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Assessment of Dust in Surface Mine at Different Working Conditions - A Case Study

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Abstract-Mining is viewed as one of the important economic activities which have the potential of contributing to the development of economies. At the same time, the environmental and health impacts of mining on surrounding communities have been a major concern to governments, the general public and stakeholder organizations and individuals. Whiles the contributions of mining activities to economic development of region is well acknowledged, others contend that the gains from the mining sector to the economy is achieved at significant environmental, health and social costs to the country. If the dust concentration at different location in and around the mining area can be measured, then the places with the potential of high concentration build-up can be identified and appropriate Protective measures can be taken. This thesis includes introduction to the dust generation in limestone mines, sources and effects of dust generation, also study of generated dust has been done on limestone mine over a time period to plot the variations in dust generation. Further, analysis of plot has been done to find the period of maximum dust generation and what preventive measures can be taken to minimize or avoid the dust generation in limestone mines. The present study was undertaken to identify Time-weighted average (TWA) respirable dust concentrations calculated for 8-hour work shifts.

Keywords-Dust, mining, operation, sampling

I. INTRODUCTION

Mining is considered one of the most hazardous professions; the health of miners has always been the center of attention of the administrators and producers of minerals. Mining in India has been going since pre-historic times and the history of mining of Zinc and Copper can be traced back to almost 6000 years as is evident from the archeological findings in Zawar, Dariba, Khetri, etc. Historians believe that large-scale mining for minerals in India started during the reign of the Mauryan dynasty. It was known for years that mine workers had a predilection for the development of lung diseases and needed special care.

Kautilya in his Arthashastra (as early as 4th century BC), while making the budget of the state mentions that a separate allocation for miners' health is required because miners suffer from a group of special diseases attributed to their occupation and it is necessary to take care of them.
During mining and processing of limestone, several 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 cases the dust produced by the mine is fugitive in nature i.e. the sources can't be easily defined and mainly consists of disturbances of the surface. Surface mining methods produce a significant amount of dust as compared to underground dust due to the use of HEMM, high mechanization, and large surface area which are vulnerable to dust production on the action of air.

In opencast mines, a huge quantity of overburden has to be removed to facilitate accessing minerals. The removal of overburden requires dumpers, shovels, and draglines, etc. which discharge an enormous quantity of fine particles into the atmosphere. Blasting operations too generate a huge quantity of dust. The closure of mine also involves loading and transportation of overburden and contributes to dust generation. The large surface area of the overburden dump is also quite vulnerable to dust production if efficient measures are not taken to suppress it.

After China, India is ranked second in terms of total worldwide limestone production and thus marks it as the most versatile mineral. India has large limestone resources distributed over different parts of the country and important raw materials for various industries, such as the construction industry, steel production, cement manufacturing, etc. Limestone is a calcareous sedimentary rock mainly composed of carbonates. Calcite and dolomite are the major mineral components of

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limestone. Limestone containing a minimum of 45% calcium oxide is generally used in cement manufacture.

1. Background of the Study:

The environmental responsibility of mining operations is the protection of the air, land, and water. Mineral resources were developed in the United States for nearly two centuries with few environmental controls. This is largely attributed to the fact that environmental impact was not understood or appreciated as it is today. In addition, the technology available during this period was not always able to prevent or control environmental damage.

Mining dust has captured people's notice for a long time. Not only for the mortal healthy effect produced by respirable dust during mineral work but also because of their environmental and nuisance effects. Particulate emissions comprise a problem in almost all forms of mining. They are produced through a range of processes starting from blasting to transporting, sample preparation, processing, and handling (Arup Environmental 1995).

The study on respirable dust has been gaining people's attention by its adverse effects. The dust with particle size below 10μm is known as respirable dust, and the environmental effects produced by such dust is apparent, such as air, soil, and water contamination by transported hazardous dust into receiving body, reduced transparency in the air by a dust cloud and surface soiling on car windows by dust settling. Due to hazardous constitutes in minerals themselves, there are toxic chemicals used in mineral processing, dust particles often contain poisonous elements.

Therefore, respirable dust is also threatening human health if people get in contact with air, soil, or water contaminated by hazardous particles. In addition, the emission of mineral dust increases the loss of raw material and surface soiling on operation machines increases maintenance cost, which both create an adverse economic effect. Therefore, we carried out this research to have people's attention on this fraction of respirable dust around the mining area.

All methods of mining affect air quality. Particulate matter is released in surface mining when the overburden is stripped from the site and stored or returned to the pit. When the soil is removed, vegetation is also removed, exposing the soil to the weather, causing particulates to become airborne through wind erosion and road traffic. Particulate matter can be composed of such noxious materials as arsenic, cadmium, and lead. In general, particulates affect human health adversely by contributing to illnesses relating to the respiratory tract, such as emphysema, but they also can be ingested or absorbed into the skin.

2. The Hazard of Dust:

Most mining operations produce dust which, when air-borne, becomes a serious hazard to the health of the workers. Besides, inflammable specks of dust, like that of coal and sulfide ores can lead to disastrous explosions. The problem of dust has been there since the early days of mining, but in recent times with the introduction of mechanization of mines, it has become a greater menace than ever, since machine operations usually throw up much more dust than hand operations do.

Dust of any Kind when inhaled in large quantities leads to the development of respiratory diseases such as chronic bronchitis and pneumoconiosis. Pneumoconiosis is a general term used for occupational lung diseases due to dust and has been redefined by the ILO working group in 1971 as the accumulation of dust in the lungs and tissue reactions to it. Specific names such as silicosis, asbestosis, siderosis, talcosis, etc. have been used to indicate pulmonary diseases caused by specific dust such as silica, asbestos, iron oxides, talc, etc.

3. Statement of the Research Problem:

The limestone mining process produces high concentrations of dust and therefore, exposes the workers to various respiratory and pulmonary diseases due to dust inhalation. When deposited on the skin and in the eyes the dust may cause skin and eye irritation depending on the chemical composition and the concentration of the dust.
The health condition may worsen where the workers are ignorant of these risks and thus do not appreciate the importance of using protective clothing and gear when provided at work. The longer exposure to dust, especially at the point sources, and the many years they have worked in mining expose the workers to respiratory and pulmonary diseases and are also at high risk of developing silicosis (Langer et al., 2004).

4. Objectives of the Project Work:

The research aims are to make people believe that there is an urgent need to start the study on the dust around the mining area. This statement is proved by presenting the impacts of mining dust from various aspects, meanwhile, we described a well-developed study on respirable mining dust and there are merely a few people paying attention to the fraction of mining dust.

Several objectives were identified in support of this aim and they are presented at the bullet points below.

- This project aims to understand measure and evaluate how dust is produced from processes that take place in a mine.
- To compare the results obtained from the various processes and to identify their critical differences.
- Comparison of the winter concentrations data with summer of same year.

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- How do different mechanisms associated with common industrial processes influence the generation of ore particulates.
- To know whether the environment is harmful or not by comparing with the environmental standards.

5. Significance of the Study:
Dust inhalation by the workers exposes them to respiratory and pulmonary problems. The workers may develop silicosis if they are exposed to dust containing crystalline silica over long periods. It is, therefore, necessary to study the dust and address the health risks that the dust poses to the mineworkers. It is envisaged that this report has come up with information and results that are useful to different users. The outcome of the study may be useful literature for other similar studies.

6. Scope and Limitation of the Study:
The study focused on limestone mining. The study analyzed the dust concentration and the concentration of the elements identified in the mine dust. The study area had covered category A & B opencast limestone mechanized mines situated on hilly terrain. All their activities including rock drilling, blasting, loading, and hauling known point sources of the dust were at the study area.

II. LITERATURE REVIEW

Dust is a generic term used to describe fine particles that are suspended in the atmosphere. A range of definitions may be found in the literature which discriminates between different particulate characteristics.

Ghose and Majee (2000) assessed dust generated due to opencast mines. Emission factor data was used to quantify the generation of dust. The main sources of air pollution were identified. It was estimated that topsoil removal, overburden (O/B) removal, extraction of coal, size reduction generated 7.8tonnage of dust per day. Wind erosion generated 1.6 t of dust per day and the whole operation produced dust which accounted for 9.4 t/day. This caused air pollution in the work zone and surrounding locations. This methodology may be used to quantify generation for other projects also.

Ghose and Majee (2001) observed that in India, Opencast mines contribute their highest share in air pollution. To keep track of the local atmosphere impact, a survey was conducted by them taking emissions data which were utilized to find out the dust generation due to various mining activities. They noticed that the air pollutants coming from mines and their seasonal fluctuations in their quantity had high pollution potential and a greater negative impact on human health. They have given a lot of control measures to deal with this situation and even chalked out 'afforestation and tolerating capability of trees' against the dust particulate matter. They emphasized the need for utilization of different chemicals to minimize the air pollutants coming from haul roads and stated that a pollution-free environment can be achieved by implementing suitable abatement measures.

Chakraborty et al. (2001) carried out a detailed study to predict the emission rates of various mining activities in opencast mines. Seven different coal mines and three iron mines were selected by them based on different parameters like geographical location, accessibility, working conditions, etc. to study the emission rates. 12 empirical formulae were developed to estimate the NOx and SO2 emission rates for different opencast mining activities. Results were validated at the Rajpura opencast mine and the data obtained were found to be of good accuracy ranging from 77.2% to 80.4%. The authors also found that suspended particulates have the highest contribution to the total pollution created in the mine and the contribution of NOx and SO2 was negligible in that respect. The results obtained by the authors proved to be of great significance to the environmental engineers for air quality monitoring.

