Project Title:

Studies on Determination of Free Silica (a-Quartz) Content in Respirable Air Borne Dust (ARD) in Coal Mines and Preparation of Data Bank of Free Silica and other Minerals present in Dust as well as in Coal.

Project No.
GAP/MS/MOC/85/2010-11

Executive Summary:

Most of the coal mining operation generate significant amount of respirable dust. Prolonged exposure of this dust is known to cause various respiratory diseases including the deadly pneumoconiosis among the miners. However, coal mining is inevitable for meeting energy requirement of the country and in absence of any alternatives potential clean energy source, it will continue to maintain its lead for foreseeable future. With increased level of mechanization and pressing demand to boost production for minimizing demand supply gap, problem of air borne respirable dust is increasing every day.

Indian coals are considered to be of 'drift' origin and therefore contain high mineral matter. Quartz is one of the major minerals present in coal and therefore miners are exposed to health risks due to inhalation of quartz laden coal dust. The health risk of the miners depends on the nature of coal and its mineral content, condition of the mines, nature of job handled and finally the quality and efficacy of the safety measures adopted.

With a view to protect miner's health and to provide safe and healthy work place environment, various provisions have been made in the regulation. This involves periodical monitoring of Respirable Airborne Dust in mines and taking appropriate ameliorative measures when dust concentration exceeds its permissible limit value (TLV). This TLV varies and reduces below 3mg/m^3 with increasing free silica content in the dust beyond 5%. Therefore determination of free silica concentration of airborne respirable dust is of prime importance to ascertain the safe and healthy working environment. The free silica determination in vary small amount of airborne dust sample collected on small dia (25 mm) filter paper are technology intensive involving costly and sophisticated instruments, which may not be feasible to be maintained at mine management level.

National Dust Prevention Committee (NDPC) has also expressed serious concerns about growing problem of dust hazards and emphasized to eradicate pneumoconiosis completely. Accordingly, CSIR-CIMFR, Dhanbad has taken up a research project entitled, **"Studies on Determination of Free Silica (α-Quartz) Content in Respirable Air Borne Dust (ARD) in Coal Mines and Preparation of Data Bank of Free Silica and other Minerals present in Dust as well as in Coal"** with following five objectives:

(a) Determination of Free silica Content in Air Borne Respirable Dust samples from various statutory required representative workplaces and identified class of workforces.
(b) Determinations of free silica content from coal/rock samples collected from the parent body and study its correlation with free silica content of air borne respirable dust samples.
(c) Preparation of data bank of free silica content representing almost all types of working seam and excavating technology as a ready reference tool for free silica content.
(d) Determination and preparation of Database for minerals associated with coal seams of different location.
(e) Organisation of Training and Awareness Programmes related to

Dust Sampling and analysis.

The project was taken up to cover most of the mines of various subsidiaries of Coal India Limited (CIL) and is expected to provide following deliverables.

- An updated status report of air borne respirable dust conditions prevailing at various workplaces representing all geo-mining conditions in various coalfields.
- A databank of free silica content of different seams which can be used a ready reference tool for ascertaining free silica content of air borne dust in any specific situation with reasonable accuracy.
- An empirical relation between the free silica content of air borne respirable dust and its parent/host rock will be established which may be very useful in ascertaining free silica content without going through a costly and sophisticated instrumental analytical procedure.
- Determination and Preparation of Database for minerals and trace metals associated with coal seams of different location. No such data base is available for Indian coal Seam at present. Such database may help in better utilization of coal.
- All the potential grey area needing remedial steps will be identified, categorized/ classified and site specific possible ameliorative advisory measure will be provided.
- Well trained team of officers and supervisors in various mines and subsidiaries for conducting air borne dust related studies.

The project implantation started with development of laboratory equipped with state-of-the- art-facilities for taking up the study which were hitherto not available in India. Accordingly the following facilities were created which will not only become a tool for the conducting the present study under project but will become centre for excellence for all aspects of study related to air borne respirable dust in future.

1. Fourier Transform Infrared Spectroscopy (FT-IR)
2. X-ray Diffraction Spectrometer (XRD)
3. Microbalance with charge remover facility
4. DGMS approved personal dust samplers
5. Real time Aerosole Monitor

After procurement of above equipment, following facilities and capabilities were developed for analytical required under the R&D project:

1. A quick, reliable and non-destructive method for quantitative determination of free silica present in air borne respirable dust deposited on filter papers was developed. The method essentially requires calibration of FTIR for quantitative analysis using MDHS 101 guidelines. For the same, a calibration chamber was developed in the laboratory for calibrating peak height of the silica obtained from the FTIR spectrum with amount of free present in filter paper. A calibration equation was developed for quantitative estimation of free silica in dust deposited on filter paper. This fulfils the DGMS requirement

[DGMS (tech) circular of 2010] for determination of free silica in air borne respirable dust.

