DUST MONITORING, CHARACTERIZATION AND PREDICTION IN AN OPENCAST COAL MINING PROJECT

A THESIS SUBMITTED IN PARTIAL FULFILLMENT

OF THE REQUIREMENTS FOR THE DEGREE OF

BACHELOR OF TECHNOLOGY

in

MINING ENGINEERING

BY

ANSHUMAN BADU

110MN0629

DEPARTMENT OF MINING ENGINEERING

NATIONAL INSTITUTE OF TECHNOLOGY

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UNDER THE GUIDANCE OF

PROF. D.P. TRIPATHY

DEPARTMENT OF MINING ENGINEERING

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National Institute of Technology

Rourkela

CERTIFICATE

This is to certify that the thesis entitled, "**Dust Monitoring, Characterization and Prediction in an Opencast Coal Mining Project**" submitted by **Mr. Anshuman Badu, 110MN0629,** in partial fulfilment of the requirement for the award of Bachelor of Technology Degree in Mining Engineering at the National Institute of Technology, Rourkela (Deemed University) is an authentic work carried out by him under my supervision and guidance.

To the best of my knowledge, the matter embodied in the thesis has not been submitted to any University/Institute for the award of any Degree or Diploma.

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ABSTRACT

Dust pollution is the most important environmental issue associated with any opencast mining activity. Drilling, blasting, loading, transportation, crushing, conveying, haul road and the exposed overburden face generate large quantities of fugitive dust. 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. Prediction of dust concentration in and around the mine is essential to have an impact assessment of the mining activity over the surrounding environment.

In the view of this, current project work focuses on the real time monitoring of dust level at different sources of the mine using DustTrak II, personal exposure of dust to different workers using personal dust sampler, characterization of dust collected from different locations using FT-IR and finally prediction of dust concentration at different locations of the mine and nearby areas using AERMOD view software. Lakhanpur opencast project, the largest opencast mine of MCL in the Ib valley area producing more than 15MT of coal per annum, was chosen for study to have a better knowledge about the impact assessment due to dust from large opencast mines. The monitoring was conducted during December 2013 to assess scenario of dust pollution. The dust concentration was found to vary between 0.474mg/m^3 to 150.0mg/m^3 in PM$_{10}$. Drilling and Surface Miner operations were found to be the major sources of dust generation. The dust exposure of worker was found to vary between 4.55mg/m^3 to 29.41mg/m^3. Minimum quartz content was found at coal transport road at 0.23% and maximum quartz content was found at wet haul road of LOCP at 0.49%. The predicted value of dust concentration (PM$_{10}$) at most of the places was found to be below NAAQS-2009 limit for annual average of 60µg/m^3.

Key Words: Fugitive Dust, DustTrak II, PDS, AERMOD, Quartz, FTIR

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CHAPTER 1

INTRODUCTION

INTRODUCTION

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 collagenous/non-collagenous (non-fibrogenic). Based on size particulates can be divided into TSP, PM_{10} and $PM_{2.5}$. 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 monitoringz 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.

In this project, an attempt has been made to carry out dust monitoring and dust characterization at Lakhanpur opencast coal project using real time aerosol monitor DustTrak II and FTIR. Finally dust dispersion modelling was carried out using AERMOD to assess the magnitude of the dust concentration at the working and peripheral areas of the study area vis-à-vis NAAQS standards.

1.1 Objectives

- To monitor dust at different sources using DustTrak II
- Assessment of personal dust exposure using Personal Dust Sampler (APM-800)
- To determine quartz content of dust using FTIR and
- To carry out dust dispersion modeling using AERMOD

1.2 Plan of Work

The plan of work mainly focussed on a comprehensive assessment of the impact of dust due to mining activities. Previous work of the researchers in the field of dust monitoring, characterization and dispersion modelling were studied. The focus of the work is mainly to assess dust generation at different sources, to assess to effect of dust on the health of workers by going for characterization and to predict impact of dust generated by mining activities to the air quality of the surrounding area. A flow chart of the work plan is presented in Fig 1.1.

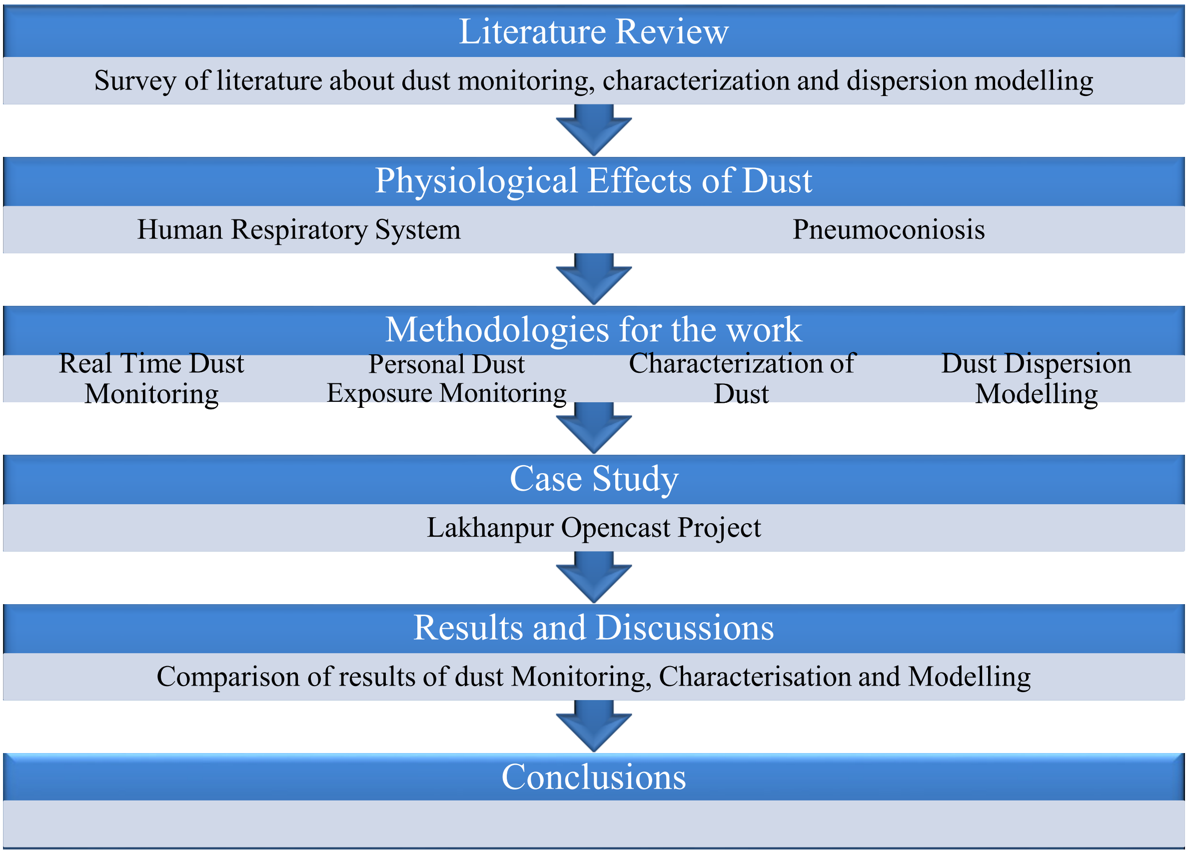

Figure 1.1 Plan of work

CHAPTER 2

LITERATURE REVIEW

LITERATURE REVIEW

2.1 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.

2.1.1 Atmospheric Dust

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.

2.1.2 Fugitive Dust

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 characterised as fugitive dusts since they are mostly generated from non-point sources.

2.1.3 Mine Dust

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.

2.2 CLASSIFICATION OF DUST

The composition of dust generated in mines depends upon the mineral content of the ore. Depending upon the harmfulness of dusts, they can be classified in the following manner:

I. **Fibrogenic Dust**
   a. Silica (quartz, crystobalite, tridymite, chert)
   b. Silicates (asbestos, talc, mica, silimanite)
   c. Metal fumes
   d. Beryllium ores

    e. Iron ores
    f. Carborundum
    g. Coal (bituminous, anthracite)

II. **Carcinogenic Dusts**

    a. Asbestos
    b. Radon daughters
    c. Arsenic
    d. Diesel particulate matter (a suspended carcinogen)
    e. Silica (a suspended carcinogen)

III. **Toxic aerosols (poisonous to body organs and tissues etc.)**

    a. Dusts of ores of beryllium, lead, uranium, radium, thorium, chromium, vanadium, manganese, arsenic, mercury, cadmium, antimony, selenium, nickel, tungsten, silver.
    b. Mists and fumes of organic and other body-sensitising chemicals

IV. **Radioactive dusts**

    a. Ores of uranium, radium, thorium (injurious because of alpha and beta radiation)
    b. Dusts with radon daughters attached (source of alpha radiation)

V. **Explosive dusts (combustibles when air borne)**

    a. Metallic dusts (magnesium, aluminium, zinc, tin, iron)
    b. Coal (bituminous, lignite)
    c. Sulphide ores
    d. Organic dusts

VI. **Nuisance dusts (little adverse effects on humans)**

    a. Gypsum
    b. Kaolin
    c. Limestone

However, when present in excess amount, nuisance dust can be harmful to human health. As it increases, the particle clearing mechanism of lung is affected which can have detrimental effects on human health [12].

2.3 PHYSIOLOGICAL EFFECTS OF MINERAL DUST

2.3.1 Human Respiratory System

Through nose and mouth air is introduced into the respiratory system. With air other aerosols (dust, bacteria, and pollen) are also introduced into the body. When the aerosols pass through the nasal passages, larger particles are cleared by hair and mucus. After that air flows through the nasopharynyx region, where it is warmed. Then air passes through the trachea (windpipe), the bronchi (the two short branches off the trachea), and the bronchioles (branches off the bronchi) and into the alveoli (the terminal lung sacks where oxygen is transmitted into the blood stream). Along the trachea, bronchi and bronchioles, particles of medium size are impacted on the mucous layer lining the openings. Particles larger than 10µm are caught in ciliary escalator and brought back up through the bronchial tree to the throat. This material is then coughed or swallowed.

However, smaller particles are deposited on the lung surface through setting, impaction, Brownian motion. For these types of dusts, body's defence mechanism consists of phagocytes (wandering scavenger cells) called alveolar microphages. These microphages engulf the particles and isolate them to lymph nodes for disposal. These scavenger cells are called the garbage collector of respiratory system as they ingest invading particles. If the particles are common household dusts, then ingestion takes place and the particles are walled off by microphages. However, if the microphages ingest free silica particle, it explodes. The lung is left with destroyed microphages and free silica particle. The particle is then ingested by another microphage which in turn is destroyed by explosion and this process goes on.