Ghose and Majee (2007) during the study successfully quantified the amount of dust generated from various opencast mining projects. The assessment carried out by the authors involved the usage of emission factor data for the quantification of the amount of dust generated. The results obtained showed that wind erosion and coal handling activities are the major sources of dust in opencast mining projects. The authors also showed that the heavy mechanization of the opencast mines, under high productivity demands, is the major source of air pollution in those mines. The emission factor suggested in this work could be used for the accurate estimation of dust generated by various activities in an opencast mining project.

Trivedi et al. (2009) examined different sources of dust generation and quantified dust emission rates from different points, areas, and line sources considering background dust concentration at one of the opencast coal projects of Western Coalfields Limited. Air quality modeling using the Fugitive Dust Model revealed that dust generated due to mining activities did not contribute to ambient air quality significantly in surrounding areas beyond 500 m in normal meteorological conditions. Predicted values of total suspended particulate matter were 68 – 92 % of observed values. They formulated a management strategy for effective control of air pollution at source and other mitigative measures including green belt design were also recommended.

Mishra and Jha (2010) carried out dispersion modeling in an opencast coal mine and validated the results with the actual field data. The research was aimed at the validation of the FDM model. They have assessed activity-wise dust generation potential and studied distance vs dust concentration to determine the impact zone of dust

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concentration. Major polluters were hauling road and coal transportation roads. Dust emission from the mine was directly proportional to the length of the transportation road and the speed of the vehicle. Fugitive dust modeling used for dust dispersion modeling was 90% accurate in predicting dust concentration. They have found that dust particles are largely deposited within 100m. Concentration decreases with an increase in distance away from the 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.

The volume and variety of air-borne dust particles in the ambient air are ever-increasing and causing air pollution problems in the surrounding areas. It has also been reported that vehicular traffic on haul road of mechanized open cast mines can contribute as much as 80 percent of dust emitted. It has also been reported that about 50% of total coal dust is released during journey time on an unpaved haul road, while 25% for both during loading and unloading of dumper Gruber et al. (2011).

Drilling is perhaps the next important source of fugitive dust. Another major source of fugitive dust is wind erosion from coal stockpiles.

Mandal et al. (2011) analyzed that majority of air pollutants that are contaminating the atmosphere trace their source from the haul and transport roads in coal mining areas thus enhancing different health problems. As high as 93.3% of total generated dust comes from haul roads of South African coal mines, according to the analysis carried out by Amponsah-Dacosta using USEPA guidelines. Due to the partial failure of the available techniques, the dust doesn't get removed from the haul road completely.

Erol et al. (2013) 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 an MRE 113A dust sampler and the quartz content of the dust was determined using Fourier Transmission Infrared Spectroscopy (FTIR), FTIR. The mean respirable dust concentration at most of the coal faces was 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.

Dust emissions from mineral sites can affect the environment, agriculture, and ecology of a region. The principal cause of dust emission at mineral workings is wind blow, which lifts specks of dust from the surfaces, disperses them, and deposits them away from the source. Weather conditions (i.e. rainfall patterns, atmospheric turbulence, seasonal changes, etc.) and topography are also determinative parameters to the dust emission process (Office of the Deputy Prime Minister 2005). Materials-related properties like moisture content and rock type can significantly affect uncontrolled emission levels (US EPA 1998b).

Dust deposition is one of the major environmental impacts resulting from particulate emissions from mineral sites. Deposition rates are related to the size of the airborne particles. Research has shown that large particles (> 30µm) deposit within 100m of sources of dust, intermediate-sized particles (10 – 30µm) are likely to travel up to 200 – 500 m whereas smaller particles (<10µm) can travel up to 1 Km. Dust deposition is greatly influenced by weather conditions and topographical characteristics (Office of the Deputy Prime Minister 2005).Nuisance from surface soiling is determined by the color contrast between the deposited dust and the surface, "the cleanness" of the surface before settlement, public opinion, and any other special characteristics of the area (MIRO 2005).

The effects of bags of dust on the agriculture and ecology of an area are determined by the concentration of dust particles in the ambient air, their size distribution, the deposition rates, and the chemistry of the dust. These factors can influence the chemistry of the soil and the health of surrounding plants, the meteorological and local microclimate conditions, as well as the penetration rate of dust into vegetation (Arup Environmental 1995). Apart from vegetation, dust deposition can affect animal communities and woodlands (Balkau 1993).

Dust is one of the largest occupational hazards and it has been one of the largest occupational killers through the years. Whenever materials are handled or broken down, dust is liable to be produced (Trade Union Congress 2001). Exposure to any dust in excessive amounts can create respiratory problems.

Different clouds of dust may affect the body in different ways and may cause harmful effects through the skin or eye contact and ingestion, as well as by inhalation (depending upon the individual physical and chemical properties of dust) (Health and Safety Executive 1997).

Dust can also cause many diseases, the commonest of which associated with mining activities and individuals, are (Trade Union Congress 2001; World Health Organization 1999):

- Lung damage such as pneumoconiosis and in particular silicosis, asbestosis, CWP (coal workers pneumoconiosis) as well as cancer.
- Damage to the nose, throat, and eye.
- Damage to the skin: Dust may cause various types of dermatitis, which are a widespread and often serious problem or even skin cancer (e.g. cement)

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- Systematic poisoning and skin absorption: It can occur if water-soluble materials dissolve in sweat and pass through the skin into the bloodstream, (e.g. lead).
- Gastrointestinal tract irritation through ingestion: It is likely when poor hygiene allows eating, drinking, or smoking in contaminated or dirty workplaces.
- Irritation and inflammatory lung injuries. Certain dust may cause chronic bronchitis, which can lead to chronic emphysema (e.g. chromium compounds and manganese)
- Allergic reactions like occupational asthma or in the skin like rashes and eruptions. (e.g. cobalt, platinum, chromium, nickel, etc.)

Dust can affect safety at work leading to reduced visibility in the workplace and therefore the nuisance value of such concentrations should not be underestimated (SIMRAC 2003). Dust can also minimize productivity and cause product damage. It adheres to machinery and products reducing the life cycle of equipment, modifying the properties, and minimizing the value of the commodities (Maxwell 1999). For instance, dust that contains high concentrations of silica can be abrasive, leading to the wear of equipment (Wilkinson et al. 1989).

Personal sampling provides essential information on occupational health and human exposure patterns, which is beneficial for the prevention and controlling of dust and employer's exposure (Martin Marietta Corporation 1987). Different instruments are needed according to whether respirable or inhalable dust is to be collected (Health and Safety Laboratories 2000).

The personal sampling apparatus need to facilitate the breathing zone of the human. The essential features of all systems are a collection substrate such as a filter and a pump for pulling the air through it (Health and Safety Laboratories 2000).

Personal protective equipment should be used when all control possibilities have been explored but they do not provide adequate protection. Personal protective equipment (PPE) includes respiratory protective equipment, protective clothing, and other accessories used in workplaces. It is mainly provided for welfare purposes and it should not be considered as a control measure except as a last resort (Trade Union Congress 2001). When considering personal protective equipment, the dust characteristics need to be taken into account. The use of personal protective equipment requires hazard awareness and training on the part of the user. Employers and employees must understand the equipment's purpose and limitations (US Department of Labour and Occupational Safety and Health Administration 1998). Maintenance and replacement shall take place at a right time or otherwise their use will not provide maximum protection.

Dust measurements in real operating conditions are demanding due to a large number of variables, such as weather conditions, study setup, and measurement points, influencing the results. Because dust measurements in quarries indicate highly varying results (Sairanen et al., 2018), studies of similar setups in diverse types of quarries are needed to better understand dust emission, concentration variation, and dust concentration decrease with increasing distance.

1.Dust Measurement Standards:

National Ambient Air Quality Standards (NAAQS) has notified so many versions related to ambient air dust monitoring in which the fourth provision was related to the air (Prevention & Control of Pollution Act), 1981. The aim of the central pollution control board (CPCB) is to provide uniform air quality to the entire area and irrespective use of land Patterns across the whole over the country.

There are so many parameters in the ambient air that affect the human body, some of those parameters are shown below according to their CPCB limits.

Table 1.National Ambient Air Quality Standards: Revised CPCB National Ambient Air Quality Standards (NAAQS notification, dated 18.11.2009).

