Assessment of Respirable Dust and its Free Silica Contents in Different Indian Coalmines

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Abstract: Assessment of respirable dust, personal exposures of miners and free silica contents in dust were undertaken to find out the associated risk of coal workers’ pneumoconiosis in 9 coal mines of Eastern India during 1988–91. Mine Research Establishment (MRE), 113A Gravimetric Dust Sampler (GDS) and personal samplers (AFC 123), Cassella, London, approved by Director General of Mines Safety (DGMS) were used respectively for monitoring of mine air dust and personal exposures of miners. Fourier Transform Infra-red (FTIR) Spectroscopy determined free silica in respirable dusts. Thermal Conditions like Wet Bulb Globe Temperature (WBGT) index, humidity and wind velocity were also recorded during monitoring. The dust levels in the face return air of both, Board & Pillar (B&P) and Long Wall (LW) mining were found above the permissible level recommended by DGMS, Govt. of India. The drilling, blasting and loading are the major dusty operations in B&P method. Exposures of driller and loader were varied between, 0.81–9.48 mg/m³ and 0.05–9.48 mg/m³ respectively in B&P mining, whereas exposures of DOSCO loader, Shearer operator and Power Support Face Worker were varied between 2.65–9.11 mg/m³, 0.22–10.00 mg/m³ and 0.12–9.32 mg/m³ respectively in LW mining. In open cast mining, compressor and driller operators are the major exposed groups. The percentage silica in respirable dusts found below 5% in all most all the workers except among query loaders and drillers of open cast mines.

Key words: Coalmine, Working face, Respirable dust, Personal exposure, Threshold limit value, Free silica

Introduction

Coal is prime source of energy in India. There are about 5.5 lakhs of employees engaged in about 500 coalmines in different coalfields of India. Eastern coalfields of West Bengal contribute about 18.11 million tonnes of higher-grade coal from 114 mines compared to the total production of 229 million tonnes (1991–92) to meet the demands of loco and other industries. In India coal is produced both underground and open cast mining but present thrust is being given to increase open cast mining where gestation period is much shorter (Indian Mineral year book (IMYB), 1994). A focus on the Occupational hazards and overall condition prevailing in Indian coalmines are felt to be important.

Simple Coal workers’ pneumoconiosis (SCWP) and progressive massive fibrosis (PMF) are the major occupational respiratory diseases of coal miners caused due to exposure to respirable dust generated during various mining operations. The concentration of respirable coal dust, the period of exposure and free silica content are important factors associated with pneumoconiosis risks. Assessment of respirable dust in coalmines and its control are of primary importance to undertake preventive measures. Available report on dust assessment and sampling strategies adopted in mines indicated that during, 1949–1970, thermal precipitators were mostly used in British coal mines whereas personal impingers in US coal mines. So both these types of samplings were also used in Indian Coal mines for dust
assessment and the standards were based on number of particles per cubic centimeters. The concentration on number basis led to some anomalies in dose-response relationships and it was observed that the incidence of Pneumoconiosis was better correlated with concentration on mass basis than the number count (Johannesburg Pneumoconiosis Conference, 1959) and thus standard based on respirable particle mass concentration was recommended.

Since 1970 onwards, the new Gravimetric Dust Sampler (GDS), Type 113A, capable to collect 50% of 5 µm equivalent diameter and upper cut off at 7.1 µm as per British Medical Research Council (BMRC) designed and developed jointly by National Coal Board (NCB) and Mines Research Establishment (MRE), UK, was approved for statutory sampling in UK mines after extensive field trials. In USA coalmine Personal repairable dust samplers capable to collect particles of size 10 µm and below were used for particle mass concentration. Similarly, in India both GDS and personal sampling methods were used during early eighties. Several epidemiological studies conducted in different countries reported a reducing trend of pneumoconiosis mortality since last two decades due to gradual reduction in dust levels at work faces through stringent control measures. There are number of scattered studies reported in Indian coalmines by different agencies and the prevalence of the disease varied widely from one another to draw any definite conclusion on the prevalence, distribution and determinants of the disease. Roy KB, 1956 first reported pneumoconiosis cases in bituminous coal mines of Madhya Pradesh prior to that it was presumed occupational diseases like silicosis, pneumoconiosis were not properly diagnosed in India.

