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Dust Monitoring Systems and Health Hazards in Coal Mining: A Review

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ABSTRACT

The dust produced during mining operation causes critical illness to miners. The mining workers are constantly at the risk of getting respiratory illness due inhalation of mining dust, particulate matter (PM) and heavy metals. The current research studies the hazards of mining and effect of coal dust on health of workers. The instruments that can be used to measure quartz content, coal dust concentration is also discussed. The mathematical modelling of dust dispersion is also studied.

KEYWORDS: *Coal mine, coal dust, health hazards*

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1. INTRODUCTION

Dust is used to describe fine particles suspended in the air. The size of dust particles vary from few nm to 100μm and the concentration of dust vary from few micrograms to hundreds of micrograms per cubic meter of air. Various factors such as dust lifted by weather, volcanic eruptions, pollutions, mining activity, construction activity etc. contribute to the formation of dust. The formation of dust can be attributed to the fine particles which become entrained in the atmosphere due to turbulent disturbances produced by wind; it is also formed from mechanical disturbances and through release of particulate rich gaseous emissions. Dust includes wide range of particles varying from 1mm to less than 1μm. But the size range normally varies from 1-20μm. because particles above 20μm are usually quick to settle and particles below 1μm don't form in abundance. The size of particle considerably influences its characteristics. Depending upon the size dust can be classified as

1. Particles greater than 10μm: These particles settle according to the law of gravity. In still air, they settle with increasing velocity.
2. Particles between 0.1μm to 10μm: These particles settle with a constant velocity obeying Stoke's law. The velocity depends upon density and size of particles, acceleration due to gravity and viscosity of the medium.
3. Particles between 0.01μm to 0.1μm: These particles don't settle in air rather remains in colloidal state.