S. N.	New Standards (Schedule VII, Rule 3 (3B) 18th Nov 2009				
	Pollutant	Time weighted Average	Industrial AreaResidential,Rural & otherAreas	Ecologicallysensitive area(Notified byCentral Govt)	Methods of measurement
1	SulphurDioxide (SO2)	Annual Avg*	50.0 µg/m3	20.0 µg/m3	-Improved West and Gaeke method
		24 hours**	80.0 µg/m3	80.0 µg/m3	-Ultraviolet fluorescence
2	OxidesNitrogenNO2 Ofas	Annual Avg*	40.0 µg/m3	30.0 µg/m3	OxidesNitrogen NO2ofas

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		24 hours**	80.0 µg/m3	80.0 µg/m3	Chemiluminesc ence
3	ParticulateMatter(si zeLess thanThan10um)	Annual Avg*	60.0 µg/m3	60.0 µg/m3	-Gravimetric
		24 hours**	100.0 µg/m3	100.0 µg/m3	-Beta attenuation
4	Particulate Matter (sizeless than2.52.5um	Annual Avg*	40.0 µg/m3	40.0 µg/m3	-Gravimetric -TOEM
		24 hours**	60.0 µg/m3	60.0 µg/m3	-Beta attenuation
5	Lead (Pb)	Annual Avg*	0.50 µg/m3	0.50 µg/m3	-AAS/ICP method for sampling on
		24 hours**	1.0 µg/m3	1.0 µg/m3	EPM2000 or Equivalent Filter paperED-XRF using Teflon filter paper

Annual Arithmetic mean of minimum 104 measurements in a year taken twice a Week 24 hourly at uniform interval,

** 24 hourly / 8 hourly or 1 hourly monitored values as applicable shall be complied with 98 % of the time in a year. However, 2% of the time, they may exceed the limits but not on two consecutive days of monitoring.

In order to ensure that the work place is safe for the workers to work continuously for a period of eight hours in a shift, many studies and investigations have been carried out world over and the maximum exposure limits (MELs) have been prescribed. In India, the MEL is prescribed as 3 mg/m3 for eight hour time-weighted average provided the concentration of silica in the respirable dust remains less that 5%. In case the % of Silica content in the respirable dust exceeds 5, the MEL is calculated to be 15 divided by the % of Silica content in the respirable dust. Regulation 123 of the Coal Mines Regulations, 1957 as well as regulation 124 of the Metalliferrous Mines Regulations, 1961 clearly specify provisions therefor.

It is advised that the mine management should ensure that the workers are not exposed to respirable crystalline silica dust concentrations above this level. If exposure cannot be controlled to 0.1 mg/m3 (8-hour TWA) or below, by elimination, engineering or process control, then the exposure must be controlled by provision and use of suitable respiratory protective equipment as provided under sub regulation (4) of regulation 123 of the Coal Mines Regulations, 1957 and that of the Metalliferrous Mines Regulations, 1961.

III. INSTRUMENT STUDY

Dust sampling is capturing the contaminant from a known volume of air, measuring the amount of contaminant captured, and expressing it as a concentration. The air is passed through a filter medium. The volume of air is measured against the amount of contaminant captured. This gives the concentration, which is expressed either as milligrams per cubic meter (mg/m3).

The volume of air is calculated by multiplying the flow rate through the filter medium by the time in minutes. Calibration of the flow rate is important and should be carried out before and after each sample is taken, where the flow is often set at around 2 litres per minute achieved using a rotameter. Battery operated pump to a filter medium is preferred as it is capable of drawing air through the filter at a constant rate for a time above 8 hours, even in adverse conditions. These criteria are based on the recommendations that samples should be taken on a personal basis for an 8 hour Time Weighted Average (TWA).

Dust is split into three size ranges, which have different effects on the respiratory system of a human being namely inhalable fraction up to 100 microns, thoracic fraction up to 30 microns and respirable fraction up to 12 microns. The smaller the particle the deeper into the lungs it can penetrate where it can settle onto the lining and cause respiratory illness, for example, a well-known problem caused by respirable dust is Silicosis in the mining

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industry. The respirable fraction of airborne dust is the dust that reaches the lungs and leads to the development of silicosis. Respirable dust cannot be seen with the eye. Conversely, if a dust cloud is visible, a portion of the airborne dust will likely be in the respirable size range. To quantify the amount of harmful respirable dust that is in the mine air, sampling instrumentation must be used.

Fig 1. Personal dust sampler for use in mining.

1.Data Collection Instruments and Procedures:
This sampler consists of a constant-flow sampling pump, a size-selective cyclone, and a filter cartridge. In metal/nonmetal mining operations, the pump should be operated at 2.0 lpm. Cyclone separates the oversize dust from the respirable fraction (usually considered to have an aerodynamic diameter of 10 microns or less). The oversize dust is deposited into the grit pot at the bottom of the cyclone, while the respirable fraction is deposited onto a 37-mm-diameter polyvinyl chloride (PVC) filter.

Care must be taken after a sample is collected to ensure that the cyclone assembly stays in an upright position. Otherwise, the oversize dust particles that are in the grit pot can be deposited onto the filter and invalidate the sample. The filter collects the respirable dust and is weighed to determine the mass of dust that has been collected during sampling. The mass of dust and the volume of sampled air is used to calculate the average concentration of respirable dust in mg/m3.

Fig 2. Cassettes with the filter inthe desiccators.

Calculation of the volume of air sampled:
Volume of air sampled = Sample flow rate x sample time
Example: Flow rate = 2 l/min
Sample time = 8 hours = 8 x 60 = 480 minutes
Volume of air = 2 (l/min) x 480 (minutes) = 960 litres
Volume of air = 960 / 1000 = 0.96 m³ (cubic metres)

Calculation of time weighted average (TWA):
To determine an 8 hour TWA from more than one sample within any 24 hour period:

$$TWA = \frac{(C1 \times T1) + (C2 \times T2) + ...(Cn \times Tn)}{8}$$

Where C is the occupational exposure and T is the time for that exposure.

Example: An operator is exposed to 0.12mg/m³ for 7 hours and 20 minutes.

The 8 hour TWA is therefore 7h20min @ 0.12mg/m³ (C1 x T1) plus 40min at 0mg/m³ (C2 x T2).

$$TWA = \frac{(0.12 \times 7.33) + (0 \times 0.67)}{} = 0.11 mg/m^3$$

2. Sampling Strategies:
To quantify the amount of dust liberated by a source, area dust sampling can be conducted in a manner that isolates the potential dust source. This is achieved by placing dust samplers at the source in question and utilizing the difference between these sampling results to determine the quantity of dust liberated by the source. When personal dust samplers are used for the evaluation, the samplers must operate long enough to ensure that sufficient mass is collected during sampling.

For quantifying exposures for an operator of a more mobile piece of equipment, the use of a dust sampler would be beneficial to quantify dust exposure from multiple sources. The dumper operator would be exposed to dust generated during loading of the truck, hauling to and from the dumpsite, and during the dumping of the load. Similarly, the excavator operator would be exposed to the dust generated from loading minerals as well as for overburden. A personal dust sampler was mounted near the operator's compartment on the dumper to monitor dust exposures throughout the normal haul cycle.

This sampler overcomes some of the difficulties encountered with other sampling devices. It is less prone to the effects of air movement around it than others and utilizes a cassette rather than just a filter paper.

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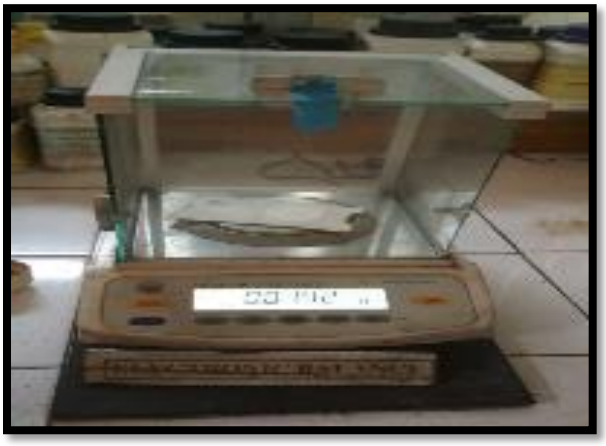

Fig 3.Weighing thefilter paper.

It is important that when a sample is taken the cassette and filter paper are pre and post weighed as a single unit. By doing this all the dust on both the filter paper and on the internal walls of the cassette are included. The two halves of the cassette clip together and can be separated with gentle pressure.

Once separated a filter can be placed in the support grid. The cassette is replaced into the body of the sampler and the front plate screwed on firmly so that all of the O ring seals are compressed, thus ensuring there are no leaks.

3. Construction of Sampler:

It is important that when a sample is taken the cassette and filter paper are pre and post weighed as a single unit. By doing this all the dust on both the filter paper and on the internal walls of the cassette are included. The two halves of the cassette clip together and can be separated with gentle pressure.

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3. Construction of Sampler:

Fig 4. Dust sampler assembly.

Mount one of the filter papers into the cassette. Place the cassette into the sampler body and screw on the front cover and connect the sampler with filter paper fitted, to the sample pump using the flexible tubing.

Fig 5. Flow rate adjusting through screw driver and rotameter.

To set the flow rate required, in this case, 2.0 litre/minute, a flow calibration device such as a Defender primary calibrator or a rotameter is used as shown in the above images, the pump flow rate is adjusted using the smallest bladed screwdriver attachment of the toolkit supplied with the pump. Lift the hinged clear cover on the top of the pump, and switch on the pump using the on/off push-button. Once the flow is set to the required level of 2.0 litre/min, switch the sample pump off.

Thereafter, the sampler is mounted onto the worker who is to wear it during the sample. The sampler should be mounted as close to the breathing zone as is practical and comfortable. The pump can be clipped to a belt or placed into a pouch. Once the pump is adequately mounted on the worker, remove the cassette cover and switch on the pump noting down the start time of the sample.

Fig 6. Sampler mounted to driller.

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At the end of the sample switch off the pump, note the finish time of the sample. Remove the filter cassette from the sampler and post weigh the filter and cassette. The sample is then sent to a laboratory for further analysis, the cassette is refit to cover and fit a cassette clip.