Every human being has billions of microphages. The human body has evolved into an efficient organisation designed to eliminate particles found in natural environment. However, when an individual inhales sufficient particles below 10µm, the microphages are overwhelmed. When enough microphages are destroyed, the residual biological material forms scar tissues. Initially the scars are small enough but consequently adjacent scars coalesce. As the scar tissue continue to increase, more lung tissue is rendered useless. Individual develops shortness of breath and his life expectancy is reduced. Fig.2.1 shows human respiratory system.

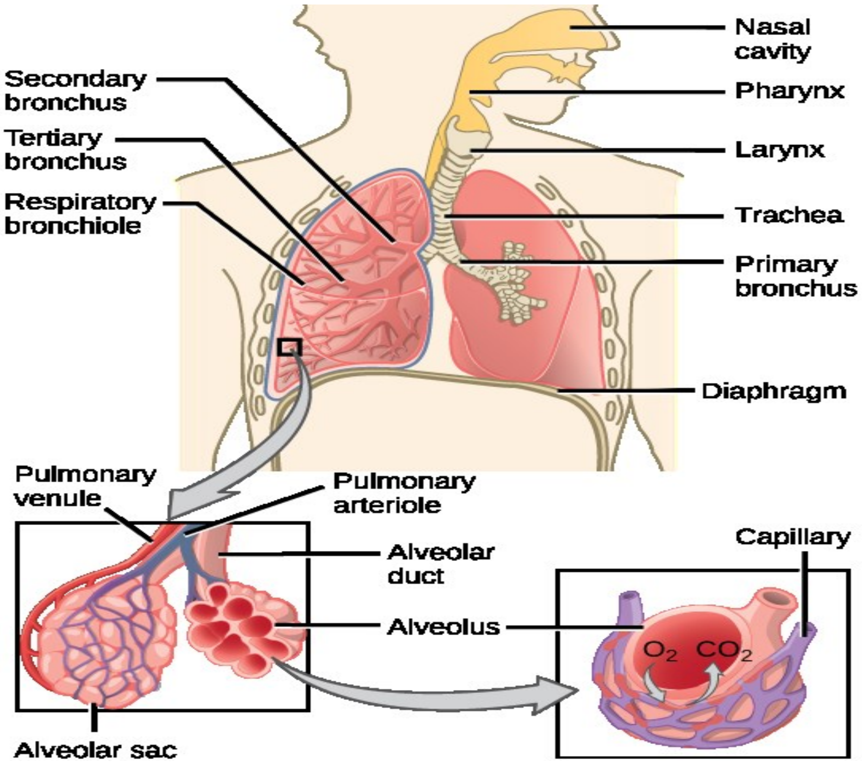

Figure 2.1 Human respiratory system

Source: http://cnx.org/content/m45536/latest/?collection=col11487/latest

2.3.2 Pneumoconiosis

Pneumoconiosis is defined in the ILO working group in 1971 [15] as the accumulation of dusts in lungs and the resulting reaction of dusts of lung tissues to it. It is the most common lung dysfunction seen among miners. Pneumoconiosis is characterised by the formation of fibrous tissues in lungs due to dust deposition. Pathologically, pneumoconiosis is divided into two groups

- Collagenous
- Non-collagenous

Non-collagenous pneumoconiosis is caused by non-fibrogenic dusts. General features are

- Alveolar architecture remain in tact
- Least stromal reaction comprising primarily reticular fibres
- Reversibility of dust reaction

Collagenous pneumoconiosis is caused by fibrogenic dusts as altered tissue response to non-fibrogenic dust. It is categorised by:

- Permanent modification or destruction of alveolar architecture
- Collagenous stromal reaction from moderate to highest point
- Permanent scarring of lungs

However, difference between collagenous and no-collagenous pneumoconiosis is tough and constant exposure may cause conversion from non-collagenous to collagenous.

Depending upon specific casual material, different terminologies are associated with different types of pneumoconiosis. Such as

- Silicosis (dusts of quartz, trydymite and cristobalite)
- Silicate pneumoconiosis (dusts of silicate mineral such as kaolin, talc, tremolite, actinolite and anthophylite)
- Coal workers' pneumoconiosis (coal dust)
- Beryllium disease (dusts of beryllium compounds including ores)
- Siderosis (dusts of iron including ores) [8]

2.3.2.1 Factors Responsible for Pneumoconiosis

Health effects of dust chiefly depends upon

- Composition
- Concentration
- Size of particles
- Time of exposure

a. Composition

Chemical and mineralogical composition of dust is probably the most important factor in determining the degree of harmfulness of dust. Some mineral dusts are harmless where as some other mineral dusts are harmful e.g. free silica is more harmful than combined silica, asbestos is carcinogenic in nature. The surface energy of the particles and solubility is also very important in case of toxic dusts. Free silica content is accepted universally as the most dust reaching lung, not that of the air borne dust or the mineral or rock producing the dust that is important. Free silica content of dust can be determined through X-ray diffraction analysis, differential thermal analysis (DTA) and infra-red spectrograph.

b. Concentration

Concentration of dust can be measured in 3 different ways:

a. Mass of the dust per unit volume of air. (mg/m^3 or micrograms/m^3)
b. No. of particles per unit volume. (ppcc)
c. Surface area of particles per unit volume.

Mass concentration in the respirable size range has been established as the criteria for the determination of pneumoconiosis occurrence. For silica dust, surface area concentration of the respirable fraction is needed to determine harmfulness, as the toxicity of silica dust is more closely associated with the surface area of particles, because surface area determines the solubility of the particle. Tyndalloscope is the only instrument through which particle surface area concentration can be measured.

c. Time of Exposure

Most of the diseases associated with mineral dust exposure take a long time of occupational exposure to develop to critical level. Asbestosis takes nearly 10 years to develop whereas silicosis may develop within a few years of exposure. The period of exposure required to develop silicosis increases with decrease in concentration. Some diseases like coal worker's pneumoconiosis cease progressing when exposure to the dust is eliminated. Whereas silicosis is progressive in nature, once developed it progresses even if exposure to dust is terminated.

There is a certain extent to which human respiratory system can dispose inhaled dust. Larger size particles deposited in the upper respiratory tract is removed through ciliary action. Where as in case of fine particles, microphages engulf them and remove them to lymph nodes, whereas fibrosis may develop. When the lymph nodes attain saturation fibrosis develops. Hence, it is obvious that incidence of occurrence of pneumoconiosis can be directly co-related to exposure time.

d. Size of the Particles

It is the most important factor in determining the harmfulness of dust as it controls the location of the respiratory tract where the dust particles will reside. Particles size refers to the equivalent diameter, which is defined as the diameter of the spherical particles of unit density having the same falling velocity as the particle in question. Particles lesser than 5µm diameter are most likely to penetrate to lungs and became deposited in alveoli. Maximum damage is caused by particles of 1µm size. It decreases for both higher and lower sizes. It happens because particles larger than 5µm are deposited in the upper respiratory tract, whereas particles of 1µm or lesser size reach the alveoli.

2.4 DUST MONITORING, CHARATERISATION, PREDICTION IN MINES: PREVIOUS INVESTIGATIONS

Dust is the single most environmental concern for any mining activities and the problem is more severe in case of opencast mines. Monitoring has been carried out by different researchers at different sources of dust emission in mines. The most polluting and least polluting sources in the mine are identified and dust control methods are also recommended. Pneumoconiosis is a major health problem among the workers of mine for their continuous exposure to dust. Extensive studies have been carried out to assess the personal exposure level of dust and silica content in the respirable range vis-a-vis regulatory limits. Silica is a carcinogen and monitoring its exposure level among the workers is essential. Finally prediction of concentration levels of dust around the mine due to the dust released from the mining activities is essential to have an overall environmental impact assessment for any mine. Local meteorological conditions play an important role for the dispersion of dust. Various mathematical models are developed for this purpose. Researchers have often validated these models for different meteorological conditions and come out with the most appropriate model for a particular meteorological condition. Some of the research works are presented below

Erol et al. (2013) [4]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) [5] 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.

Chaulya (2004) [3] carried out an assessment of air quality around Lakhanpur area of Ib valley. TSP, PM_{10}, SO_2, NOx were monitored at 13 locations for a period of one year. 24 hour and annual average concentrations of TSP and PM_{10} exceeded NAAQS standards whereas SO_2 and NOx remained within the limit. 31.94% of TSP was found to be within PM_{10}. Green belts were prescribed as a mitigation measure.

Kumari et al. (2011) [7] 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 $3mg/m^3$ 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) [10] 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) [9] 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) [14] 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.

Chaulya et al. (2002) [2] 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.

CHAPTER 3

METHODOLOGIES FOR DUST MONITORING, CHARACTERIZATION AND DISPERSION MODELLING

METHODOLOGIES FOR DUSTMONITORING, CHARACTERIZATION AND DISPERSION MODELLING

3.1INTRODUCTION

The methodology followed for carrying out the research investigations have been presented in Fig.3.1.

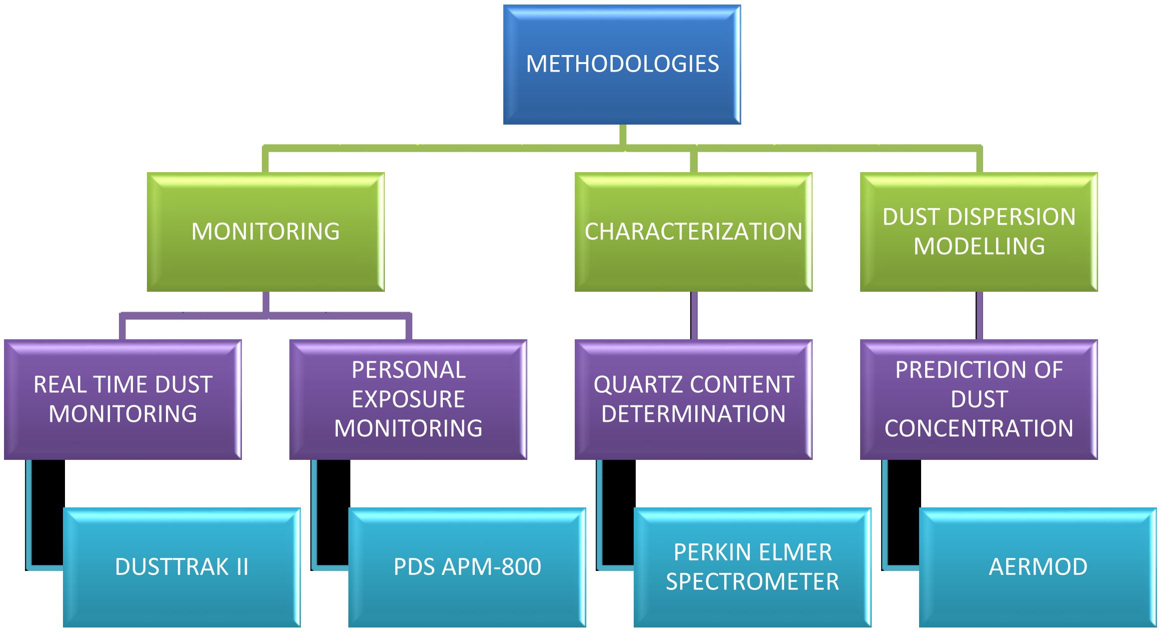

Figure 3.1 Methodology adopted for project work

3.2Dust Monitoring

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.