Atmospheric dust is formed by saltation and sand blasting of sand seized grains from surfaces through the action of wind. Troposphere is the medium of transportation of atmospheric dust. Mostly atmospheric dust comes from the dry and arid regions which are more susceptible to weathering through high velocity wind. During dust generation particulate matter became airborne and flows in the downwind direction. When a dust is derived from a mixture of sources or when the source can't be easily determined, then it is termed as fugitive dust. In mining activities fugitive dust generates from the movement of HEMM over non paved haulage roads and from blasting and loading operation. Mine dusts are generally characterized as fugitive dusts since they are mostly generated from non-point sources. During mining and processing of ore body a number of stages of drilling, blasting, crushing, grinding are required. Abrasion and crushing of surface due to action of mechanical force produced fine particles which remain suspended in air due to small size. The movement of dumpers and other HEMM along the haul road also produces dust. In most of the cases the dust produced by the mine is of fugitive nature i.e. the sources can't be easily defined and mainly consists of disturbances of surface. Surface mining methods produces significant amount of dust as compared to underground dust due to use of HEMM, high mechanisation and large surface area which are vulnerable form dust production on action of air. In opencast mines, huge quantity of over burden has to be removed to facilitate accessing minerals. The removal of overburden requires dumpers, shovels, and draglines etc which discharge enormous quantity of fine particles into atmosphere. Blasting operations too generates huge quantity of dust. The closure of mine also involves loading and transportation of overburden and contributes to dust generation. Large surface area of overburden dump is also quite vulnerable to dust production if efficient measures are not taken to suppress it. Most mining operations produce dust when air-borne becomes serious hazard to miner's health and may cause respiratory diseases e.g. chronic bronchitis/pneumoconiosis. It can be collage nous/non-collage nous (non-fibrogenic). Based on size particulates can be divided into TSP, PM10 and PM2.5. Dust is generally measured in terms of weight of particles per cubic meter of air. Dust is a primary thing associated with all mining activity. In every step of operation there is generation of dust. Open cast mines produces more dust as compare to underground mines. The mining activities like drilling, blasting, loading, transportation, crushing, conveying, haul road and the exposed overburden face generate large quantities of fugitive dust. In view of this, identification dust emission sources and determination of emission rate of various activities of the mine site is pertinent to assess impact of mining activities on surrounding air quality. Silica is a potential carcinogen and its exposure to the workers may be detrimental to their health which may result in progress of silicosis and lung cancer. Hence determination of silica content in the respirable air is essential to assess its impact on miner's health. Dust emission, dispersion patterns are difficult to predict through dispersion models due to the wide range of fugitive sources in mining activities that may give rise to dust, empirical emission factors for these activities, and the impact of local meteorology and topographic features. Dispersion modelling can provide simple predictions of probable isopleths, and ambient air quality monitoring can provide validation of possible levels of dust concentration in and around a site. In order to accurately predict dust concentration levels around the mine, long-term and comprehensive dust monitoring is essential. Dust dispersion patterns are often affected by wind speed, short lived dusting events, precipitation and the source of emission itself. Sometimes dust emission from the mining site itself may be low or immaterial, but the receptor may be subjected to background dust sources. Coal dust plays a significant role in the gas explosion process. Meanwhile, coal dust can also cause explosion itself. Coal is an inherently combustible material, and when it is broken into dust, the contact area between coal and air significantly increases, leading to a higher explosion potential once an ignition source appears. The shockwaves generated by earlier explosions will raise secondary dust in the roadway, resulting in explosion propagation, which poses a great threat to miners and the mine. In addition, dust particles, containing harmful elements (e.g., silica), with an average diameter of less than 2.5 μm can directly enter the alveoli in the human body and combine with toxic host cells (especially macrophages) to cause permanent damage,7 leading to pneumoconiosis and other diseases.8−12 Moreover, dust can also accelerate the mechanical wear of equipment and reduce the visibility of the working face, thereby increasing the risk of safety hazards. In the past, much concerns have been concentrated on the prevention of sudden accidents rather than on the harmful influence of coal dust on the human body. In recent years, social and technological progress has led to enhanced health awareness and an ever-increasing emphasis on dust reduction in coal mines. The Chinese government issued the Technical Specifications of Comprehensive Dust Control Measures for Underground Coal Mines, which requires coal mines to adopt strict dust reduction measures. Therefore, the systematic study of dust characteristics is related to personal health, production safety, and environmental air quality, i.e., the HSE of the underground space of the mine. The working face generatesabout60%ofthetotalamountofdustinacoalmine,18 which deserves the focus of control efforts. The study of dust characteristics is an important step toward achieving the goal of dust control. Historical studies were conducted mainly by crushing coal in a laboratory to generate dust rather than collecting dust from the working face, 19−22whichwasunrealistic because the chemical composition, particle size, wett ability, and harmful elements of real dust are different depending on individual coal types or the surrounding rock. The proximate analysis results (Table 1) show that the dust in each mine is mainly composed of organic matter, along with different amounts of minerals. The ash content varies greatly among the mines within the range of 12.59−77.08% (avg. 28.85%). However, in the same mining area, the ash content of the dust from the working face dust is always higher than that of the dust from the air intake roadway and there turn air road way. In particular, the ash content of JLS-2 reaches 77.08%, while those of JLS-1 and JLS-3 are only 22.34 and 36.69%, respectively. The ash content of the dust from the different positions of Hebi no. 6 (HB6) shows low differences, with the ash content of HB6-2 of 17.83% and those of HB6-1 and HB6-3 being17.30 and 14.7%, respectively. It can be seen that the dust composition is complex.

Table 1 Proximate Analysis of Dust

sample ID	dust source	sampling location	M_{ad} (%)	A_{ad} (%)	V_{ad} (%)	FC_{ad} (%)
JLS-1	Jiulishan coal mine	intake airway	4.14	22.34	7.67	65.85
JLS-2		coalface	4.20	77.08	7.23	11.49
JLS-3		return airway	1.5	36.69	6.24	55.57
HB6-1	Hebi no. 6 coal mine	intake airway	1.93	17.30	28.21	52.56
HB6-2		coalface	1.17	17.83	25.12	55.88
HB6-3		return airway	0.67	14.7	13.18	71.45
DY	Daiyang coal mine	return airway	12.43	12.59	8.03	66.95
LTS	Lutaishan coal mine	return airway	2.23	42.64	10.69	44.44
PM2	Pingmei no. 2 coal mine	return airway	0.68	25.33	20.71	53.28
SH	Sihe coal mine	return airway	4.01	21.96	6.97	67.06

There are quite a number of ways in which monitoring airborne dust can be carried out. Based on principles of operation, they can be classified as