2. Analysis of airborne respirable dust using XRD for phase identification and semi quantitative analysis of various minerals present in it.

   Microbalance with charge removing facilities were used for accurate weighing of small amount of dust deposited in filter paper which are prone to be erroneous due to accumulation of electrostatic charges during sampling.

3. DGMS approved personal dust sampling for conducting air borne respirable dust sampling in miners as per DGMS guidelines and provisions of Coal Mines Regulations Act, 1957.
4. Real time aerosol monitor for studying the particle size of dust in work place environment specially in PM1, PM2.5, PM10 and total respirable dust along with facility for collecting the dust on filter paper for its laboratory analysis.
5. Laboratory equipped with air conditioning and dehumidifier for equilibration of filter papers before and after sampling as well as for housing FT-IR and other associated set ups.

Since the project envisaged large number of sample collections which required the support of supervisor and staff of mines for sampling. To ensure accuracy and consistency in air borne respirable dust sampling, training programs as per following schedule were organized for executives/supervisors/staffs on methodology for sample collection, equipment and sample handling and preparation of sample identification sheet.

Sl. No.	Subsidiary/place the training program organized	Dates of Training Programs	No of persons trained
1	Eastern Coalfields Limited +NEC	16-17 April 2013	47
2	Bharat Coking Coal Limited (BCCL)	08-09 April 2013	83
3	Central Coalfields Limited (CCL)	18 April 2013	51
4	South Eastern Coalfields Limited (SECL)	24-25 April 2013	91
5	Mahanadi Coalfields Limited (MCL)	22 April 2013	37
6	Western Coalfields Limited (WCL)	26-27 April 2013	65
7	Northern Coalfields Limited (NCL)	23 Sept. 2013	25
8	CSIR-CIMFR, Dhanbad (participant from all subsidiaries)	9 Sept 2013	17
		Total	**416**

Besides, there were on the job training and guidance during the Project

execution for each and everyone needing any assistance. A training booklet was prepared and each coal mine was provided with one training booklet during training for its use.

For sampling purpose 100 nos of DGMS approved personal dust samplers were procured and distributed in various subsidiaries as per advise of Coal India Limited. Following sampling strategy was followed to collecting the samples and its analysis.

1. One nodal officer was identified in all the subsidiaries who was responsible for co- ordinating airborne respirable dust sampling from each mines under the subsidiary.
2. Filter papers after its temperature equilibrations, weighing, coding were given to each mine for sampling alongwith a form for each filter sample which needs to be filled by officer/supervisor responsible for sample. The form requires description of samples, sampling times & duration, location etc. Attempts were made to cover all major dust generating operations and worker working close to these operations (category workers) for which DGMS guidelines were also referred.
3. Coal and immediate rock samples were also collected from all the seams which were processed and analysed in the laboratory for free silica and other mineral content.
4. One software Alpha quartz was developed for handling, managing, analysing, utilising the vast amount of data generated in the project. All the data were in entered in the softwere leading to development of a DATA BANK.

A total of 285 coal mines were covered in the study wherein 2301 air borne respirable dust samples, as detailed below, were collected from various different coal mines.

Sl. No.	Subsidiaries	Total no. of areas	Total no. of mines	No of ARD samples-personal sampling	No of ARD samples-static sampling	Total No. of ARD samples
1.	BCCL, Dhanbad	13	23	140	Nil	140
2.	CCL, Ranchi	18	61	239	Nil	239
3.	ECL, Sanctoria	15	63	326	46	372
4.	MCL, Sambalpur	10	22	328	63	391
5.	NCL, Singrauli	10	10	244	36	280
6.	NECL, Margherita	01	01	30	Nil	30
7.	SECL, Bilaspur	18	66	622	34	656
8.	WCL, Nagpur	10	39	193	Nil	193
Total		**95**	**285**	**2122**	**179**	**2301**

Similarly 966 samples of coal and immediate rock, as detailed below, were collected and studied with a view to understand about sources of air borne respirable dust generated in the work places.

Sl. No.	Subsidiaries	Total no. of areas	Total no. of mines	Total samples	No of coal samples	No of OB samples
1.	BCCL, Dhanbad	16	30	101	72	29
2.	CCL, Ranchi	16	47	126	72	54
3.	ECL, Sanctoria	13	50	152	115	37
4.	MCL, Sambalpur	10	22	190	120	70
5.	NCL, Singrauli	10	10	76	39	37
6.	NECL, Margherita	01	01	09	05	04
7.	SECL, Bilaspur	18	62	198	106	92
8.	WCL, Nagpur	09	25	114	56	58
Total		**93**	**247**	**966**	**585**	**381**

Overall, the implementation of the project, collection and analysis of the airborne respirable dust samples lead to following conclusion and contribution to the existing state of knowledge in the research area.