3.2.1 DustTrak II Aerosol Monitor (Model No- 8532) [17]

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. 3.2.

Figure 3.2 DustTrak II

3.2.1.1 Features

- Real time concentration readings and data logging which enables during and after sampling.
- It can measure concentration corresponding to different particle size like PM_1, $PM_{2.5}$, PM_4 and PM_{10}
- Continuous graph display.
- Gives statistical information about aerosols during and after sampling.
- It can measure concentration range from 0.001mg/m^3 to 150mg/m^3

3.2.1.2 Principle of Operation of DustTrak II

DustTrak II is an instrument based on optical method. Optical method utilises the properties of scattering of light by a suspension of fine particles. Light scattering photometers are generally direct-reading type in which samples are not collected. DustTrak II is used for spot check of dust concentration in workplace. The intensity of the scattered light is given by

$$\frac{\mathbf{Is}}{\mathbf{Io}} = \mathbf{KND^2} \qquad \text{...} \ \mathbf{(1)}$$

Where,

Io : Intensity of incident light

Is : Intensity of scattered light

Io : Intensity of incident light

D : Diameter of particles

N : No. of particles per unit volume

K : constant depending upon the refractive index, absorption co-efficient and shape of the particles as well as the wavelength of the light, angle of scattering and the distance of the point of observation from dust cloud

3.2.2 Personal Dust Sampler

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 occupation exposure of worker to dust. It is a portable instrument operated in battery power capable of measuring both total suspended particles and respirable particles for the total shift of 8 hour. It is a light weight 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 human being. For measuring the respirable fraction of dust, a separate cyclone can be attached to the sampler. The cyclone is designed for a cut off of particle size of 5µm as recommended by DGMS. Glass fibre filter of 37mm diameter is used for sampling. The air after passing through the cyclone gets deposited over the filter paper. The filter paper can be analysed further to determine the constituents of dust. A personal dust sampler is shown in Fig. 3.3.

Figure 3.3 Personal dust sampler PDS APM-800

Source: http://www.esuppliersindia.com/envirotech-instruments-pvt-ltd/cyclonic-attachment-personal-sampler-pr46576-sCATALOG-swf.html

3.3Dust Characterisation

The WHO/ILO International programme (1995) [16] on the global elimination of silicosis puts emphasis on characterisation of dust and its sources which involves determination of quartz content in respirable air borne dust. Silica present in dust is a potential carcinogen. Hence determination of silica content of dust is essential to Figure out harmfulness of dust.

Quartz content of dust can be determined through

- Infrared Spectrometer

- X-Ray powder diffractometer
- Chemical methods
- Gravimetric methods
- Differential Thermal Analysis method

For this project work, FT-IR was used to analyse the quartz content of dust.

3.3.1 Fourier Transform Infrared Spectroscopy

The aim of the absorption spectroscopy is to determine the amount of light absorbed or transmitted for each wavelength. The spectra of the sample contain emission, absorption and transmission corresponding to the frequency. Infrared spectrum is just like a finger print for a particular sample. The structure of the molecule can be determined with the characteristics absorption of infrared radiation for each wave number. The molecule absorbs radiation of particular wavelength and goes to the excited state. FT-IR shows peaks corresponding to the frequencies of vibration between the bonds of the atoms present in the sample. The constituent molecules of the sample can be identified by the characteristics peaks associated with each molecule. The height of the peak represents the quantity of a particular compound present in the sample. Hence infrared spectroscopy can be used for both qualitative and quantitative analysis of the material. Interferogram of the sample is obtained using an interferometer. Then the interferogram is analysed in computer using fourier transform to obtain spectra of the sample. For this study Perkin Elmer Spectrum Two Spectrometer is used. The spectra of the sample are obtained from wavenumber of $4000cm^{-1}$ to $400cm^{-1}$ with a resolution of $4cm^{-1}$ and 4 numbers of scans per sample. The spectrometer used for the experimental purpose is shown in Fig. 3.4.

Figure 3.4 Perkin Elmer spectrum two spectrometer

3.4Dust Dispersion Modelling

Dust dispersion modelling is generally carried out to predict the dust concentrations in the surrounding area so as to ensure dust levels don’t exceed the permissible limits. It takes into account various sources of emission from the mine and also the local meteorological conditions. Upper air data is also considered for predicting concentration levels. Topography of the area also plays an important role for the prediction of dust dispersion around the mine. The most important part is that the modelling method should accurately estimate the emission and dispersion of dust from a mining site.

3.4.1 Mathematical Models for Dust Dispersion

Several mathematical algorithms [11] are used for dust dispersion modelling. Some of them are

- Box Model
- Gaussian Model
- Eulerian Model
- Lagrangian Model

3.4.1.1 Box Model

Box model assumes the air shed in the shape of a simple box. It is also assumes that the air inside the box is of homogeneous concentration. The equation representing Box model is

$$\frac{\mathbf{dCV}}{\mathbf{dt}} = \mathbf{QA + uCinWH - uCWH} \;\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\;\mathbf{(2)}$$

Where,

Q : emission rate of pollutant per unit area. (gm/sec)
C : homogeneous species concentration within the airshed. (mg/m^3)
V : volume described by box. (m^3)
C_{in} : species concentration entering the airshed. (mg/m^3)
A : horizontal area of the box (L*W). (m^2)
L : length the box. (m)
W : width of the box. (m)
u : wind speed normal to the box. (m/sec)
H : mixing height. (m)

The main shortcoming of this model is that it assumes pollutant to be of homogenous through the air shed. But it is not the case in real world situation. Box model can be used to predict average pollutant concentration over a large area around the source.

3.4.1.2 Gaussian Model

The Gaussian models are the most common mathematical models used for air dispersion modelling. They are based upon the assumption that the pollutant will disperse according to a normal distribution. The Gaussian Equation used for point source emissions is

$$C(\mathbf{x,y,z}) = \frac{\mathbf{Q}}{\mathbf{2\pi u\sigma y\sigma z}}\left\{\mathbf{exp}\left(\frac{-(\mathbf{z-h})^2}{2\sigma \mathbf{z}^2}\right) + \mathbf{exp}\left(\frac{-(\mathbf{z+h})^2}{2\sigma \mathbf{z}^2}\right)\right\}\left\{\mathbf{exp}\left(\frac{-(\mathbf{y})^2}{2\sigma \mathbf{y}^2}\right)\right\}\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\mathbf{(3)}$$

Where,

C(x,y,z): Pollutant concentration as a function of downwind position (x, y, z) (mg/m^3)
Q : mass emission rate (gm/sec)
Y : distance in horizontal direction (m)
Z : distance in vertical direction (m)
H : effective stack height (m)

U : wind speed (m/sec)
σ_y : standard deviation of pollutant concentration in y (horizontal) direction (m)
σ_z : standard deviation of pollutant concentration in z (vertical) direction (m)

3.4.1.3 Eulerian Model

The Eulerian model takes into account conservation of mass equation for the given pollutant to determine the concentration levels. The equation representing Eulerian model is

$$\frac{\partial \langle Ci \rangle}{\partial t} = -\bar{U}.\nabla < Ci > -\nabla.< Ci'U' > +D\nabla^2 < Ci > +< Si > \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(4)$$

Where,

U : $\bar{U}$+U’ (m/sec)
U : wind field vector U(x,y,z). (m/sec)
$\bar{U}$: average wind field vector. (m/sec)
U′ : fluctuating wind field vector. (m/sec)
C : <C> + C′ (m/sec)
C : pollutant concentration. (mg/m^3)
<C> : average pollutant concentration, (mg/m^3)
C′ : fluctuating pollutant concentration. (mg/m^3)
D : molecular diffusivity. (kelvin)
S_i : source term. (gm/sec)

3.4.1.4 Lagrangian Model

Lagrangian model predicts the dispersion of pollutants based on a shifting reference grid. This is based on the predominant wind direction, or the common direction of the movement of dust plume. The Lagrangian model can be represented as

$$< c(r,t) >= \int_{-\infty}^{t} \int p(r,t|r',t')S(r',t')dr'dt' \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(5)$$

Where,

<c(r,t)> : average pollutant concentration at location r at time t (mg/m^3)
S(r’,t’) : source emission term (gm/m^3)

p(r,t r',t') : the probability function that an air parcel is moving from location r' at time t' (source) to location r at time t

The probability function is derived by considering meteorological conditions. Particle size distribution and density must be considered if the source of emission consists of particles.

3.4.2 Emission Factors for Different Mining Activities

Most of the sources of dust for mining activity are of fugitive nature, i.e. it's difficult to identify the sources of these emissions. However attempts have been made to derive empirical formulae for various mining activities like drilling, loading, transportation etc.

Chakraborty et al. (2002) [1] have proposed empirical formulae for emission rate for different mining activities. They have carried out a study on seven coal mines and three iron ore mines to determine the emission rate and to develop empirical formulae to calculate emission rates of various mining activities. They have developed 12 empirical formulae for various mining activities ranging from drilling, loading to transportation etc. Emissions of gaseous pollutants are also considered developing formulae for NOx and SO_2. The validation study was carried out which shows an accuracy of 77.2% to 80.4%. The study was carried out during winter season to evaluate worst possible air pollution due to low ventilation co-efficient. The emission rates of different mining activities were calculated on the basis of modified Pasquil and Gifford formula.

$$\mathbf{Cx, o} = \frac{\mathbf{Q}}{\boldsymbol{\pi u \sigma y \sigma z}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\mathbf{(6)}$$

Where,

$C_{x,o}$: difference in pollutant concentration (downwind - upwind) (g/m^3)
Q : emission rate of pollutant (g/sec)
Π : 3.14159
u : mean wind speed (m/sec)
σ_y : horizontal dispersion coefficient (m)
σ_z : vertical dispersion coefficient (m)

Coal and ore handling plants, haul and transport road are found to be the major emission sources for the mine.