The start and finish times, sample duration, worker's name, start and finish flow rates pre and post sample weights and any other relevant details of the sample should be noted down and indexed to the filter paper or cassette by number or code.

4.Static Dust Monitoring Instruments:

The Gravimetric method of dust sampling is used to measure the quantitative amount of airborne dust which is collected from the different workplaces. These measurements are carried out to estimate occupational exposures to evaluate the efficiency of air pollution control technology. The gravimetric sampling technology is a method in which air is gone through the channel and this channel is the filter paper whose initial and final weight would be calculated to analyse the dust concentration. The sampling instruments are given below:-

4.1 Envirotech APM 550 NL: In these forms of air samplers, the dust particles of PM2.5 can be measured. That is also known as the fine dust particle sampler. The dust particle of 2.5 microns or less can be measured by this instrument. In this, the ambient air enters the downward-directional in APM 550 series sampler to provide a clean aerodynamic cut-point for particles that are greater than 10 microns in size.

Particles in the air stream which are smaller than 10 microns proceed to a second impactor chamber, which has an aerodynamic cut-point at 2.5 microns where the filter paper of 47mm diameter is placed. The particle which has a diameter of more than 2.5 microns are collected on this and the remaining air stream would come out from the below part. It can be worked with a single individual sampling pump.

Fig 7. PM 10 Sampler (Envirotech APM 550 NL).

4.2 Envirotech APM 460 NL: The Envirotech APM 460 NL is used for the PM10 and heavy particular mater in the cyclone. In this, at the top, a filter paper of (8"x10") is used for the collection of PM10 size particles and the larger particles go down into the cyclone bucket. As shown in the given Fig. 4 after proper supply of power through the motor the air passes completely through the samplers and the filter system.

Fig 8. PM2.5 Sampler Envirotech APM 460 NL.

The filter paper is pre-weighted by the weighing machine and then starts the machine. Then after the completion of 24 hours, the difference in the filter paperweight gives the particular dust mass. In this, the difference of mass is divided by the volume of air sampled which gives the concentration of TSP.

The upper chamber of the sampler collects airborne particles from 10 to 100 micrometers (μm) in diameter, the PM10 Particles are collected on the filter paper and the large particles go down in the cyclone. high volume dust samplers are also used to measure total suspended particles and the gases or chemical elements present in the atmosphere which are harmful to human health for example the measurement of SO2, NO2, CO etc.

5. Field Monitoring Investigations And Laboratory Work:

5.1 Sampling and the analysis of PM10 with Envirotech APM 460 NL:

In this methodology first of all a fresh filter paper is selected of the size of 20.3cm x 25.4 cm (8"x10") and the air drawn through a size particular. The ordinary flow rate would be 1132 L/min. The process of sampling would be done for the entire shift or for a day the particles that are less than 10 microns in diameter or equal to them are collected on the filter paper after sampling. The flow rate would be in the range of 1.02-1.24 m3/min. The mass of PM10 concentration can be calculated with the difference of the weight of filter paper before and after sampling.

The flow rate would be in the range of 1.02-1.24 m3/min. The mass of PM10 concentration can be calculated with

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the difference of the weight of filter paper before and after sampling. It suggests that as the mass weight increases, the concentration of PM10 increases. The concentration of the PM10 is calculated by the weight gain in the filter paper to the volume of air sampled.The concentration of particulate matter 10 can be given by the following formula which shows the presence of dust in µg per cubic meter.

Concentration of PM10 (µg/m3) = (Wf - Wi) x 106/ V

Where,
PM10 = Concentration of PM10, µg/m3
Wf = Initial weight of filter in gm
Wi = Initial weight of filter in gm
106 = Conversion of gm to µg
V = Volume of air sampled, m3

IV. STUDY AREA

This chapter discusses the study area, research design, sampling design, data collection methods and instruments and analysis techniques. It also gives a brief on the geology of the study area.

The airborne respirable dust survey was carried out in the state of Rajasthan. The study area has two well-known open cast limestone mines which manufacture basic raw materials for cement production. The mines are fully mechanized with the use of HEMM & deep whole blasting. The Lease Area of Mine1 is 468.6875 Hectares and Mine2 is 256.0 Hectares, both of the mines producing 8MT and 1MT respectively.

The Area falls within Survey of India No. 45 H/1 Toposheet. Mine1 Lies between latitudes N 24048'25" & N 24050'15" and longitudes E 73006'00" & E 73008'00" whereas Mine2 Lies between latitudes N 24048'30" & N 24050'20" and longitudes E 73008'07" & E 73008'59"

1. Geological Succession:
Geologically the limestone deposits of the area belong to the Ajabgarh Group of Delhi Super Group, and can be classified as "Intricate type" as per CRI (NCBM) Norms. The area is mostly hilly with long and high hills. The hillocks are isolated and scattered in a continuous long belt. The NW side of the lease area is steeply sloping up to the valley level and beyond this, there is a vast flat barren land. Towards SW, the slope is gentle and beyond the lease area, there are some irrigated fields and barren land. The main geological formation exposed in the deposit is crystalline limestone which is exposed in almost the entire lease area in the form of hills and valleys aligned in the general trend of NE-SW which is parallel to the regional trend of the Delhi Supergroup.

The other rock types present in the area are phyllite and mica-schist followed by small hillocks of weathered mixed gneisses further down southwest. The area has been intruded by the synorogenic and post-orogenic intrusives such as pegmatites, amphibolites and quartz veins. Fig.4.1 shows the location of mines on the map of India whereas fig.4.2 and fig.4.3 simultaneously shows the mining site of Mine1and Mine2 respectively.

Fig 9. Location of Opencast Limestone Mine project.

Fig 10. Working site of Mine 1.

Fig 11. Working site of Mine 2.

Mining work is carried out over 24 hours a day in three shifts. Shift A operates between 06:00 am to 02:00 pm, shift B operates between 02:00 pm to 10:00 pm and shift C operates between 10:00 pm to 06:00 pm. There is an additional (overlapping) shift for various administrative

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and general maintenance works, which operates between 08:30 am to 05:30 pm.

2.Study of Dust Generation:

2.1 Dust Sampling:

We have seen that air-borne dust is of considerable danger to the health of miners. To affect suitable preventive and suppressive measures for analyzing dust in a mine it is essential to have a suitable device to estimate or sample air-borne dust likely to be breathed by miners.

The following facts must be considered in the choice of sampling instrument:

- Whether the parameter of dust assessed is a true measure of the danger to health. This necessitates that the sample should be able to give a knowledge of the necessary dust concentration in the dangerous size range. Mass concentration of the respirable fraction of the dust is widely accepted today as the relevant concentration.
- The duration of sampling should be such that to give a true picture of the dustiness of any mining operations or place of work without necessitating a large number of samples to be taken. The Present trend is to obtain a sample over a complete shift.
- The sample should be representative of the dust cloud in the breathing zone of the worker.
- The sampling instrument should be easily portable and robust for rugged conditions and should require minimum maintenance, operated with minimum skill, should have a self-contained power supply and should render the measurement of dust in as little time as possible without involving too much accessory work.

3. Duration and Interval of Sampling:

Dust production in any mining operation varies a great deal with time and the variation is greatly irregular due to irregularities in normal cycles of operation. Hence the time and duration of sampling should be very carefully chosen to give a fairly accurate estimation of the dustiness over a long time.

A true estimate can however be obtained by a continuous sampling device working over the whole shift or even several shifts. From this, a true shift mean or, in general terms, a true period means can be obtained.

While considering the positioning of sampling points, it must be borne in mind that the uniformity of distribution of dust in an airstream is dependent on the uniformity of flow in the airway and to order to get a representative sample, it is necessary to collect the sample in straight portion of the airway at least ten diameters away from any bend or major obstruction. The best sample having direct relevance to health hazards is one collected at the breathing point of the worker. This has led to the development of personal dust samplers which collect a sample of the respirable dust fraction over a sufficiently long period, usually a shift.

4. Personal Dust Exposure Sampling:

Generally, workers keep on moving in the mine throughout the shift period for which it is difficult to monitor the exposure of workers to dust through any ordinary dust monitoring instruments. Hence personal dust sampler is used to determine the occupational exposure of the worker to dust. It is a portable instrument operated in battery power capable of measuring both total suspended particles and respirable particles for a total shift of 8 hours. It is a lightweight instrument hence can be easily used by the workers. It can be mounted on the body of the workers through a belt and clip. The flow rate can be maintained as per the breathing rate of the human being.

Different sources of dust generation in the mine e.g. loading point, drilling, dumping, blasting operation, haul road and transportation roads were chosen for monitoring. Personal Dust Exposure of different workers associated with mining operations was measured using, UK make Personal Dust Sampler Sidekick 224-51MTX from SKC Ltd is used to check dust dose of individual employees susceptible to dust exposer. The flow rate was maintained at 2.0 l/min for the duration of the exposure. Cyclone was used to measure dust within the respirable zone i.e. within 5 µm. The Table shows the exposure of dust of different workers of the mine. As per MMR 124, a place shall be deemed to be in a harmless state for a person to work if the weighted average concentration of airborne respirable dust during an 8-hour shift is less than three.

Airborne personal respirable dust samples from different working locations /operations /operators in the mine1 were collected by using DGMS approved dust sampling instrument Sidekick 224-51MTX from SKC Ltd. It was observed that the 8 hours' Time Weighted Average (TWA) permissible limit for respirable dust in all the sampled locations was within the permissible limit (i.e. 3 mg/m3) as prescribed under Regulation 124 of Metalliferous Mines regulation 1961.