1. An state-of-the-art laboratory has been developed at CSIR-Central Institute of Mining and Fuel Research, Dhanbad for study of various aspect of air borne respirable dust environment at different mines and other
2. A method for determination of free silica content was developed using FTIR following MDHS (method for determination of hazardous substances) 101 guidelines of Health and Safety Executives, Government of UK. This is a non-destructive, quick and reliable method for quantitative analysis of crystalline quartz in airborne respirable dust deposited on filter papers. The method conform prevailing statutory guidelines of DGMS (Tech) circular of 2010.
3. An empirical relationship has been developed for 5 micron, 25 mm filter using Perkin Elmer FTIR model spectrum which is as follows:

   Quartz (mg) = 1.628 × Peak Height + 0.021

   Similarly, the relationship for 5 micron, 25 mm filter Portable FTIR model ALPHA of Bruker, Germany is as follows:

   Quartz (mg) = 1.404 × Peak height + 0.016
4. The FTIR was also used to develop technique for determination of quartz in powder samples. The technique requires preparation of KBr mixed pellets, generating its spectrum using FTIR and developing calibration equation which is as follows:

   Calibration equation for spectrum 100 for 1000 mg pellet mix

   True Quartz = 100/94 (3.194 × peak Height - 0.071) and For Bruker Alpha for 1000 mg pellet mix

   True Quartz = 100/94 (3.608 × Peak height -0.2591)
5. A sample filter holder has been developed which will fit exactly into sample compartment of FTIR spectrometer and facilitate taking FTIR spectra of dust loaded filter paper at different position of filter by providing rotatable specialty. This enables obtaining representative spectra for improving accuracy in the

analysis result. It can accommodate both type of PVC membrane filter of 37 mm and 25 mm diameter.

6. Free silica concentration have been determined in coal samples collected from different coal seams and airborne respirable dust samples collected from a work place in almost same area. Study suggest following correlation equation

   X = 1.0553 Y -0.9309 where, X = % quartz in air borne respirable dust and Y = % quartz in Coal

   Thus, for a quartz value of 5% to 10% in coal, the quartz in dust varies from 4.35% to 9.62% suggesting almost 1:1 correlation in quartz content of seam and that in air borne respirable dust.

7. A total of 538 coal samples from various coal seams have been collected and analysed for its free silica content. In view of criticality of the free silica content from the health hazard point of view, the seams have been classified low (free silica <5%), high (free silica 5-10%) and very high (free silica >10%) silica content seams. Out of the 538 seams studied, 321 seams samples has been found as low, 215 seams as high and 2 seams as very high free silica content seams. This classification of seams suggests careful precautionary/preventive approach for dust exposure among the miners while working underground for high and very high category seams. A subsidiary wise of summary of low, high and very high category seams are presented below:

Sl. No.	Subsidiary	Total no of seam	No of seam with Low free silica content (<5%)	No of seam with High free silica content (>5% and <10%)	No of seam with very high free silica content (>10%)
1.	CCL	54	37	17	0
2.	NCL	38	17	21	0
3.	BCCL	75	51	24	0
4.	ECL	107	63	44	0
5.	WCL	55	35	18	2
6.	SECL	95	76	19	0
7.	MCL	109	37	72	0
8.	NEC	5	5	0	0
Total		**538**	**321**	**215**	**2**

8. Dust exposure profile study in 285 coal mines were conducted on important category workers involved in dust generating operations in different coal mines. Although the data shows significant variation within the same category of workers which may be mainly due to variation in the working condition,

	condition of machine operation and coal/rock parameters. Still a generalized trend for dust exposure and their impending risk due to the exposure is as follows: a. The mining operation which involves rock cutting viz., Continuous Miner(CM), Mechanical Operator (Road Header), Drilling, roof bolter are higher risk operations and need special care for their operators and those working in the vicinity of these operations. b. The mining operation which involves handling of fragmented rock/coal viz., operators for Shovel, dumper, dozer, Tippler SDL, LHD, Pay Loader, Trammer comes next in order. c. All other category workers like General mazdoor, sampling mazdoor, Over man, supervisor etc may be considered low risk category worker and generalized precautions for protection against air borne respirable dust protection may be taken for these categories. The study provides very useful information regarding dust generation behavior and trend through different mining operations, and exposure pattern of different category workers in different mines of Coal India Limited. However, its suggest further and focused studies about mining operations involving coal/rock cutting specially continuous miners which generates more dust and has promising future in boosting India's coal production. Such studies may includes (i) dust generation behavior and potential of these machines, (ii) particle size spectrum of dust generated (iii) relationship between type/amount of dust generated with rock/coal properties and (iv) optimization of dust suppressing mechanism attached with these machines, and developing ventilation standard for diluting dust generating in these operations.