The emission factors for different mining activities are tabulated in Table 0.1.

Table 0.1 Emission Factors of Different Mining Activities

Activity	Emipirical Equation
Drilling	$E = 0.0325[\{(100-m)su\}/\{(100-s)m\}]^{0.1}(df)^{0.3}$
Overburden loading	$E=[0.018\{(100-m)/m\}^{1.4}\{s/(100-s)\}^{0.4}(uhxl)^{0.1}]$
Coal/mineral loading	$E=[\{(100-m)/m\}^{0.1}\{s/(100-s)\}^{0.3}h^{0.2}\{u/(0.2+1.05u)\}\{xl/(15.4+0.87xl)\}]$
Haul road	$E=[\{(100-m)/m\}^{0.8}\{s/(100-s)\}^{0.1}u^{0.3}\{2663+0.1(v+fc)\}10^{-6}]$
Transport road	$E=\{(100-m)s\}/\{m(100-s)\}]^{0.1}u^{1.6}\{1.64+0.01(v+f\}\}10^{-3}$
Overburden unloading	$E=[1.76h^{1/2}\{(100-m)/m\}^{0.2}\{s/(100-s)\}^{2}u^{0.8}(cy)^{0.1}]$
Coal/mineral unloading	$E=0.023[\{(100-m)sh\}/\{m(100-s)\}]^{2}(u^{3}cy)^{0.1}$
Exposed overburden dump	$E=[\{(100-m)/m\}^{0.2}\{s/(100-s)\}^{0.1}\{u/(2.6+120u)\}\{a/(0.2+276.5a)\}]$
Stock yard	$E=\{(100-m)/m\}^{0.1}\{s/(100\ s)\}\{u/(71+43u)\}[\{cy/(329+7.6cy)\}+\{lx/(30+900lx)\}]$
Coal handling plant	$E=[\{(100-m)/m\}^{0.4}\{a^{2}s/(100-s)\}^{0.3}\{u/(160+3.7u)\}]$
Workshop	$E=[0.064\{(100-m)/m\}^{1.8}\{as/(100-s)\}^{0.1}\{u/(0.01+5u)\}10^{-4}]$
Exposed pit surface	$E=[2.4\{(100-m)/m\}^{0.8}\{as/(100-s)\}^{0.1}\{u/(4+66u)\}10^{-4}]$
Overall mine (for SPM)	$E=[u^{0.4}a^{0.2}\{9.7+0.01p+b/(4+0.3b)\}]$
Overall mine (for SO2)	$E=a^{0.14}\{u/(1.83+0.93u)\}[\{p/(0.48+0.57p)\}+\{b/(14.37+1.15b)\}]$
Overall mine (for NOx)	$E=a^{0.25}\{u/(4.3+32.5u)\}[1.5p+\{b/(0.06+0.08b)\}]$

Where,

m : Moisture content (%)
s : Silt content (%)
u : Wind speed (m/s)
d : Hole diameter (mm)
f : Frequency (no. of holes/day)
h : Drop height (m)
l : Size of loader (m^3)
v : Average vehicle speed (m/sec)
c : Capacity of dumper (ton)

a : Area (km^2)

y : Frequency of unloading (no. / Hr)

x : Frequency of loading (no. / Hr)

p : Mineral production (Mt/yr)

b : OB handling (Mm^3/yr)

E : Emission rate (g/sec)

3.4.3 Dust Dispersion Modelling Using AERMOD View

AERMOD stands for AMS/EPA Regulatory Model. This model based on planetary boundary layer principle. ISC-AERMOD integrates the standard U.S. EPA models like AERMOD, ISCST3, and ISC-PRIME into one interface. These models are used for determination of dispersion, concentration levels and deposition of various pollutants for different sources. AERMOD fully integrates the PRIME building downwash algorithms, terrain features, advanced depositional parameters and state-of-the-art meteorological turbulence calculations. This model is applicable to rural and urban areas, surface and elevated releases, flat and complex terrain and for multiple sources like point, area and volume sources.

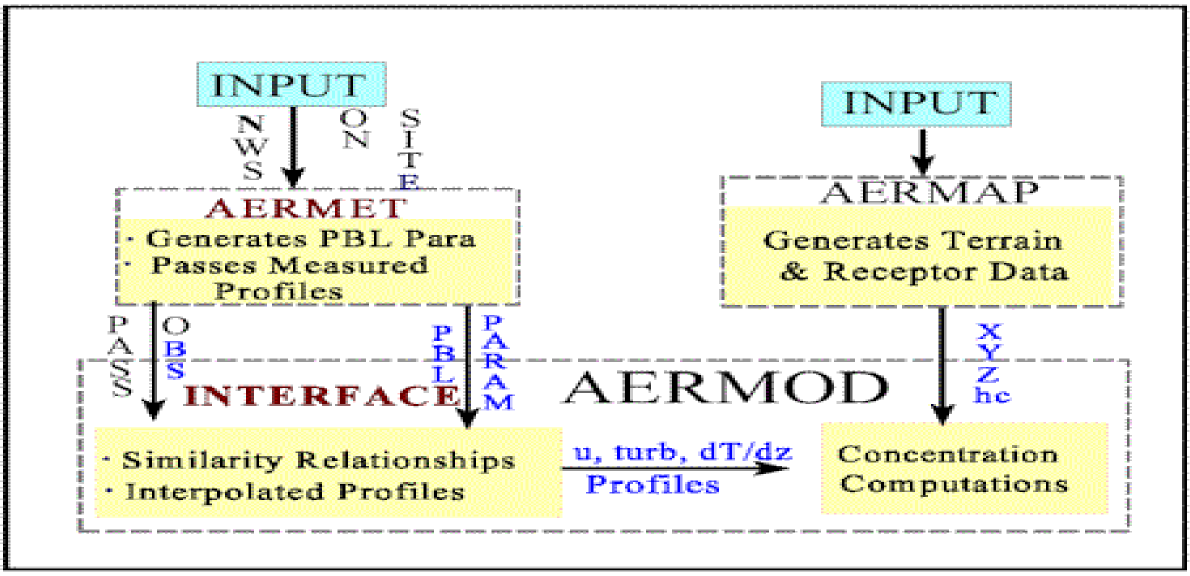

Figure 3.5 Data flow in AERMOD modelling system

(Source http://www.weblakes.com/guides/aermod/section2/index.html)

As shown in the Fig.3.5 AERMOD requires two pre-processors like AERMET and AERMAP.

3.4.3.1 AERMET

AERMET is used for processing meteorological data to compute boundary layer parameters so that they can be passed to AERMOD which requires two kind of meteorological data files containing surface scalar parameters and vertical profiles as input. These data files are being prepared by AERMET by processing surface and upper air data. Input to AERMET requires surface meteorological observations (like temperature, humidity, cloud cover, station pressure, wind speed, wind direction, hourly precipitation, ceiling height and global horizontal radiation) and Surface characteristics (like albedo, surface roughness and Bowen ratio). After the data is input to AERMET, it calculates PBL parameters like friction velocity (u*), mixing height (z_i), convective velocity scale (w*), Monin-Obukhov length (L), surface heat flux (H) and temperature scale (*). AERMOD extracts these data for the calculation of vertical profiles of wind speed (u), potential temperature gradient (d/dz), potential temperature ( ), the horizontal Lagrangian time scale (TL_y), and lateral and vertical turbulent fluctuations (v, w). Fig.3.6 represents various processing stages of AERMET.

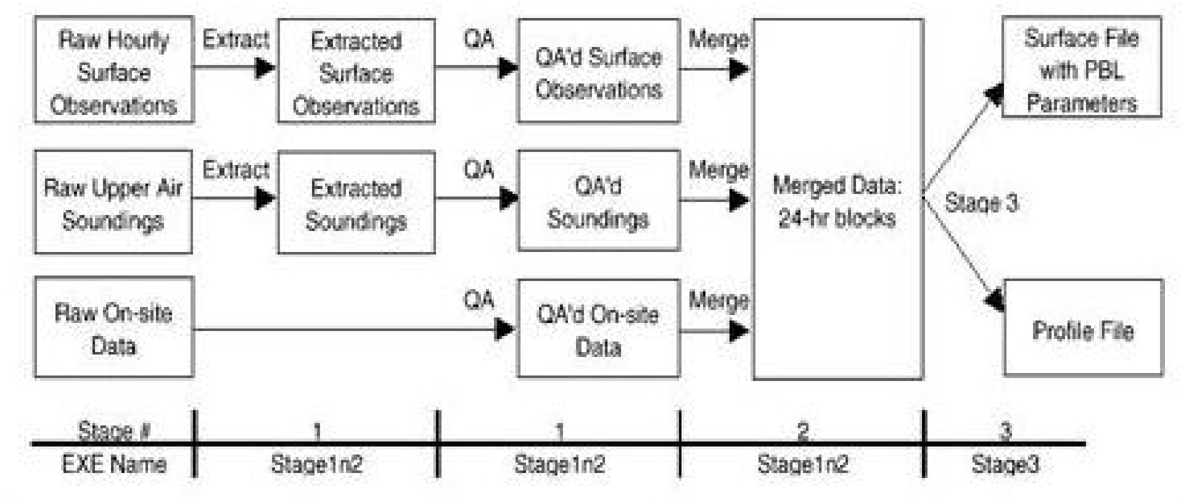

Figure 3.6 Processing stages of AERMET

(Source: U.S. EPA User's Guide for AERMET – DRAFT)

3.4.3.2 AERMAP

AERMAP stands for AMS/EPA Regulatory Model Terrain Pre-processor. AERMOD requires height and locations of each receptor and sources. Hence AERMAP is used to process terrain data like x, y, z co-ordinates and elevation for each receptor. The data required by AERMAP is obtained from Digital Elevation Mapping (DEM) data. AERMAP produces two output files like Receptor Output File (*.rou) which contains the calculated terrain elevations and scale height for each receptor and Source Output File (*.sou) which contains the calculated base elevations for all sources. For each receptor, AERMAP passes information like the receptor's co-ordinates (x_r, y_r), its height above mean sea level (z_r) and the terrain height scale (h_c) of the receptor to AERMOD.

3.4.3.3 Google Earth

Goole earth can be used as an additional feature of AERMOD. Site domain boundary, sources of emission, uniform Cartesian receptor grids, contours, terrain contours generated by AERMOD can be exported to google earth to have a natural view of the dispersion and isopleths. Concentration and co-ordinates of each location can be determined by just clicking on those locations in google earth. It provides a user friendly interface to see the output generated by AERMOD. It is also useful to see the extent of dispersion of the pollutants around the source with satellite view.