Two types of mining methods of extraction, conventional Board & Pillar (B&P) and long wall (LW) or continuous are generally adopted in Indian mines. With increasing demand of coal as major source of energy, the coal mining in India advanced in phased manner from manual pick mining to semi-mechanised and mechanised processes by inducting newer mining machineries leading towards higher productions and accordingly the concentration of respirable dust in working face increased with increased mechanisation. In conventional mining coals are extracted by mining processes like drilling, blasting, loading and timbering where workers work in groups to complete the extraction process. Coal cutting machines are also used in B&P for loosening the coal strata followed by blasting to win coal from coal seams. In case of LW, the coal is mined by driving the DOSCO heads and Shearer machine through the coal seam. The loosened coals fall on the conveyer belt and transferred to the surface through different transfer points. The movable steel props support the roof immediate to the coal seam and the roof behind the work-face is allowed to fall. These mining operations generate large quantities of fine particulate in the respirable range <10 µm to which the miners are exposed. Besides, there is another mining process of winning the coal called open cast (OC), which involves extraction of coal from coal strata, by removing earth and rock layers from surface (over burden).

A permissible limit of exposure is developed based on the dust dose, duration of exposure and incidence of pneumoconiosis by most of the countries. In Indian coalmines the Directorate of Mines Safety (DGMS), Govt. of India, has prescribed a dust concentration of 3 mg/m³. The sampling guidelines recommended the NCB/MRE GDS sampler, type 113A for monitoring of air borne dust in Indian mines and personal sampler giving same cut off characteristic curve as BMRC for assessment of dust dose of individual workers during work shift.

This study reports assessment of respirable dust in mine air, personal exposures of different categories of workers in mines and silica content in the personal dust, thermal conditions and air ventilation to furnish an overall conditions of Indian coal mines.

Methods

Environmental monitoring in 9 different types of conventional and mechanised coal mines in Eastern India was undertaken for assessment of respirable dust during 1988–91. Area dust levels in B&P and LW at working coal faces (within 10 m), main intake (30 m out bye of the first working face) and main return air (not more than 30 m from the last working face) were assessed by using the MRE, 113A GDS, facing the ventilation current. The instrument was placed at breathing level away from the sides of roadway to ensure the safety of the instrument. Area dusts samples were collected on 47 mm GF/A, Whatman glass fiber filter fitted within an aluminium rim. During the area sampling of different mining operations like drilling, blasting, loading, GDS samplers were placed where the workers were at work. Personal exposures of different category of miners (engaged in conventional, mechanised or open cast mining) were assessed by attaching the AFC 123 Personal samplers (Cassella, London) to the lapel of the workers for entire shift and the time spent in actual work and rest periods were recorded for each category of worker as per Sampling guidelines, DGMS, 1988. Personal dust samples were collected on 37 mm GF/A, glass fiber filter for general purpose but 37 mm (Whatman) cellulose membrane filter.
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was used for free silica estimations. The respirable dusts collected on the membrane filters were treated for by Fourier Transform Infra-red (FTIR) Spectroscopy. Sample preparation for silica estimation was done by ashing the samples at 600°C followed by mixing the ash thoroughly with 200 mg of potassium bromide (KBr) with the pestle. The mixture was transferred to 13 mm evaluable pallet die, it was pressed using standard technique and Maghetti sampler holder was used for studying spectra in the wave length range, 10–15 µm and the calibration was done at wavelengths 12.5 and 12.8 µm

Thermal Condition like WBGT index, dry-bulb, wet-bulb and humidity were obtained by WBGT thermometer (Cassella, London) and wind velocities were recorded during the course of monitoring by using an Anemometer (Cassella, London).

Results

Table 1 shows the dust levels at main intake air, face return and main return air of coal mines of two different mining methods of working, B&P and LW. Mean dust levels in the coal face return air of both B&P and LW mining were obtained above the permissible limit, 3 mg/m³ as recommended by DGMS, GOVT. of India. 63.1% of values of respirable dust at coal face return air in B&P were found above the permissible limit whereas in LW 38.7% of the values exceeded the limit. The main return of both the mining methods however showed dust concentration below the permissible limit though 20.0% and 31.2% of the values respectively in B&P and LW were above the limit.

Table 2 shows the dust levels of three major mining operations drilling, blasting and loading. Drilling was found to be the most dusty operation producing a mean dust level of 4.81 mg/m³ above the permissible limit and a range of 1.63–8.35 mg/m³. Blasting is the next dusty process of the coal mining producing higher mean dust level above permissible limit, 3.13 mg/m³ in the range, 1.85–4.42 mg/m³, followed by loading operation.