Table 2. Personal Dust Exposure of Different Persons

Person	Initial wt.of filter	Final wt. of filter	C1	C2	Avg flow rate (l/min)	Total Time (Min)	Duration(Hrs)	Vol of Air sampled (m3)	Respirable Dust Conc. (mg/m3)	TWA

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	A	B	(B-A)		F	T	T1	F*T*0.001	R	(T(C1*T1)+(C2*T2))/8
Drill Operator	13.5	16.3	2.80	0.00	2.00	400	6.67	0.80	3.50	2.60
ExcavatorOperator	11.6	13.6	2.00	0.00	2.00	400	6.50	0.78	2.56	1.51
Dumper Operator	11.4	12.7	1.30	0.00	2.00	405	6.75	0.81	1.60	0.96
Blast Helper	12.3	14.2	1.90	0.00	2.00	180	3.03	0.36	5.18	0.71

The drill operators were exposed to a mean respirable dust concentration of 3.45 mg/m3 which is relatively on the higher side. The respirable dust exposure level for the excavator operator ranged between 1.0 mg/m3 to 1.96 mg/m3 with a mean concentration of 1.51 mg/m3. The dumper operators were exposed to dust concentrations ranging between 0.96 mg/m3 to 1.38 mg/m3 with a mean dust concentration of 0.96 mg/m3. The blasting helper was exposed to dust concentrations ranging between 0.56 mg/m3 to 0.83 mg/m3 with a mean dust concentration of 0.71 mg/m3

Fig 12. Personal dust monitoring of Drill Operator.

Fig 13. Personal dust monitoring of Excavator Operator.

Fig 14. Personal dust monitoring of Dumper Operator.

Observations

Table 3. Dust Concentration at Mine 1.

Respirable Dust Concentration(mg/m3)				
Month	Drill	Excavator	Dumper	Blasting
April	3.14	2.44	1.83	5.00
May	3.47	2.56	1.73	5.41
June	3.67	2.80	1.36	5.26
July	3.91	2.82	2.30	6.11
August	3.64	2.91	2.18	5.68
September	3.89	2.67	1.95	6.11
October	3.75	2.43	1.87	4.17
November	3.17	2.40	0.97	4.72
December	3.45	2.43	1.60	5.00
January	2.86	2.16	1.08	4.44
February	3.59	2.37	1.34	5.28
March	3.50	2.03	0.83	5.00
Avg	3.50	2.50	1.59	5.18
Max.	3.91	2.91	2.30	6.11
Min.	2.86	2.03	0.83	4.17

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Table 4. Respirable TWA conc. at Mine 1.

Time Weighted Average				
Month	Drill	Excavator	Dumper	Blasting
April	2.42	1.71	0.69	0.68
May	1.88	1.63	1.02	0.77
June	2.39	1.96	0.93	0.79
July	3.45	1.79	1.31	0.83
August	2.93	1.89	1.38	0.81
September	3.28	1.00	1.37	0.83
October	2.50	1.39	1.09	0.56
November	2.22	1.41	0.53	0.64
December	2.54	1.39	1.10	0.68
January	2.10	1.23	0.62	0.60
February	3.16	1.43	0.94	0.71
March	2.33	1.32	0.61	0.68
Avg	2.60	1.51	0.96	0.71
Max.	3.45	1.96	1.38	0.83
Min.	1.88	1.00	0.53	0.56

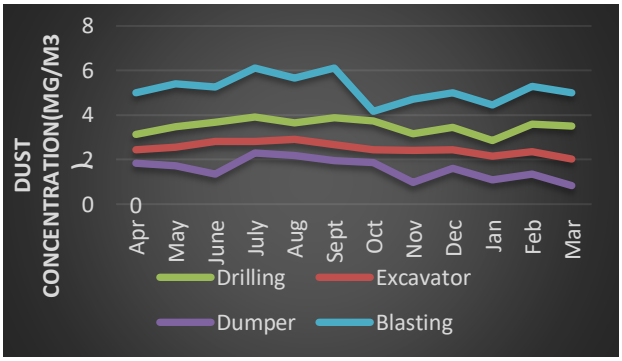

Fig 15. Plate 4.1: Respirable dust conc. Monthly.

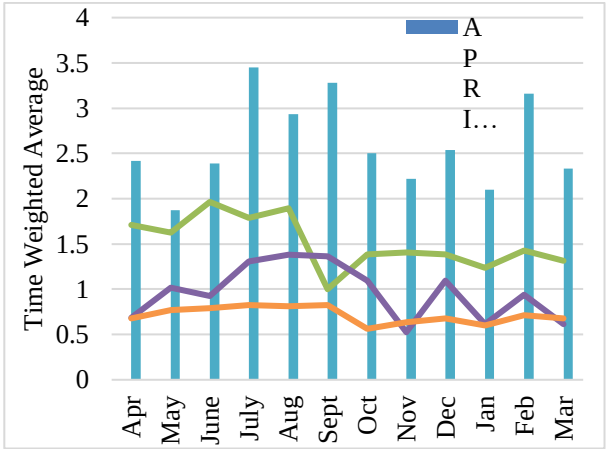

Fig 16. Plate 4.2: Respirable TWA conc. monthly

This graph shows dust generations by drilling, excavator, dumping and blasting in different months over a year. As it can be seen the maximum dust concentration is in the months of June, July and September as the temperature during these months is higher than in other months. In the winter season that is from November to February, there is a slight decrease in dust concentration and least in the case of the rainy season because in the rainy season dust is suppressed and the spreading of dust reduces, hence dust concentration also reduces. This plot is a combined observation of dust concentration of various seasons on a monthly basis which provide a proper idea for analyzing dust generation in limestone mines and helps in reducing dust pollution and increasing work efficiency.

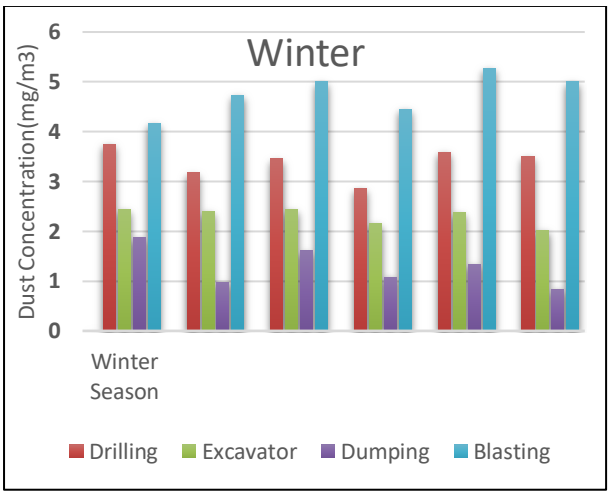

Fig 17. Plate 4.3: Comparison of dust concentration in winter season.

Dust concentration in the above graph is observed during the winter season by comparing dust generation due to various machines used in the mining process. In the winter season, with a decrease in temperature, the amount of dust generation and spreading also decreases but it remains suspended into the atmosphere due to fog, which creates an uneasy environment nearby dust sources. Also, it can be stated from the graph that the maximum amount of dust concentration in mines is due to blasting followed by drilling, excavator and dumping.

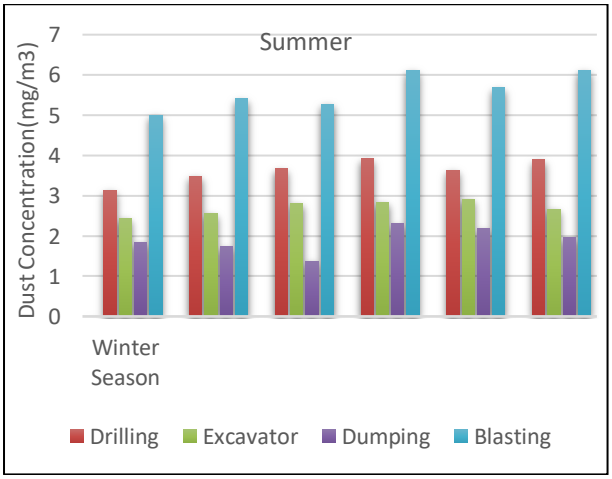

Fig 18. Plate 4.4: Comparison of dust concentration in summer season.

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In this graph, dust concentration is observed in the studied area in the summer season for various mining operations. Dust concentration in the summer season is recorded higher than that in the winter season by each machine because in summer huge amount of dust is generated all over the atmosphere. Water spraying also becomes inefficient in summer, as the higher temperature dries out the surface early. Therefore, dust control is needed in this area and hence proper analysis of dust generation helps in better dust control.

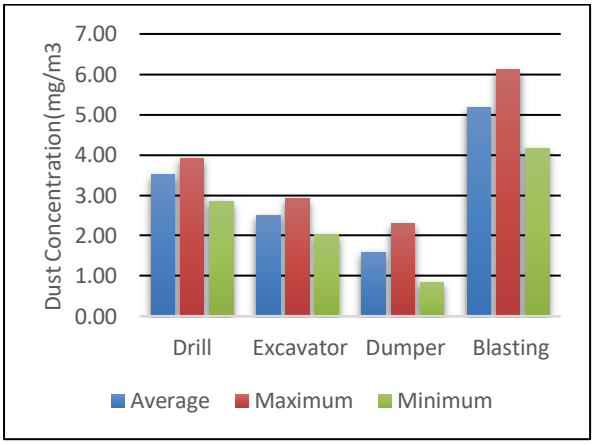

Fig 19. Plate 4.5: Respirable dust Concentration (Max., Avg., and Min.) in studied area.