3.4.4 Input Data Requirement of AERMOD

The input data required for AERMOD are

- Location of Reference Point (latitude, longitude)
- Location of the mine (latitude, longitude)
- Base Map of the area
- Hourly Micrometeorological Data
- Pollutants to be modelled
- Location of Sources (latitude, longitude)
- Emission Factors for Different Sources
- No of Receptors
- Terrain Features

3.4.5 Work Process of AERMOD

First, the location of the reference point was chosen. The exact latitude and longitude of the reference point was determined. Then, the projection system for the project was selected. According to the projection system and its corresponding datum, the UTM zone of the project site was determined. There are 60 UTM zones (from 1 to 60) and two hemispheres (north and south) in the world. Based on the position of the reference point, projection system and datum, the UTM zone (from 1 to 60) and hemisphere (north or south) were identified. This can be done by converting latitude and longitude of the reference point to the projection and datum of interest. There are various projections available for this purpose like

- UTM: Universal Transverse Mercator
- Other: Local Cartesian Coordinate System
- Unknown
- ITM: Israeli Transverse Mercator (New Israeli Grid)
- OSNG: Ordnance Survey National Grid (Great Britain Grid)

Similarly there are various datum associated for a particular projection system. Some of the datum used for this purpose are

- WGS84: World Geodetic System 1984
- ETRS89: European Terrestrial Reference System 1989
- NAD27: North American Datum 1927
- NAD83:North American Datum 1983
- OHD: Old Hawaiian Datum
- PRD: Puerto Rico Datum
- WGS72: World Geodetic System 1972
- WGS84: World Geodetic System 1984
- ED50: European 1950
- ETRS89: European Terrestrial Reference System 1989
- NAD27: North American Datum 1927
- NAD83: North American Datum 1983
- OHD: Old Hawaiian Datum
- PRD: Puerto Rico Datum
- WGS72: World Geodetic System 1972
- WGS84: World Geodetic System 1984
- ED50: European 1950
- NID: New Israeli Datum (GRS80 ellipsoid)
- OSGB36: Ordnance Survey Great Britain 1936

After the projection system, datum, UTM zone and hemisphere have to be identified then radius of the modelling area has to be selected. The radius has to be chosen in such a manner that the concentration levels of pollutants at the location of interest can be predicted. After specifying the radius of influence, the data can be exported to google earth to see the satellite view of the area of interest. After projecting the data to google earth the area of interest is delineated and base map is generated.

Then, AERMOD imports the base map. The reference point can be chosen as the centre of the base map. Then the area to be modelled can be seen in the interface of AERMOD.

The input to AERMOD is generally divided into various parts like

- Control Pathway
- Source Pathway
- Receptor pathway
- Meteorological Pathway
- Output pathway
- Terrain processor

3.4.5.1 Control Pathway

In control pathway dispersion options (concentration, total deposition, dry deposition, wet deposition), type of pollutants ($PM_{2.5}$, PM_{10}, NOx, SO_2, TSP), pollutant averaging time options (1hr, 3hr, 24hr, period, annual), terrain options (elevated, flat, flat and elevated), dispersion co-efficient (rural, urban) are specified.

3.4.5.2 Source Pathway

In source pathway, different kinds of sources like point, area, line, and volume are identified. Their locations (co-ordinates), base elevation, release height, emission rate, gas exit temperature, gas exit velocity, gas flow rate, and stack inside diameter are specified. Building down wash and background concentration can also be specified.

3.4.5.3 Receptor Pathway

In receptor pathway, number of receptors, their spacing, co-ordinates of the grid, centre of the Cartesian grid can be specified. The grids can be of different types like uniform Cartesian, non-uniform Cartesian, uniform polar, non-uniform polar, multi-tier and nested. Similarly the discrete receptors can be of different types like discrete Cartesian, discrete polar and discrete ARC.

3.4.5.4 Meteorological Pathway

In meteorological pathway, the files generated by the AERMET (i.e. Surface met data *.PFC and profile met data *.PFL) are passed to AERMOD. For producing surface met data and profile met data, AERMET requires hourly micrometeorological data.

There are 13 parameters which need to be input to AERMET. Those are

- Year
- Month
- Day
- Hour
- Cloud Cover (tenths)
- Dry Bulb Temp (°C)
- Relative Humidity (%)
- Station Pressure (mbar)
- Wind Direction (deg)
- Wind Speed (m/s)
- Ceiling Height (m)
- Hourly Precipitation (1/100th of inch)
- Global Horizontal Radiation (Wh/m^2)

Samson format files should be input to AERMET. However, Excel files can also be imported and converted into Samson format files so that they can be input to AERMET. Along with the hourly micrometeorological data, upper data is also required. However, upper air estimator can also be used. Surface characteristics (like albedo, surface roughness and Bowen ratio) are also required. Based on the land use type and season, these parameters can be estimated.

3.4.5.5 Output Pathway

In output pathway output options such as plot files and threshold violation files can be specified. Output options for each short term averaging periods for pollutants can be defined. Highest value option controls high value summary table by receptors. The maximum value option controls output for overall maximum value summary tables. Contour plot file option allows producing file suitable for modelling purpose.

3.4.5.6 Terrain Processor

In order to determine the terrain elevations of all receptors, sources and buildings, US EPA AERMAP model must be run. AERMAP can extract digital terrain data from WebGIS server for the particular area. SRTM3/SRTM1 map can be selected for this purpose. SRTM stands for Shuttle Radar Topography Mission. Once the terrain data got imported, AERMAP model can run. After the model run is completed, import elevations of the source, building and receptors can be imported to the model.

3.4.5.7 Running AERMOD

AERMOD has to be selected among the other model options in the model menu. Then the status of the model has to be checked. Any missing data or error can be identified at this stage which can be rectified before the model is run. If there is no information about the error in the project status page then the model can be run. The model run can take from few minutes to several hours depending upon the nature of the source. If the source is point sources then the running time is less but for line source the running time is quite high. After the model run has completed successfully isopleths for different time periods as specified in the output pathway is generated. The results of the output like site domain boundary, sources of emission, uniform Cartesian receptor grids, contours, terrain contours can be exported to google earth to determine the dispersion of pollutants at different locations. Google earth provides a user friendly interface to see the output generated by AERMOD. By just clicking on any point in the map the maximum and minimum concentration level, elevation and co-ordinates of that point can be found out.

CHAPTER 4

DUST MONITORING, CHARACTERIZATION AND DISPERSION MODELLING- A CASE STUDY

DUST MONITORING, CHARACTERIZATION AND DISPERSION MODELLING- A CASE STUDY

4.1 Study Area: Lakhanpur Opencast Project

Lakhanpur opencast project (LOCP) of Ib valley coalfield of Mahanadi Coalfields Limited (MCL) was selected for the study. The mine deploys state-of- the-art eco-friendly technology i.e. surface miner and is producing 15 Million Tons of coal per annum. Lakhanpur OCP is situated in Lakhanpur Tahsil of Jharsuguda district in Orissa. It lies between latitudes 21’43’30” to 21’46’44” and longitudes 83’49’11” to 83’52’38”. The mine was divided into 3 quarries, i.e. quarry1 to quarry 3. At present, quarry 1 is being worked by conventional shovel-dumper combination for overburden (OB) and by surface miner and tippers combination for coal.

Lakhanpur OCP envisages working of only one seam namely Lajkura seam. The upper two seams, namely Belpahar and Parkhani seams do not exist in the area very prominently and cannot be extracted. The two seams, namely Rampur and Ib, beneath Lajkura seam occur with large parting and can be worked by underground method, after exhausting the Lajkura seam. Lajkura seam is not exposed on the surface in the block. Width of in crop varies from 200 to 450m, occurring over 6 km along the strike. The minimum OB cover is 8m and maximum cover is about 116m. The dip of the formation is 1 in 16 and is generally towards west. The strike length of the mine is about 6 km. Along dip length of mine is about 2.5 km. Average thickness of workable Lajkura seam is 20-30m with an overall OB ratio of 2.34m^3/ton coal. The available dirt bands, 1 to 5 in numbers, are generally carb shale and ranges in thickness from 1.47m to 6.91m (cumulative). Fig.4.1 shows the location of Lakhanpur mine in the map of India. Fig.4.2 shows the mining site of LOCP. Fig.4.3 shows the satellite view of LOCP.

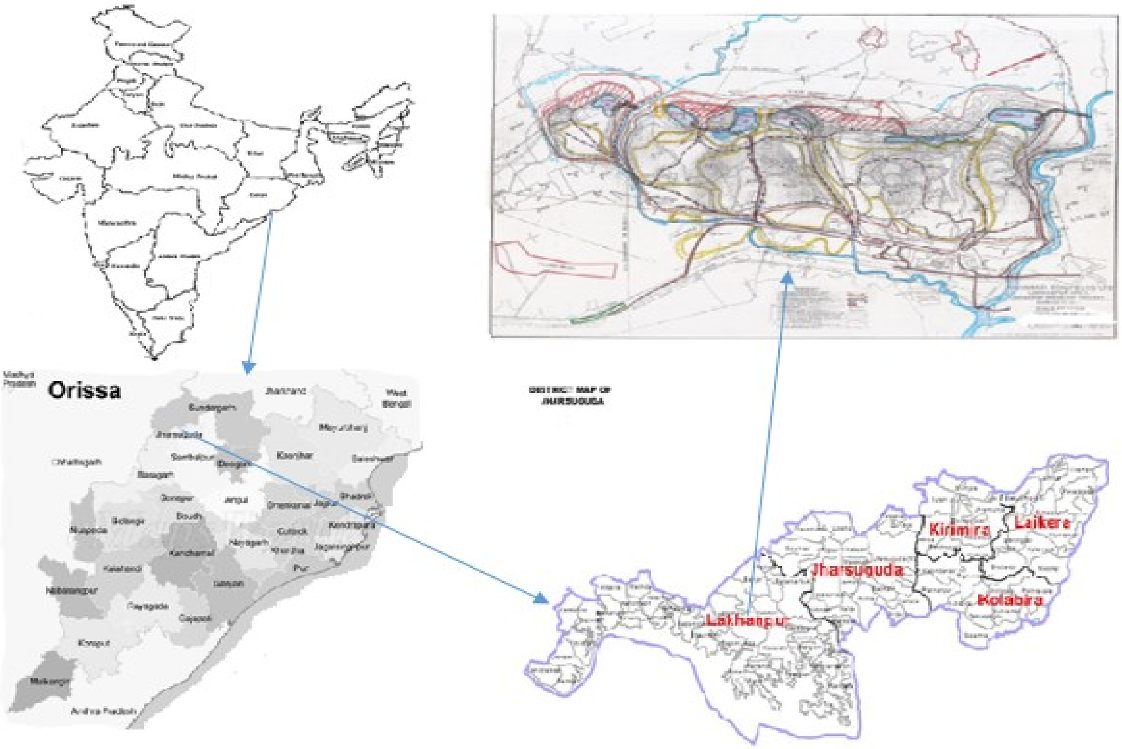

Figure 4.1 Location of Lakhanpur opencast project

Figure 4.2 Mining site of LOCP

Figure 4.3 Satellite view of LOCP

The study on the mine is broadly divided into four headings like

- Real Time Dust Monitoring at Sources Using DustTrak II
- Personal Exposure Monitoring of Different Workers Using PDS APM-800
- Characterization Using FTIR to Determine Silica Content
- Dispersion Modelling Using AERMOD