Table 3 shows the dust exposure for different categories of coal miners in B&P, LW and open cast (OC) mining. Mean personal exposures of driller, timber mistry and loaders were found to be 4.36, 3.11 and 3.03 mg/m³ respectively having an exposure range between 0.81–9.48, 0.99–6.92 and 0.05–9.48 mg/m³ for these groups. These groups were found to be the major exposed group in B&P and 65.1% of the total number of estimated samples of driller, 39.1% of timber mistry and 43.9% of samples of loaders were recorded above the prescribed permissible limit for miners. Other group of

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<th>Table 1. Dust levels (mg/m³) in different areas of underground coalmines as obtained by Gravimetric Dust Sampler (MRE 113A)</th>
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<tr>
<td><strong>Mine Area</strong></td>
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<tr>
<td>Main Intake</td>
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<td>Face Return</td>
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<td>Main Return</td>
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<td>Main Intake</td>
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<tr>
<td>Face Return</td>
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<td>Main Return</td>
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*Board & Pillar, **Long Wall.

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<tr>
<th>Table 2. Dust concentrations at working coal faces during different mining operations as obtained by Gravimetric Dust Sampler (MRE 113A, Casella)</th>
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<td><strong>Mining Process</strong></td>
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</tr>
<tr>
<td>Drilling Operation</td>
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<tr>
<td>Blasting Operation</td>
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<tr>
<td>Loading Operation</td>
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</table>

n = No. of samples.
workers like explosive gang, CCM drivers, and helpers were exposed to dust level values higher than permissible standard by 41.4%, 18.2% and 20% respectively out of the total depending upon the available working faces in any particular day. The categories of workers like trammer, line man, line mistry, mining sardar who are generally not confined always to coal face during work are exposed to dust well within the permissible limit. In LW higher mean exposure above the limit were observed for the categories of workers like shearer operator (3.50 mg/m3), face workers power support (3.38 mg/m3), DOSCO loaders (4.65 mg/m3). Almost all the categories of workers in LW were having very high maximum value in their exposure range. In case of OC mining, the mean dust exposure for general majdoor (3.18 mg/m3), compressor operator (4.26 mg/m3) and drill operator (2.89 mg/m3) were found to be the major exposed group having exposure mostly above the limit whereas other workers were having a lower mean exposure. The highest values obtained in the exposure range of most of the OC workers were found above the permissible limit. A bar diagram shown in Fig. 1 (a), (b) and (c) for the exposures of different categories of miners in three types of mining, B&P, LW and OC.

Table 4 gives the silica content (%) of airborne dust in different mines, B&P, LW, and OC. Airborne dust of OC mines was found to contain higher mean silica percentage above 5% than the other mining methods. 25% of the total estimated samples for silica found above 5% in OC and 12.5% in case of LW mining and nil in case of B&P.

Mine wise records of thermal parameters showed that the mean dry-bulb ($D_b$) were 30.6°C and 29.4°C in B&P and LW and mean relative humidity (RH%) in these mines were recorded to be 94% and 85% in respectively. Table 5 shows the number and percentage of observations exceeded the recommended ACGIH TLV (1995–96) of WBGT index in B&P and LW mining for different types of continuous physical work. 87.1% and 92.7% values of total WBGT records found above 25°C, the recommended TLV of continuous heavy nature of work in B&P and LW mining.
respectively, whereas 81.3% and 88.6% respectively in B&P and LW mining were above 26.7°C which is the recommended TLV for continuous moderate physical work. 9.6% of WBGT observations in B&P and 10.6% in LW exceeded 30°C, which is the TLV for continuous light physical work (ACGIH, 1995–96).

Table 6 presents the wind velocities in underground coalmines according to the mining methods. 15.4% of observations in B&P and 50% in LW showed stagnant values (i.e., wind velocities < 10 ft./min.) at working faces. 83.9% and 42.9% of observations in respectively B&P and LW showed low wind velocities well below 300 ft./min. These high and low wind velocities have been classified as per the recommendations of the Standard Advisory Committee (SAC) on heat stress.