A. Filtration
B. Sedimentation
C. Inertial precipitation
D. Thermal precipitation
E. Electrical precipitation
F. Optical methods based on light scattering

However, for this study DustTrak II is used for real time dust monitoring at different sources of mine. It is based on the principle of scattering of light. Personal Dust Sampler is based on the principle of filtration. DustTrak II aerosol monitor gives the real time aerosol mass readings. It is based upon the principle of light scattering through the laser photometer. It uses a sheath system which isolates the aerosol in the optic chamber to keep optic clean and to improve reliability. It can be used in harsh industrial workplaces and construction sites. It measures aerosols such as dusts, smokes, fumes and mists. Dust Track hand held model 8532 is light weight and portable. It can monitor indoor air quality, engineering control evaluations and for baseline trending and screening. It has single point data logging capability which can be used for walk through industrial sanitation survey and indoor air quality surveys. DustTrak II instrument is shown in Fig. 1.2.

Figure 1.2: DustTrak II Aerosol Monitor

2. LITERATURE REVIEW

During almost all mining activities there are various forms of activities from mining extraction to refinery that put the risk of workers and communities at risk due to dust from such activities that pollute the mining and nearby surrounding to endanger the health of those in close proximity mining environment [1, 2]. Actually the most notable dust emissions are usually particulate matter (PM), sulfur dioxide (SO2), nitrogen dioxide (NO2) and heavy metals and mostly these are suspended as dust in the mining environment. It should be noted that dust from mine environment is a very big issue as it deteriorate air quality and ultimately affect the human health, flora and fauna in and around coal mining areas [3].

The novella article, by Momoh et al., is a very explicit articles in terms of leveraging mining dust effects to human health both within mining environment and communities within their vicinities [4]. The article "Potential implications of mine dusts on human health: A case study of Mukula Mine, Limpopo Province, South Africa" published in 2013 is an important article because it is very comprehensive in establishing what dust particles are unacceptable by WHO standard. The purpose of this study was to estimate levels of Suspended Particulate Matter in ambient air within mining environment and the potential risks to mineworkers and communities nearby. While the "Respiratory Diseases Caused by Coal Mine Dust" by Laney and Weiss man is informative and insightful because the authors emphasizes a spectrum of respiratory diseases that affect miners as a results of dust from the mine environment termed as "coal mine dust lung disease" though the paper does not address the effects of mining dust on community living in close proximity, the main objective of the paper is to provide an update on respiratory diseases caused by coal mine dust.

The paper by Rey et al., in his paper "Underground Coal Mining: Relationship between Coal Dust Levels and Pneumoconiosis, in Two Regions of Colombia, 2014" published in 2015 observed that there was a high levels of coal dust and silica among the 29 companies that were sampled and that the prevalence of pneumoconiosis was much higher than what has been reported in other studies among mine workers [5]. Other studies focused on levels of dusts observed from small scale mining, like a study done by Bråtveit, Moen, Mashalla and Maalim in 2002 called "Dust Exposure During Small-scale Mining in Tanzania: A Pilot Study". This paper discusses that there is actually more dust produced from small scale mining that what has been assumed and if the focus is only on economic strides this may make sustainable mining difficult. The objectives of this pilot study were to monitor the exposure to dust during work processes, which are typical of small-scale mining in developing countries, and to make a rough estimation of whether there is a risk of chronic pulmonary diseases for the workers [6]. Lastly a paper done by Önde in a paper published in "Investigation of Dust Levels in Different Areas of Underground Coal Mines". The paper found that levels of mining is too high and there is need to control these levels.

It should be stressed that Health and safety is always the first priority in the mining industry. It requires not only to provide a safe workplace for mining operations, but also to offer a safe and sustainable environment for the communities around the mine-site. Some of the pertinent issues form mining environment that arise during an entire mine life cycle include the following categories: general workplace health and safety and the hazardous substances such as dusts that come as a result of the processes of mining [7].