4.1.1 Real Time Dust Monitoring

Different sources of dust generation in the mine e.g. loading point, drilling, surface miner, blasting operation, haul road and transportation roads were chosen for monitoring. As per The Coal Mines Regulation, 1957 (CMR): 123, the instrument was kept within 1 meter of the dust source in the downwind direction. First zero calibration was done using a zero filter. Then different size selectors like PM_{10}, PM_4, $PM_{2.5}$ and PM_1 were used in a sequence for a period of 1hour to determine dust concentration at selected locations. The data generated were transferred to desktop and TrakPro software was used to analyse the data. TrakPro provides the statistical analysis of the data along with the generation of graph. The concentrations of dust at different locations for different size are as follows.

4.1.1.1 Dust monitoring at Loading point (Shovel-Dumper)

Loading point can be considered to be a major source of dust generation in any large opencast mine. Thousands of dumpers were loaded with coal each day to meet the annual target of 15Mt at LOCP. The loading point (shovel-dumper) of LOCP is shown in Fig.4.4. A comparative study for different size segregated dust fractions at loading point was carried out. Figs. 4.5, 4.6, 4.7, 4.8 show the variation of dust concentration with time for PM_{10}, PM_4, $PM_{2.5}$ and PM_1 respectively.

Figure 4.4 Loading point at LOCP for shovel and dumper

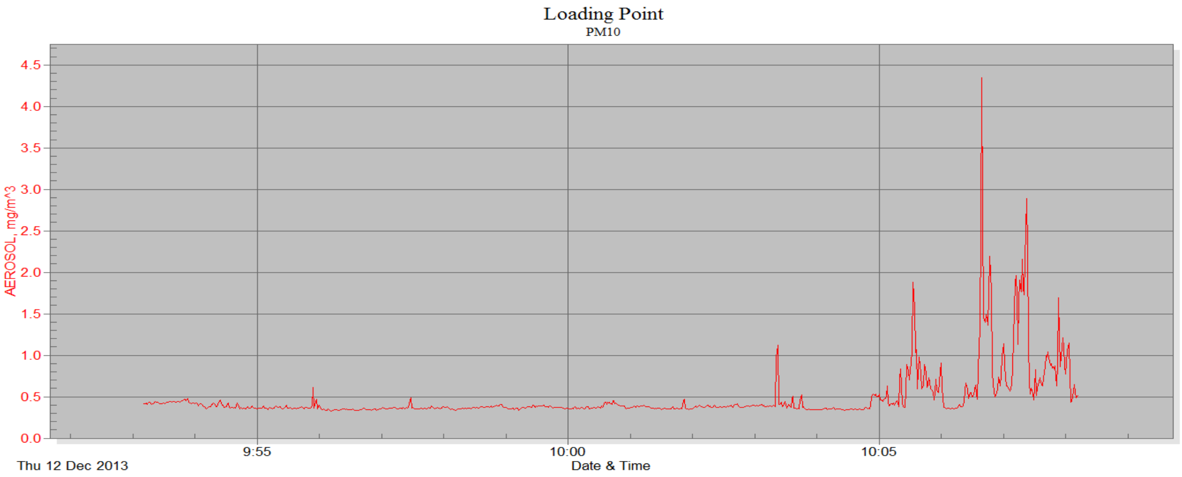

Figure 4.5 Concentration vs Time graph for dust at loading point in PM$_{10}$

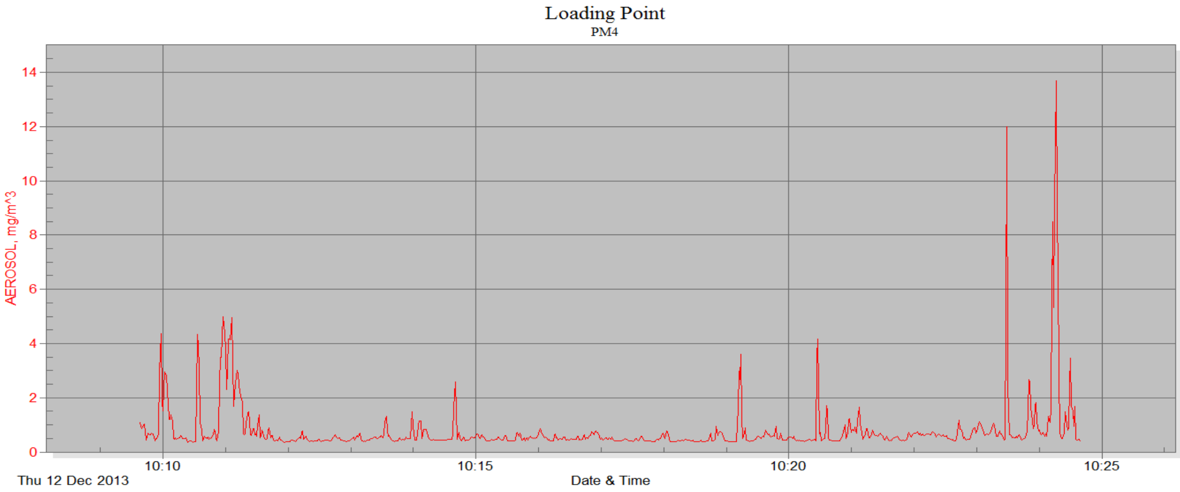

Figure 4.6 Concentration vs Time graph for dust at loading point in PM$_4$

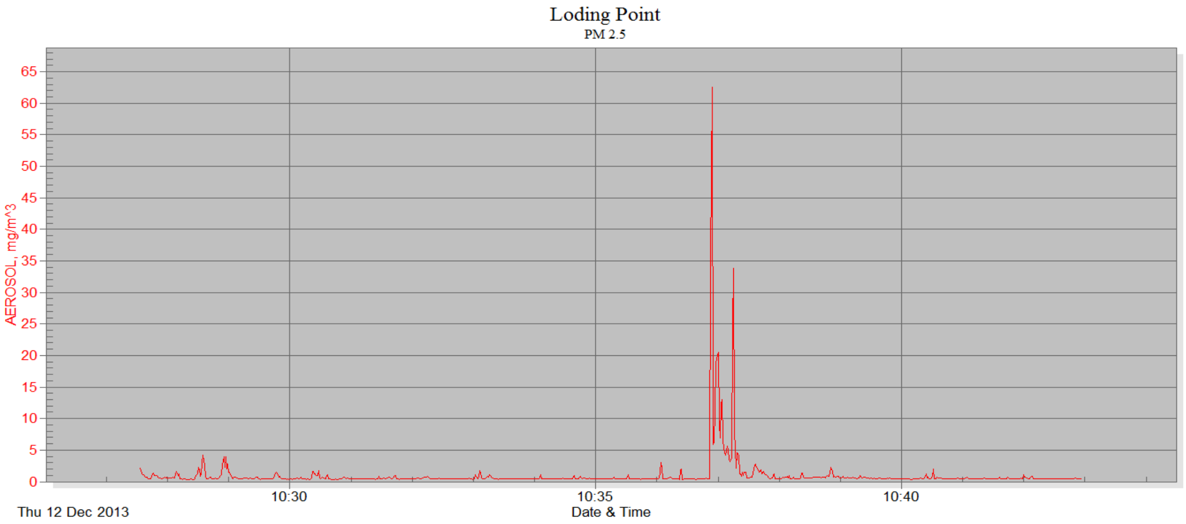

Figure 4.7 Concentration vs Time graph for dust at loading point in PM$_{2.5}$

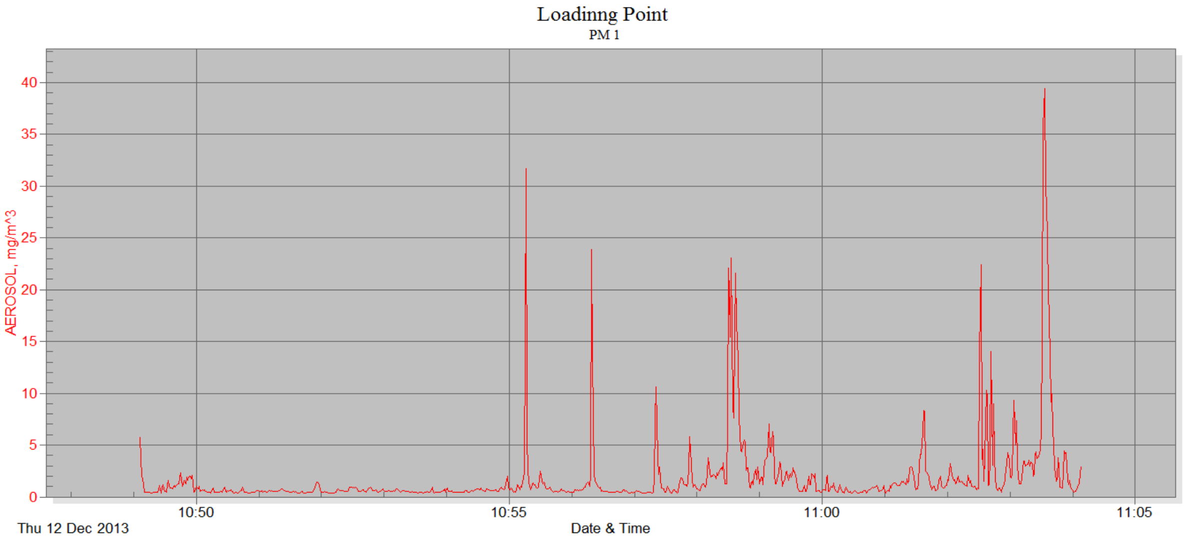

Figure 4.8 Concentration vs Time graph for dust at loading point in PM1

The peaks of the graph represents the time when loading action was taking place. Depending upon the wind direction and loading time, the peaks varied. The lower concentration part of the graph represents the time when the shovel was idle.