In the above two plots comparison of dust, generation is seen on a seasonal basis that is between winter and summer season. This data is observed annually in the studied area that is an overall analysis of dust concentration in limestone mine. Average, minimum and maximum reading of dust concentration is recorded annually for different machines used in mining, least in the case of dumper to a maximum in the blasting process. This data helps to predict that in which period over a year dust generation is maximum and which mining operation generates the maximum amount of dust. Therefore, makes dust control easier and helps in reducing dust pollution in mines.

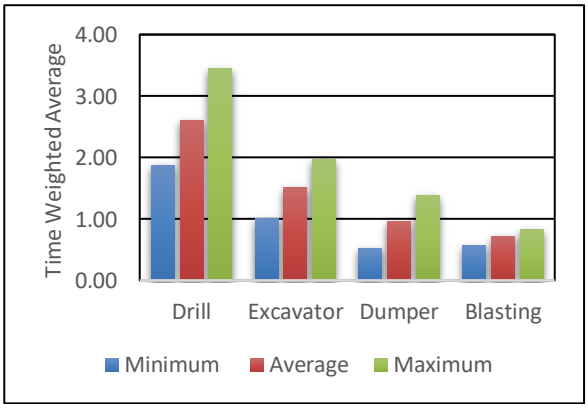

Fig 20. Plate 4.6: Time Weighted Average (Max., Avg., and Min.) in studied area.

Time-weighted average is the average exposure to dust concentration over a specified period, usually a nominal eight hours. It can be derived from the graph that the Time-weighted average of drilling is maximum and minimum in blasting; it depends on the duration of operation of a particular machine to be used in mines. As the operating time of blasting is less so its exposure to dust concentration is also less and hence time-weighted average is minimum. Whereas drilling is a continuous operation of several hours, therefore its exposure duration is high and hence has a maximum time-weighted average.

Time-weighted average is a standard limit of exposure to concentration which has to be maintained within its permissible limit for better work efficiency of machines as well as working personnel. Therefore, continuous data analysis of time-weighted average over a while is necessary and it helps in better regulation.

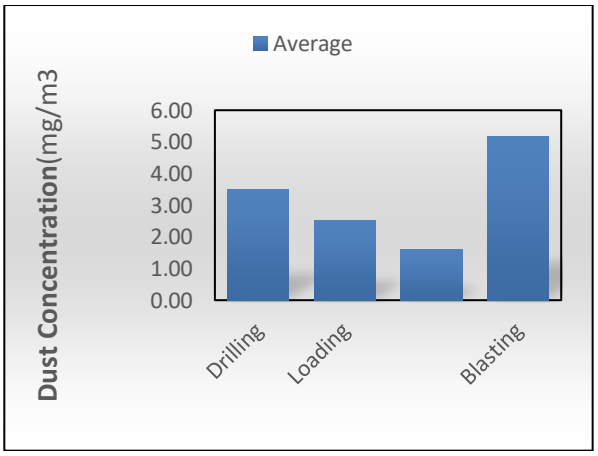

Fig 21. Plate 4.7: Comparison of average dust conc.

Table 5.Dust Concentration at Mine 2.

Respirable Dust Concentration(mg/m3)			
Month	Drill Operator	Excavator Operator	Dumper Operator
April	3.89	2.50	1.67
May	3.91	2.30	2.05
June	4.13	2.44	1.93
July	4.11	2.79	2.00
August	3.85	2.36	2.50
September	3.90	2.22	2.38
October	3.67	2.97	1.92
November	4.13	2.95	2.33
December	3.78	3.04	2.39
January	3.59	2.93	1.88
February	4.00	3.10	2.32
March	3.64	2.62	2.00
Avg	3.88	2.69	2.11
Max.	4.13	3.10	2.50
Min.	3.59	2.22	1.67

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Table 6. Respirable TWA at Mine 2.

Time Weighted Average			
Month	Drill Operator	Excavator Operator	Dumper Operator
April	3.28	2.02	1.23
May	3.45	1.31	1.65
June	3.64	1.54	1.56
July	3.47	2.15	1.69
August	2.44	1.28	2.02
September	2.73	1.52	1.75
October	3.09	1.70	1.22
November	3.64	2.38	1.97
December	3.19	2.68	1.93
January	3.16	2.59	1.25
February	3.38	2.28	1.62
March	2.93	1.93	1.51
Avg	3.20	1.95	1.61
Max.	3.64	2.68	2.02
Min.	2.44	1.28	1.22

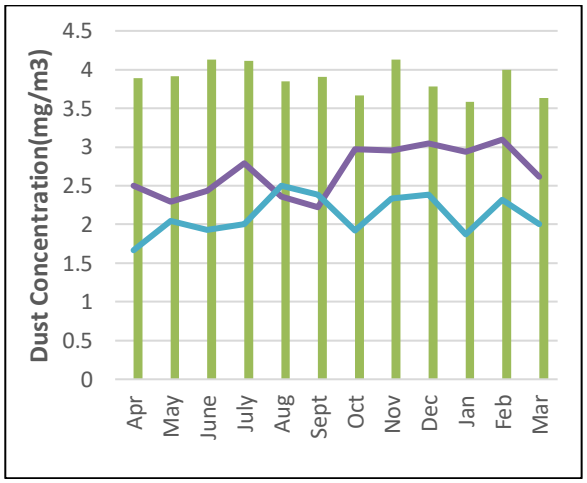

Fig 22. Plate 4.8: Respirable dust conc. Monthly.

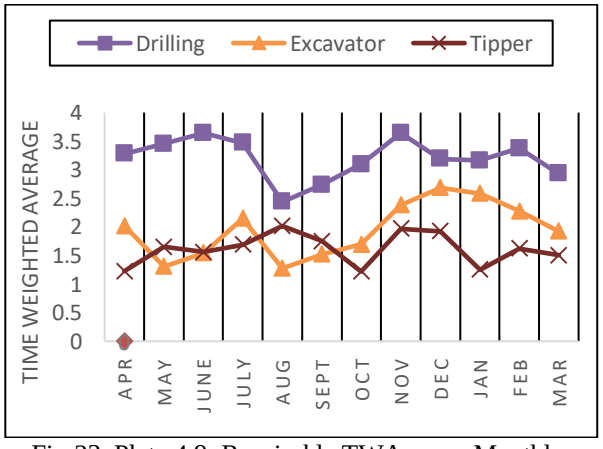

Fig 23. Plate 4.9: Respirable TWA conc. Monthly.

This graph shows dust generations by drilling, excavator, dumping and blasting in different months over a year. As it can be seen the maximum dust concentration is in the month of June, July and September as the temperature during these months is higher than in other months. In the winter season that is from November to February, there is a slight decrease in dust concentration and least in the case of the rainy season because in the rainy season dust is suppressed and the spreading of dust reduces, hence dust concentration also reduces. This plot is a combined observation of dust concentration of various seasons which provide a proper idea for analyzing dust generation in limestone mines and helps in reducing dust pollution and increasing work efficiency.

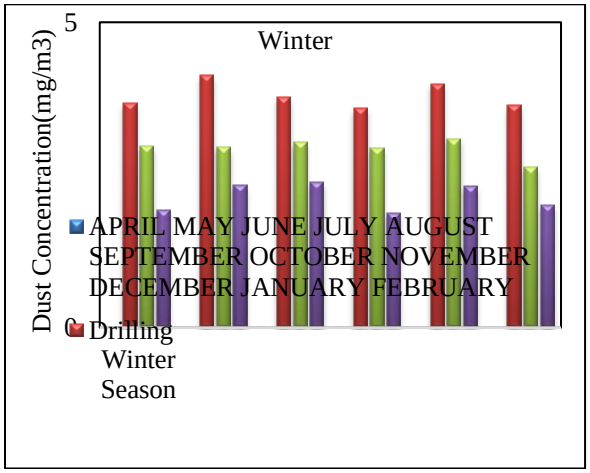

Fig 24. Plate 4.10: Comparison of dust concentration in winter season.

Dust concentration in the above graph is observed during the winter season by comparing dust generation due to various machines used in the mining process. In the winter season, with a decrease in temperature, the amount of dust generation and spreading also decreases but it remains suspended into the atmosphere due to fog, which creates an uneasy environment nearby dust sources. Also, it can be stated from the graph that the maximum amount of dust concentration in mines is due to blasting followed by drilling, excavator and dumping.

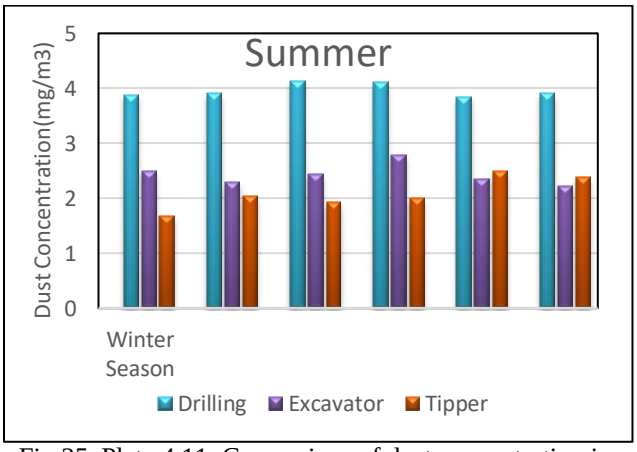

Fig 25. Plate 4.11: Comparison of dust concentration in summer season.