It should be understood that most if not all mining operations produce dust and this may result in various spectrum of health issues as far as the community is concerned and most importantly the health of workers e.g. chronic bronchitis/pneumoconiosis. Dust in the mining area could simply be viewed as particulates matters and this can be divided into TSP, PM10 and PM2.5. At the same time it is should well be understood that dust is generally measured in terms of weight of particles per cubic meter of air. There is an inherent and well understood association between mining activity and the resulting dust and this association is progressive in every step of mining operations. It should also be well noted that open cast mines produces more dust as compared to underground mines. From the above rationale, the paper by Abuh et al., does highlight that mine are as a result of mining activities' and the paper explains the different and various constituents of dust, methodologically however the paper does not seem to provide much information on what methods of data collection were used as this could be important to understand the study findings. As far as dust and mining environment is concerned every paper to address this issue should endeavor to address both the workers and community impact of dust. This paper seem to shed much emphasis on community concerns as far as the effects of dust is concerned on their health compared to other papers. The study does not also provide a progressive way for control and monitoring of dust in mining environment in light of sustainable mining. At the same time the study seem to establish an important that exposure for a risk really dependent on the dust levels. While a study by Laney and Weismman states that the most important aspect which is the fact that mining is very important for community and global economies and for the advancement of welfare of workers and community living. The study strikes a balance unlike the other studies, that when addressing dust effects on environments and human health, it is important that the benefits are weighed against the risk because given any situation any mining operations will continue to provide dust, but what matters is the amount of dust that is generated and the levels and how they risk workers and community health as well as the environment. This study however just like the preceding study does not provide for mechanism of sustainable management of dust in mining environments to curtail on the impacts of dust on workers and human health. The study too only addresses the health of workers as far as dust is concerned and fails to addresses the proximity of dust effects on communities [8]

Rey et al., study addresses coal dust mining and its effects on environment within mines and beyond. This was study was methodologically meaningful in proving reliable and valid results and this is because it was carried out as cross sectional analytical interventional study with the use of instruments to measure amount of dust in mining environment as well as the effects of dust on the workers and this was not merely dependent on other studies reports. The study also did establish one important factor that the other studies seem to fail to addressee and that is the past medical history of workers. This important as other worker smoke and are exposed to other pollutants other than that which come from the mines. This is an important investigation as the findings of a study could be confounded by any other exposure that inherently exist among those that work in the mines [5].

A study by Onder, is methodologically robust among all the studies because this study made use of records of dust measurements in the mining environment since the 1978 until 2006. This could be helpful to understand the trends in dust production over the years. Thus, information could be utilized to come up with sustainable workable measures that could address the growing concern of dust in mining. However, this study does no conclusively and comprehensively reports on the findings of such reviews. One feature that seem to fall short in the studies is the mention of an intersectoral approach when doing mining [10]. A study by Billig et a' suggest that an intersectoral approach involving community, governmental and nongovernmental agencies, and the management of the mining firm. And from this study it appears success was achieved using this approach in addressing dust from the mining environment [9, 10]

Chaulya et al. (2002) [11] carried out study for determination of emission rate for SPM to calculate emission rate for various opencast mining activities. For validation Fugitive Dust Modelling (FDM) and Point, Area and Line source model (PAL2) were used. Both models run separately for the same input data for each mine to get predicted concentrations at three receptor locations. FDM was found to be more suitable for Indian mining conditions. It was observed that coal handling plants, haul roads and transport roads were the major sources of dust emission. The average accuracy between observed and predicted values for SPM at certain locations for PAL2 and FDM model were found to be 60-71% and 68-80% respectively.

Chaulya (2004) [12] carried out an assessment of air quality around Lakhanpur area of Ib valley. TSP, PM10, SO2, NOx were monitored at 13 locations for a period of one year. 24 hour and annual average concentrations of TSP and PM10 exceeded NAAQS standards whereas SO2 and NOx remained within the limit. 31.94% of TSP was found to be within PM10. Green belts were prescribed as a mitigation measure.

Erol et al. (2013) [13]examined the quartz content in respirable dust in the working faces of coal mines and evaluated the risk of getting pneumoconiosis among the workers working at coal faces. Dust samples were collected using MRE 113A dust sampler and the quartz content of the dust was determined using FTIR. The mean respirable dust concentration at most the coal faces were above the limit. Analysis of variance (ANOVA) was performed to determine the effect of workplace and seam characteristics on dust levels. They found a remarkable variation of respirable dust and quartz content at different seams and collieries.