4.1.1.2 Dust Monitoring at Surface Miner

Surface miner is another area of concern for any large opencast mine. It is one of the eco-friendly mining methods adopted to reduce ground vibration due to blasting and to improve production. Mostly it is used in coal industry as the compressive strength of coal is within the cutting limit of surface miner and the gradient is usually flat which is also suitable for the operation of surface miner. But the surface miner produces large quantities of fine dust due to cutting of coal. Hence if proper quantity of water is not used to suppress dust then it can be hazardous to workers of the mine. At LOCP, Wirtgen surface miner was used for coal cutting purpose. The operation of surface miner at LOCP is shown in Fig.4.9. The graph of dust monitoring near surface miner at LOCP for the particle size of PM_{10}, PM_4, $PM_{2.5}$ and PM_1 were plotted in Figs. 4.10, 4.11, 4.12 and 4.13.

Figure 4.9 Surface miner in operation at LOCP

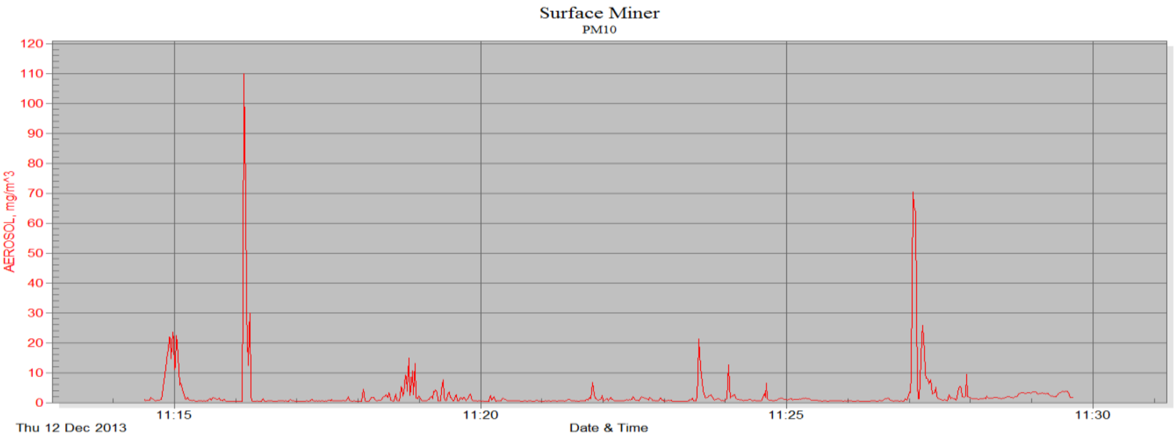

Figure 4.10 Concentration vs Time graph for dust at surface miner in PM_{10}

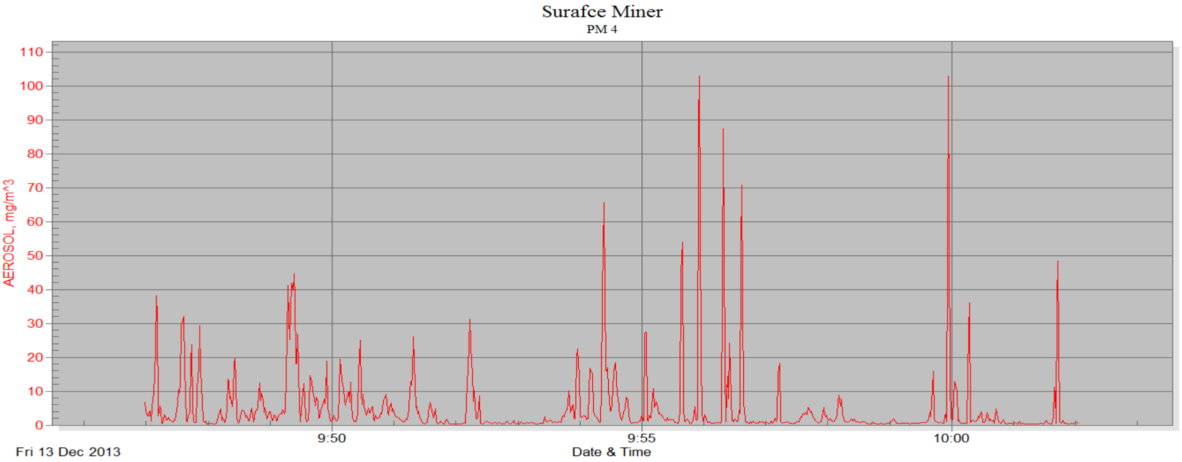

Figure 4.11 Concentration vs Time graph for dust at surface miner in PM_4

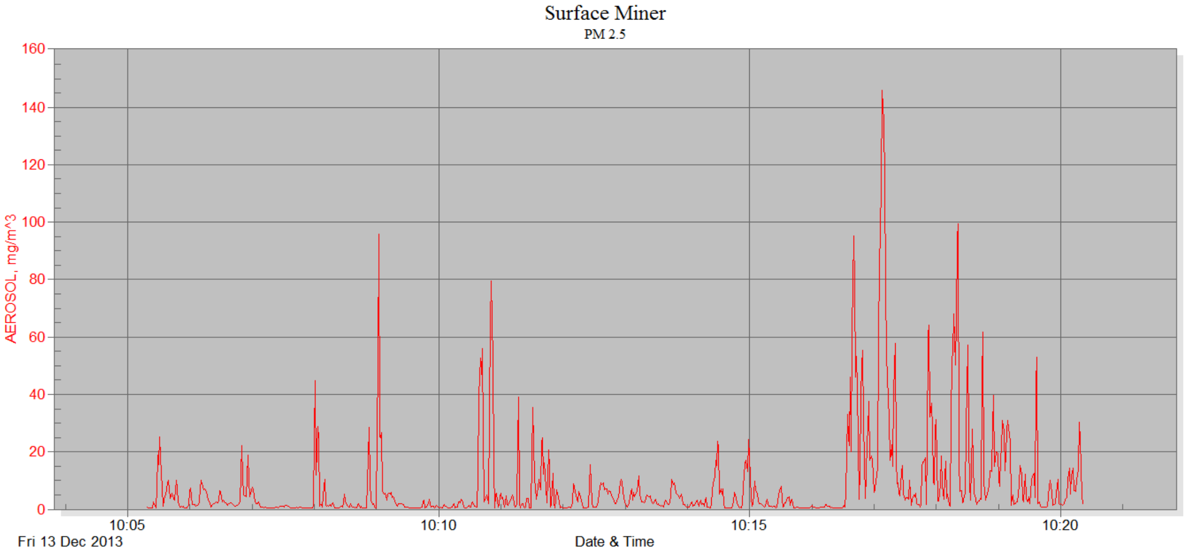

Figure 4.12 Concentration vs Time graph for dust at surface miner in $PM_{2.5}$

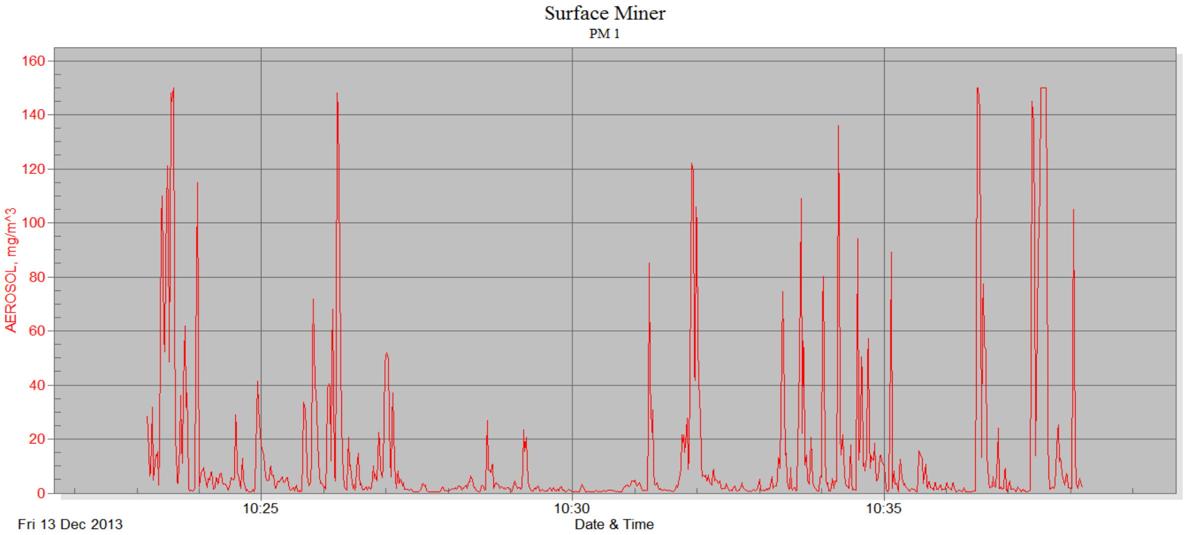

Figure 4.13 Concentration vs Time graph for dust at surface miner in PM_1

The peaks in the graph depicted surface in operation whereas low concentration shows idle time of surface miner. Wind direction also played a major role in determining the dust concentration. Adequate water was not used for dust suppression, hence the graph shows higher concentration comparing to other locations.

4.1.1.3 Dust monitoring at Drilling Operation

Drilling is probably the single most polluting source for any mine. If adequate quantity of water is not used then large amount of fine dust in the respirable range will be generated which may be hazardous to the health of workers. At LOCP drilling was generally carried out in overburden bench so that it can be blasted further for removal of overburden material. AtlasCopco drilling machine with 150mm diameter drill bit were generally used. The drilling machine is shown in Fig.4.14. However insufficient use of water for drilling resulted in highest concentration of dust at drilling point. Figs.4.15, 4.16, 4.17 and 4.18 show the variation of concentration with time for different particle range.

