0.25       | 3.9        | 3.00                     | Low            | 1.68             |
| 51  | Mn/Mine-12/Dust/loc-7   | 0.41       | 7.8        | 1.92                     | Low            | 1.02             |
| 52  | Mn/Mine-12/Dust/loc-8   | 0.78       | 9.3        | 1.62                     | Low            | 0.88             |
The dust loaded on the filter was put directly into the sample compartment of an FT-IR for direct on-filter analysis. The quartz doublet peaks was obtained at 800 and 780 cm\(^{-1}\) which is shown in Figures A and B for Zinc and Manganese mines respectively. Fig.2 shows the baseline with respect to which peak height of quartz was measured.
Fig. 1. Vertically displaced baseline corrected FT-IR spectra of a) PVC membrane filter, b) Dust loaded filter and c) Difference spectrum, b-a, showing the quartz doublet at 800 and 780 cm$^{-1}$ along with other bands of quartz, for Zinc (A) and Manganese (B) mines.

Fig. 2. Selected portion of an FTIR spectrum of one zinc mine sample showing the quartz doublet and the associated baseline drawn for quantitative analysis.
3. Results and discussion

An examination of the ARD and quartz content data of different coal mines presented in Table 1 shows that quartz content of respirable dust is less than 1% in all the mines. All the mines are located in Jharia coalfield and they contain coking coals. The respirable dust concentrations are also less than the prescribed MEL in the country, i.e., 3 mg/m³, except for the locations 5 and 7 in mine 1 where the ARD concentrations are high. These locations are near the Bunker Top and Longwall. Fortunately, as the quartz content is low in all the locations, the miners are not vulnerable to high risk of contracting silicosis. Safety measures, viz. water spray, good ventilation, may control dust emission from the locations 5 and 7. Mukherjee et al. [3] also reported less than 5% silica in RAD in nine Indian coal mines selected by him for his study. He has shown that drillers and loaders in B&P mining, shearer operators and DOSCO loaders in LONG WALL mining and compressor operator and drillers in OPEN CAST mining are categories of workers highly exposed to dust.

The personal air samples fitted in three locations in zinc mine-1 (Table 2), viz. 1, 2 and 3, are drilling site, LHD operator site, Crusher and Screen house site, respectively. The quartz content is found to be in trace amount (that is below detectable limit) in location 1. This is due to wet drilling procedure adopted. In location 3, i.e., near the crusher and screen house site, the quartz percentage as well as ARD concentration is very high. Safety measures such as rotation of workers in a shift is suggested to be the best, so that health of the workers is not affected. Similar observation of high quartz and ARD concentration have been made for locations nearer the crusher and screen house in Mine-2/location-5, Mine-4/location and Mine-5/location-2. It is noted that both quartz and ARD concentration are low in locations near the beneficiation plants in locations Mine-4/location-5 &-6, because of safety measure like water spray adopted for suppression of dust. On the other hand, because of lack of proper safety measure near beneficiation plant, both quartz and ARD concentration are high for Mine-7/location-5 & 6. It is observed that drilling, haulage, crusher house are the main high risk zones of silicosis. Quartz content is high for mine-4, whereas in mine-3 quartz content of ARD is less than 5%, which is ascribed to compositional variations of the rock strata.

Similar to observations made in the case of manganese mines, the drilling sites in Mine-1/location-1&3, Mine-2/location-2, Mine-3/location-4, Mine-4/location-4, Mine-5/location-2and-3, Mine-6/location-2, Mine-8/location-3, Mine-10/location-3,5&6, Mine-11/location-3&4, Mine-12/location-1&2 and near crushing plant (Mine-12/location-8) quartz percent is high and exposures to dust have crossed the MELS. Notably, preventive measure (wet drilling) is found to reduce both quartz and ARD concentration in Mine-2/location-1. It is worthwhile to add that besides silicosis and lung cancer due to inhalation of respirable silica, other diseases, viz. Parkinsonian syndrome due to chronic exposure to manganese, may also form.

The MELs prescribed for India and U.S.A are shown in each table for every location in a mine. On comparison of the data displayed in Tables 1, 2 and 3, it is seen that assessment of risk evaluated from the MELs of the two countries is different for the same value of ARD and quartz concentration in a mine. It is known that MEL prescribed for different country is different, vide Table of Occupational Exposure Limit values [13]. Therefore, there should a consensus among nations to follow the same MEL standard for a particular type of mine so that health risk assessed is comparable.

4. Conclusion

- The quartz content of metal mines in various strategic locations is high and calls for preventative measures to suppress airborne respirable dust.
• Weight drilling as well as improved ventilation is found to be an effective measure to control airborne dust as well as emission of quartz.
• There are some locations in metal mines and crusher houses where, even if dust suppression measures are taken, the emission of dust is not reduced to its safe level as prescribed by regulation and hence for these locations rotation of workers in a shift may be necessary.
• The quartz content is found to vary from location to location in a metal mine due to the compositional variation of the rock body.
• It is found that quartz content of ARD of high rank coals of Jharia coalfield is less than 1%. The ARD for almost all the locations in various coal mines is less than MEL.
• There should be a general consensus among nations to prescribe only one MEL for each mine so that the same limit of exposure to quartz-laden dust is followed by all.

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