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In this graph, dust concentration is observed in the studied area in the summer season for various mining operations. Dust concentration in the summer season is recorded higher than that in the winter season by each machine because in summer huge amount of dust is generated all over the atmosphere. Water spraying also becomes inefficient in summer, as the higher temperature dries out the surface early. Therefore, dust control is needed in this area and hence proper analysis of dust generation helps in better dust control.

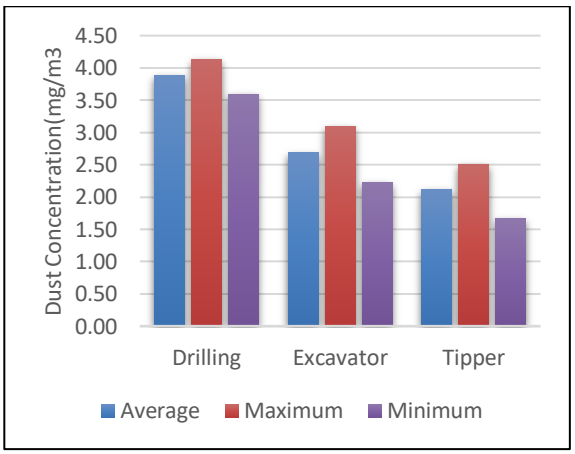

Fig 26. Plate 4.12: Respirable dust Concentration (Max., Avg., and Min.) in studied area.

In the above two plots comparison of dust, generation is seen on a seasonal basis that is between winter and summer season. This data is observed annually in the studied area that is an overall analysis of dust concentration in limestone mine. Average, minimum and maximum reading of dust concentration is recorded annually for different machines used in mining, least in the case of dumper to the maximum in the blasting process. This data helps to predict that in which period over a year dust generation is maximum and which mining operation generates a maximum amount of dust. Therefore, makes dust control easier and helps in reducing dust pollution in mines.

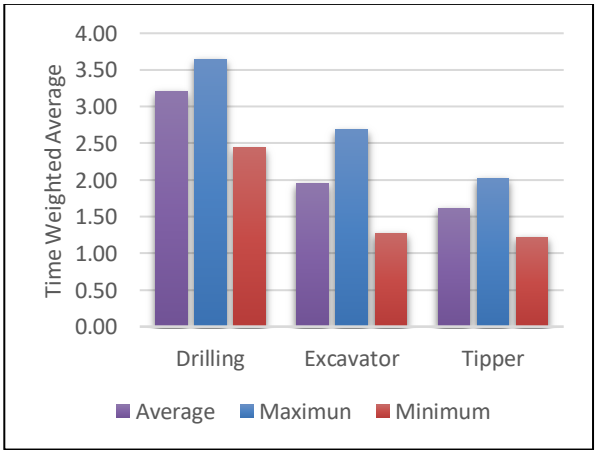

Fig 27. Plate 4.13: Time Weighted Average (Max., Avg., and Min.) in studied area.

Time-weighted average is the average exposure to dust concentration over a specified period, usually a nominal eight hours. It can be derived from the graph that the Time-weighted average of drilling is maximum and minimum in blasting; it depends on the duration of operation of a particular machine to be used in mines. As the operating time of blasting is less so its exposure to dust concentration is also less and hence time-weighted average is minimum. Whereas drilling is a continuous operation of several hours, therefore its exposure duration is high and hence has a maximum time-weighted average.

Time-weighted average is a standard limit of exposure to concentration which has to be maintained within its permissible limit for better work efficiency of machines as well as working personnel. Therefore, continuous data analysis of time-weighted average over a while is necessary and it helps in better regulation.

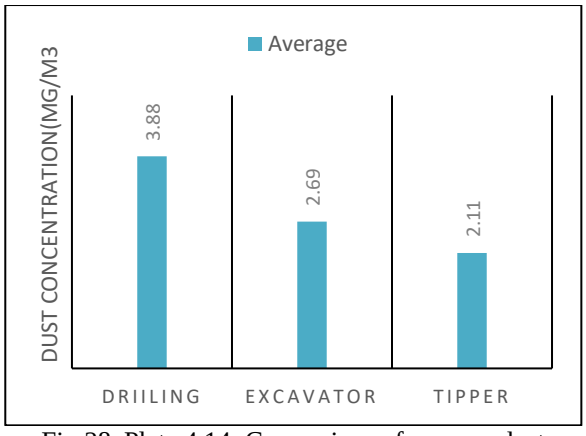

Fig 28. Plate 4.14: Comparison of average dust concentration of Personal sampler.

Table 7. Ambient air quality monitoring for PM10 at (Workshop, Crusher, Mines office).

Ambient Air			
	PM – 10(µg/m³)		
Month	Mines Workshop	Crusher	Mines office
April	65.28	74.75	61.26
May	60.37	71.09	62.61
June	63.41	74.40	60.11
July	60.00	77.02	60.34
August	62.92	70.38	55.23
September	64.51	73.19	61.32
October	66.52	73.19	63.34
November	68.43	76.52	65.47
December	63.56	71.68	63.76
January	70.68	70.03	59.52
February	70.25	66.79	58.21
March	67.07	70.73	51.22

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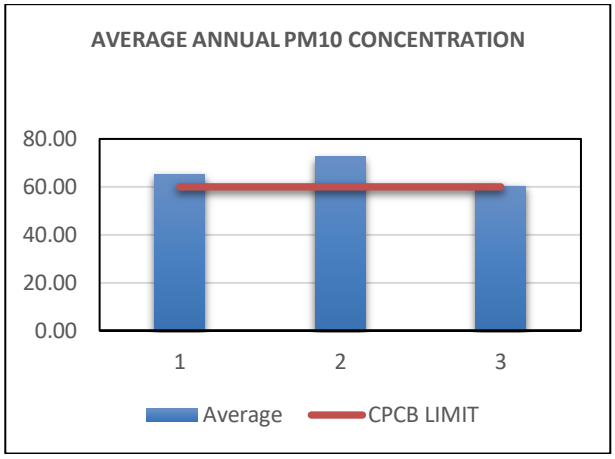

Fig 29. Plate 4.15: Concentration of PM10 particles w.r.t CPCB limit (Workshop, Crusher, Office).

In the above chart, the annual concentration of dust is high at the crusher The PM10 values of the crusher area under observation were found beyond the standards prescribed by NAAQS. Work zone and ambient air quality data reveal the high pollution in the project area and surrounding locations.

Fig 30. Monitoring of Envirotech APM 460 NL &Envirotech APM 550 NL.

Table 8. Concentration of SOx/NOx/CO (Workshop, Crusher, Mines office).

SOx/NOx/CO									
Month	Mines Workshop			Crusher			Mines Office		
	SOx	NOx	CO	SOx	NOx	CO	SOx	NOx	CO
April	9.53	13.10	0	5.85	16.03	0	5.26	13.26	0
May	8.20	13.30	0	5.40	16.78	0	8.12	14.75	0
June	7.40	13.80	0	5.88	14.25	0	7.42	12.55	0
July	7.15	14.43	0	5.40	12.93	0	6.32	13.24	0
August	8.00	15.20	0	5.88	9.60	0	5.63	10.21	0
September	7.37	14.92	0	5.62	15.70	0	6.43	11.48	0
October	8.20	12.20	0	4.98	15.90	0	6.33	10.58	0
November	7.28	12.88	0	5.05	14.73	0	7.11	12.27	0
December	7.10	13.60	0	5.25	14.53	0	6.84	11.37	0
January	7.40	13.80	0	5.88	14.25	0	5.01	10.45	0
February	7.78	14.70	0	5.98	15.73	0	4.26	12.30	0
March	7.38	14.93	0	5.63	15.70	0	3.27	9.56	0

3.2 Sampling and the Analysis of PM2.5 with Envirotech APM 550 NL

The principle of this method is to measure the dust particle size of 2.5 micrometres and smaller which are very harmful to the human body. In this, an electric powered motor is used for the monitoring of the ambient air at the average flow rate of 16.7 lpm which is maintained by a mass flow or volumetric flow controller that is coupled to a microprocessor into an initial particle size impactor which is known as the cyclone. The particular size separator separates the particulate matter of 2.5-micrometre size by the collection of 47 mm polytetrafluoroethylene (PTFE) filter over a specified sampling period.

The filter paper would be weighted carefully before and after the sampling to determine the net value of the particulate matter.