**Discussion**

Mean Reparable dust concentrations in the coal face return air of B&P and LW mining found above the prescribed Indian Standard of 3 mg/m³ (Table 1). In both types of mining, dust concentration at main return air showed lower values than the recommended standard. Air ventilation in the mines plays a very important role in maintaining a steady dustiness below permissible limit as well as personal comfort or thermal stress to the workers engaged in the area. Inadequate wind velocity may not be able to sweep away the finer coal particulate generate at the coal working faces. In most of
the cases, the wind velocity recorded in both the mining, were either stagnant or low i.e. < 300 ft./min (Table 6). The working faces that are far away from the main intake air and the ventilated air passes through diversions before reaching the working faces, wind velocity drops down to almost a stagnant air. Water spray after blasting operation reduces the dust level at work face to a large extent. In conventional mining, drillers are the most affected group with higher personal exposure above permissible limit as they work very close the dust source. In built water spray system attached to the drill machine should be in operation during drilling. As evident from the personal exposure of workers in LW, shearer operator, power support face worker and DOSCO loaders were having higher exposures than the recommended value (Table 3). The water spraying system attached to the shear machine mostly found to be not working might be the cause of higher dust in LW. The bar diagram (Fig. 1) has very well depicted the exposures of the miners at a glance in all the three types of mining. Workers engaged in LW and OC have higher dust exposures above the permissible limit and also contain free silica more than 5% in their personal dust are at a greater risk of SCWP and PMF18–20. LW and OC miners have greater risk of silica exposure than B&P during the process of coal extraction from coal seams as it passes through the stone drivages having higher quartz percentage. It is also evident that 12.5% of the samples of LW and 25% of the samples of OC showed silica content more than 5% and hence these workers are at greater risk of pneumoconiosis (Tables 3 and 4). In studies conducted earlier in US mines, higher percentage (> 5%) of quartz exposure was noticed among driller, LW machine operators, roof bolters21, 22. In a study Parobeck and Tomb (1974) showed the distribution in different range of respirable dust concentrations in US underground mines and surface operations and observed that majority of the values were at or below 2 mg/m³23. In another study, Goldberg et al. (1973) observed that the quartz content in the respirable dust during underground coal mining was only about 1% of the samples, having above 5% quartz in US underground mines24. It was also observed that if the respirable coal dust levels in the mines are regularly maintained at 2 mg/m³, the probability of developing the disease during working life of the exposed workers are minimised to zero. The respirable dust concentrations of the present study measured in the Indian mines correspond well with the findings of the US and UK mines. The thermal environment in side the coal mines found to be hot and humid and the maximum observations of WBGT index, above 26.7°C, were indicative of the fact that the mining environment is non-conductive for heavy and moderate nature of continuous work, the low ventilation at coal working work faces which are the site of dust generation may pose additional problem of dust hazard along with the thermal stress to the workers.

**Conclusion**

The respirable dust levels as observed in the conventional and mechanised Indian coalmines need to be controlled at coalfaces which always been found very dusty during mining operations. The dust concentrations in both these mining showed comparable results. The drilling, blasting and loading are the major dusty operations of B&P working method. The drillers, loaders and explosive gang are the higher exposed groups in B&P mining, DOSCO loaders, Shearer operators in LW mining and compressor operators in OC mining are the major exposed groups. The in-built water spray with the drilling machine always be made effective to reduce dust exposure. The free silica content of respirable

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<tr>
<th>Mining Methods &amp; Area of Measurement</th>
<th>Stagnant (0–10 ft./min.)</th>
<th>Low wind velocity (11–300 ft./min.)</th>
<th>High wind velocity (&gt; 300 ft./min.)</th>
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<tbody>
<tr>
<td>Board &amp; Pillar</td>
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<tr>
<td>Intake air</td>
<td>56</td>
<td>1 (1.8)</td>
<td>6 (46.4)</td>
</tr>
<tr>
<td>Working Face</td>
<td>143</td>
<td>22 (15.4)</td>
<td>120 (83.9)</td>
</tr>
<tr>
<td>Return Air</td>
<td>76</td>
<td>1 (1.32)</td>
<td>71 (93.4)</td>
</tr>
<tr>
<td>Long Wall</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intake air</td>
<td>41</td>
<td>0 (0)</td>
<td>39 (95.1)</td>
</tr>
<tr>
<td>Working Face</td>
<td>14</td>
<td>7 (50.0)</td>
<td>6 (42.9)</td>
</tr>
<tr>
<td>Return Air</td>
<td>37</td>
<td>1 (2.7)</td>
<td>27 (73.0)</td>
</tr>
</tbody>
</table>

n = No. of samples.
dust in Indian mines found mostly less than 5% and hence a strict maintenance of the exposure at work within the recommended permissible standard of 3 mg/m³ will enable to control the risk of pneumoconiosis among workers. In LW mining, during operation of shearer, the water jet system should work efficiently to control the exposure of the machine operators and face workers who are close to the coalface. The parameters, WBGT index and wind velocity reported are newer items studied in Indian mines and are very much relevant to miners’ thermal stress and dust exposure at work faces.

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