Ghosh and Majee (2007) [14] have conducted an investigation to determine air borne dust created by opencast mines at Jharia coalfield. Particles were more respirable in nature with median diameter 20μm. Work zone air was found to contain more TSP, RPM and benzene soluble matter than ambient air. Highest concentration of SPM was found at Dragline section and the next lower concentration at haul road. At feeder TSP was found to be the highest. Respirable particulate matter was found to be highest in summer. TSP concentration at day time was found to be highest compared to other two time periods as majority of the works were done during general shifts (from 0800hrs to 1700hrs). TSP concentrations at almost all locations exceed the permissible limits by CPCB during winter, summer and monsoon period. The weight percentage of respirable fraction in haul road TSP was found to be more than that of feeder breaker TSP.

Kumari et al. (2011) [15] carried out a study to determine quartz content in airborne respirable dust (ARD) using FTIR spectrometer. Personal dust samplers were used to collect airborne respirable dust at different locations of the mine using GLA-500 PVC membrane filters. Percentage of quartz was found to be less than 1% in almost all workings at Jharia coalfield. Maximum Exposure Limit (MEL) was equal to 3mg/m3 in most of the working places. However in case of metal mines, quartz content was found to be more than 5% in many workings. It has been found that good ventilation and wet drilling controls the dust problem at some locations, whereas in some other locations rotations of workers are required.

Mukherjee et al. (2005) [16] assessed respirable dust, free silica content and personal exposure of the miners to find the risk of coal worker's pneumoconiosis in 9 coal mines of eastern India during 1988-91. MRE113 and AFC123 were used for dust monitoring and the samples were analysed in FTIR. Dust levels in the return air in both B&P and Longwall are found to be above permissible limit. Drilling, blasting and loading were the major sources of dust emissions. Exposure of driller and loader were more affected in B&P workings, while DOSCO loader, power support face worker and shearer operator were more exposed in Longwall working. In opencast mining, driller and compressor operators were the major exposed groups. The percentage of free silica is found to be less than 5% in most cases except among quarry loader and drillers in opencast mines.

Mishra and Jha (2010) [17] carried out dispersion modelling in an opencast coal mine and validated the results with the actual field data. The research was aimed for the validation of FDM model. They have assessed activity wise dust generation potential and studied distance vs dust concentration to determine impact zone of dust concentration. Major polluters were haul road and coal transportation road. Dust emission from the mine was directly proportional to the length of the transportation road and to the speed of vehicle. Fugitive dust modelling used for dust dispersion modelling was 90% accurate in predicting dust concentration. They have found that dust particles are largely deposited within 100m. Concentration decreases with increase in distance away from source and within 300m to 500m after which it reaches background concentration. Also 80% of dust generated by the haul trucks is greater than 10μm.

Trivedi et al. (2008) [18] examined different sources of dust generation and calculated dust emissions from different point, line and area sources in an opencast coal mine. They have carried out air quality modelling using Fugitive Dust Model. Dust produced by different mining activities doesn't add to ambient air quality beyond 500m. Modified Pasquill and Gifford formula was used to determine level emission rate. Predicted value of suspended particulate matter was found to be 68-92% of the observed value. An exponential fall in TSPM concentration with distance from source had been observed. Dust generation due to mining activity didn't contribute to ambient air beyond 500m. The main sources of dust emission were loading and unloading of coal, overburden and haul road.

Buchanan et al. [19] found no significant association between cumulative respirable dust and opacities 2/1+ after adjustment for quartz. However, the absolute risk for opacities 2/1+ after 15 years' exposure to nonquartz respirable dust was 0.8%.

Seaton et al. [20] found that cases (change in opacities progression of at least 1+) had been exposed to higher % quartz but lower % coal and concluded that quartz might be an important factor in the development and rapid progression of opacities.

3. CONCLUSION

The scholars have conducted various studies on sources and causes of coal dust dispersion. The findings from most of the researches have shown that the effect of coal dust on ambient atmosphere is upto 500 meters. The Fugitive Dust Model is also presented by scholars which predicted the dispersion of dust particles on ambient air and in mines with 90% accuracy. The studies conducted by international institutions like WHO has raised concerns on respiratory illness (interstitial lung disease)caused due to mining activity. The safe concentration of various suspended particles like particulate matter (PM), sulfur dioxide (SO2), nitrogen dioxide (NO2) and heavy metals are also studied.

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