Following equation is used to calculate the mass of fine particulate matter on the filter paper:-

$$\mathbf{M2.5 = (Mf - Mi)\ mg \times 103\ \mu g}$$

Where,
M2.5 = total mass of fine particulate collected during sampling period (µg)
Mf = mass of the filter paper after sample collection (mg)
Mi = initial mass of the filter paper before sample collection (mg)

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103 = unit conversion factor for milligrams (mg) to micrograms (µg)

Now the volume of air sampled can be calculated according to the given formula below

V = Qavg x t x 10-3 m3

Where,
V = total sample value (m3)
Qavg = average flow rate over the entire duration of the sampling period (L/min)
t = duration of sampling period (min)
103= unit conversion factor for liters (L) into cubic meters (m3)

Now to determine PM2.5 mass concentration:-

PM2.5 = M2.5 / V

Where,
PM2.5 = mass concentration of PM2.5 (µg/m3)
PM2.5 = total mass of fine particulate collected at the time sampling period (µg)
V = total volume of air sampled according to the above equation (m3)

Lower in concentration because air direction is not in the same way, but in summer air direction is somehow in the same direction. At crushers, more fine particles are formed because mining activity produces more coarse particles and fine particles are formed due to the crushing, grinding and other mineral processing. Fine particles are due to anthropological activity. Due to lower dispersion in winter the PM2.5 contribution is more than in summer (PM2.5 / PM10).

Table 9. Ambient air quality monitoring for PM2.5 at (Workshop, Crusher, Mines office).

	PM - 2.5(µg/m³)		
Months	Mines Workshop	Crusher	Near Mines office
April	29.17	40.91	22.15
May	31.82	37.50	20.56
June	27.50	29.09	20.34
July	24.35	30.43	19.65
August	23.48	35.22	19.65
September	26.67	32.61	21.14
October	25.83	32.08	19.22
November	28.26	34.17	20.37
December	27.39	34.78	21.47
January	31.82	28.57	19.01
February	28.57	27.27	20.23
March	26.09	26.09	19.65

The PM2.5 values of the mines under observation were found close to the standards prescribed by NAAQS.

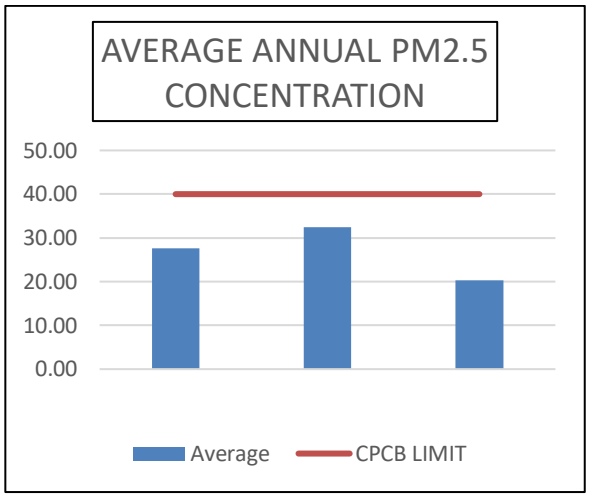

Fig 31. Plate 4.16: Concentration of PM2.5 particles w.r.t CPCB limit (Workshop, Crusher, Mines office).

V. DUST PREVENTION & CONTROL

Dust generation leads to the development of dust control measures to avoid environmental and health-related impacts. There are several available mitigation strategies and techniques and they correspond to different cost and efficiency levels. To follow a definite dust control strategy is not always straightforward due to the complexity of the dust generation process, the materials behavior and the working conditions, as well as the cost.

The most frequent method of dust suppression is the use of water. Dust suppression is the use of water or chemically treated water in the term of a spray, fog or foam to prevent the generation of airborne particulates. Suppression is achieved by adding to the moisture content of the material and thus increasing the weight/mass ratio and cohesiveness of the material.

1. Drill Dust Control:
Drill dust is suppressed by water injected through the drill steel, which has been a common practice for many years. Usually, respirable dust is reduced by 95% or better. This does not, however, prevent dust from entering the air during the initial collaring period as the drill hole is started. Various means have been tried to prevent the escape of dust during collaring. These range from simple handheld sprays to elaborate types of suction traps around the end of the drill steel.

None of these is very efficient. Drills powered by compressed air are much less common than in the past, eliminating the dust problems associated with their use.

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For example, if some of the compressed air operating the drill leaks into the front head of the drill and escapes down the drill steel, it will cause dry drilling and carry dust out of the hole. Compressed air escaping through the front-head release ports will atomize some of the water in the front head. This atomized water evaporates quickly and, if the water is dirty, many dust particles will remain in the air.

2. Blasting Dust Control:
Blasting dust and fumes gets quickly diluted and exhausted into the atmosphere, and the common practice to arrange the blasting schedule should be practised, so that the contaminated air will pass through working places when the miners are absent.

Several blasting parameters affect dust generation. The type of rock is of course most important parameter. The type of explosives determines the number of fines and dust generated during blasting. Further, the effect is of burden and spacing which produces dust. Delay timing also affects the generation of dust. Many mining operations have indeed succeeded in reducing dust hazards by eliminating detonating cord down line and by use of aggregates in place of drill cuttings.

Water-filled plastic bags are permitted devices for stemming. Water stemming bags have proven very effective in providing confinement and reducing dust. Water is important in controlling dust generated by blasting. The area surrounding the blast (walls, floor, and back) should be thoroughly sprayed beforehand. This precaution will prevent dust settled out during previous operations from becoming airborne.

A uniform rock moisture content of only 1% greatly reduces dust compared to dry rock. However, since it is difficult to wet rock uniformly under realistic mining conditions, the optimum moisture content can be much higher. The water used for dust suppression, particularly in drilling and in blasting, should be as clean as possible because the evaporation of dirty water can also release dust.

3. Transfer Point Dust Control:
The traditional approach to transfer point dust control is to tightly enclose the transfer point, exhaust the dust-laden air from the enclosure through a duct, and either remove the dust from the air with a dust collector. Transfer point dust control can be difficult because the falling rock has a piston effect due to air entrainment. This air entrainment draws mine air in at the top of the transfer point enclosure, and it can push dusty air out of the bottom of the enclosure.

The piston effect of the falling rock can be reduced by lowering the drop distance to break the fall of the rock, and by increasing the enclosure size so that entrained air can circulate back to the top of the enclosure. The tight enclosure of the transfer point requires adjustable skirt board sealing systems, a means to prevent belt sag in the loading zone, and careful sealing of belt entry and exit locations, among others.

4. Dust Control at crusher:
Crushers in mines range from small roll types used in coal mines to large cone types used in hard-rock mines and mills. Whatever the size and method of crushing, dust is controlled by water sprays and local exhaust ventilation from the crusher enclosure. The amount of water needed is hard to specify. It depends on the type of material crushed and the degree to which water will cause downstream handling problems. If the rock is dry, a starting point is to add a water quantity equivalent to 1% of the weight of the material being crushed.

The amount of air required depends on how much the crusher can be enclosed. Enough air should be exhausted from a plenum under the crusher to produce a strong draft at the jaw, grizzly, and any other openings around the crusher. The design guidelines for determining the required airflow are the same as those for transfer points.

The broken rock delivered to the crusher contains a considerable amount of attached dust from preceding operations such as blasting and loading. The grinding action on the rock as it falls produces even more dust. Dust will be reduced if the rock is thoroughly wetted before delivery to the tipping site. More water can be added at the tipping site by spraying the rock as it falls into the hopper.

5. Consolidation of roadway dust:
The best method of preventing roadway dust from getting airborne is to consolidate it. The simplest method of consolidation is by wetting the dust with water sprays, but water sprays alone do not produce good wetting of all deposited dust and a large quantity of water may be needed for producing effective results. Besides, water evaporates quickly needing very frequent spraying.

VI. CONCLUSION AND RECOMMENDATIONS

Operations of the mining industry include three steps, namely mining, mineral processing, and metallurgical extraction. The first two steps are of concern in this report because they are responsible for producing mineral dust. Metallurgical extraction does not create dust in general. The basic production cycle in mining can be expressed as drilling, blasting, loading, and hauling. All these four basic operations in the production cycle are originating dust in different extents depending on mining scale, working method as well as rock type. The operation of crushing and sizing, and grinding and milling are both mineral

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breaking down processes that certainly produces a great deal of dust.

Mining, because of the very nature of operations involves disturbing the ground, removing and handling soil and rock, and the subsequent transport, dumping, crushing and processing of this material. At all stages, there is some potential to produce particulate matter. It has become more serious and alarming due to increased production and mechanization in opencast as well as underground mines. It is seen that in the mining industry, right from the soil handling to the final transportation, dust is generated resulting in air pollution.

The respirable fraction in SPM is found to be high and alarming to human health. Air pollution control measures involve planning and implementation of a series of preventive and suppression measures in addition to a dust extraction system. There is a need for wider application of dust control chemicals on haul roads for which an in-depth techno-economic survey is essential. By proper implementation of suggested abatement measures, air pollution in opencast mine and its environment management can be suitably controlled and also a right kind of balance between sustainable development and environmental management can be maintained.

According to the objective of the project, the results are described from the field investigation and laboratory work done at different points of mine for different dust parameters with various technologies. The dust parameters results for PM10 which are measured at the working zone of the mine area consider the higher range of dust particles near to specified limit and the PM2.5 values of the mines under observation were found close to the standards prescribed by NAAQS.The correlation between the dust concentration and the distance from the source of the dust confirmed that the workers at drilling and the crusher were exposed to high concentrations and therefore are hazard zones.

VII. RECOMMENDATIONS

Environmental management systems, which include a dust management plan, should be employed in the project area to mitigate dust generation. Regular environmental audit and monitoring of mining activities should be enforced to ensure adherence to the standards and limits of the concentrations of the dust generated from the different stages of their operations. The workers should be adequately sensitized to the adverse health effects of exposure to dust and the importance of using personal protective equipment while at work.

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