Figure 4.14 Drilling operation at LOCP

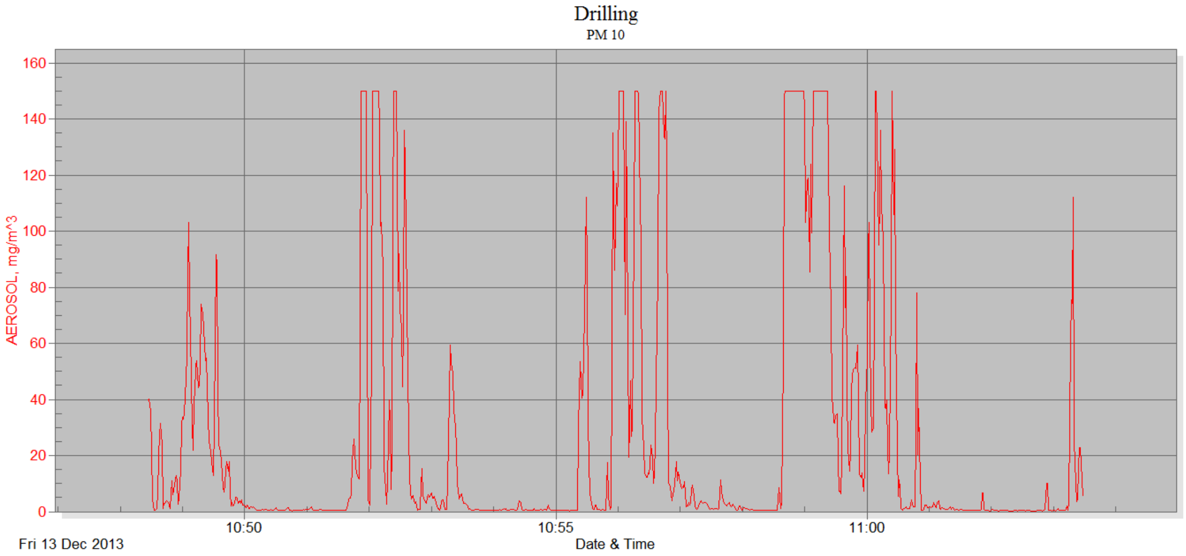

Figure 4.15 Concentration vs Time graph for dust at drilling point in PM_{10}

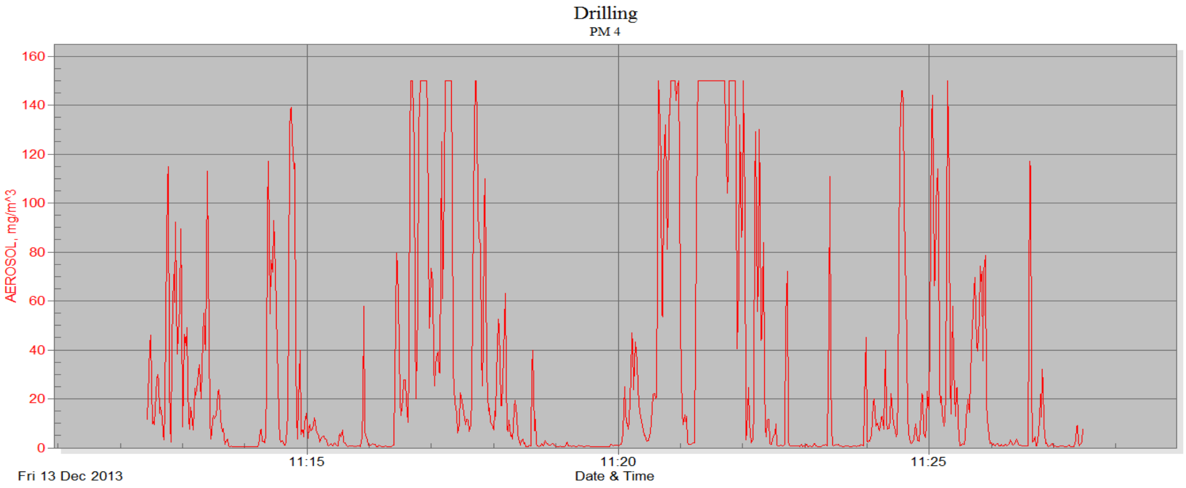

Figure 4.16 Concentration vs Time graph for dust at drilling point in PM_4

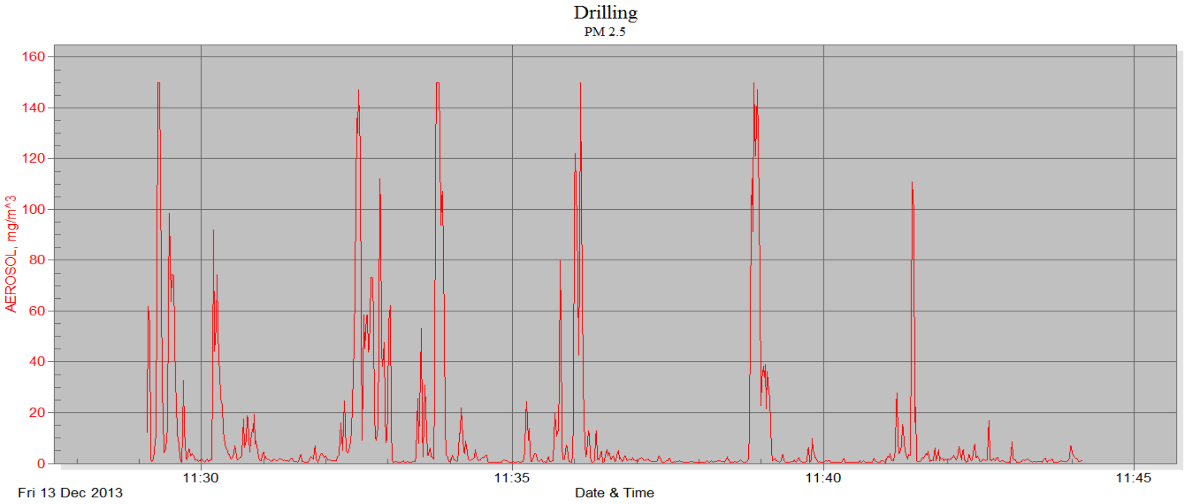

Figure 4.17 Concentration vs Time graph for dust at drilling point in $PM_{2.5}$

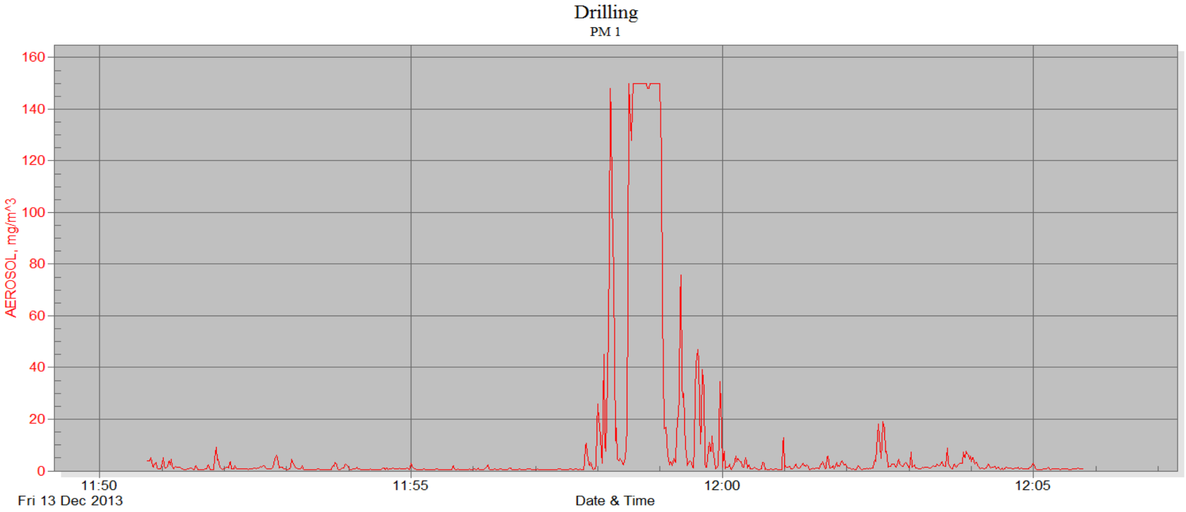

Figure 4.18 Concentration vs Time graph for dust at drilling point in PM_1

The peaks in the graph depicted drilling in operation whereas low concentration shows idle time of drilling machine. Maximum concentration was obtained at drilling point as adequate amount of water was not used to suppress dust. In all particle range, dust concentration was found to be very high. Drilling also accounted for more fine dust as there were numerous peaks in PM1.

4.1.1.4 Dust Concentration at Wet Haul Road of LOCP

Generally haul road accounts for the highest dust generation for any mine. But at LOCP proper measures were taken to reduce dust generation from the haul road. Water sprinkling was carried out in regular intervals hence dust problem was effectively managed. But as the mine utilised large number of small dumpers instead of few large dumpers hence the movement of dumpers were more which results in generation of more dust and other pollutants. Fig.4.19 shows the wet haul road of LOCP. However dust problem was balanced by effective water sprinkling. The variations of concentration with respect to time for different particle range were shown in Figs.4.20, 4.21, 4.22 and 4.23.

Figure 4.19 Wet haul road of LOCP

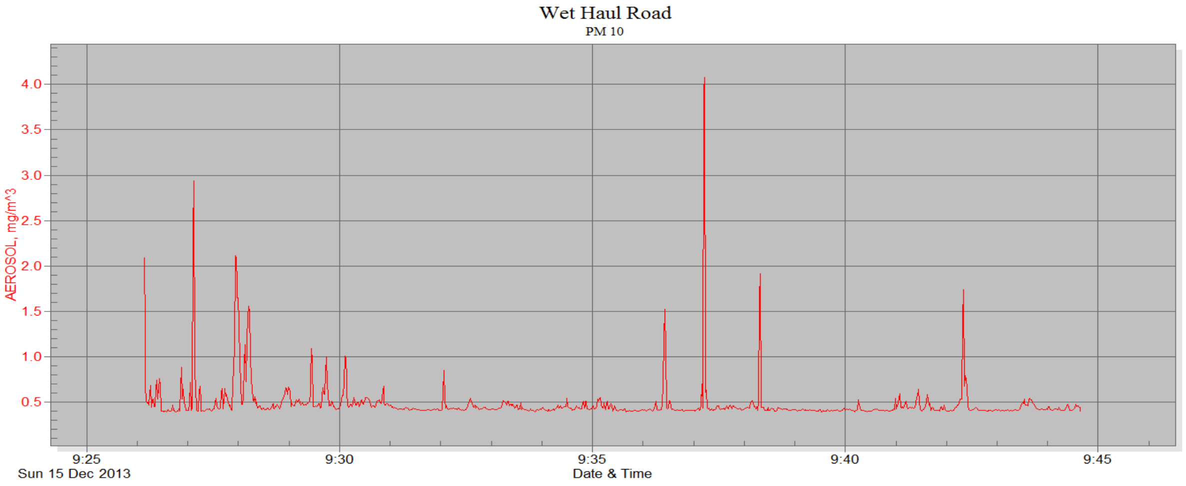

Figure 4.20 Concentration vs Time graph for dust at wet haul road in PM_{10}

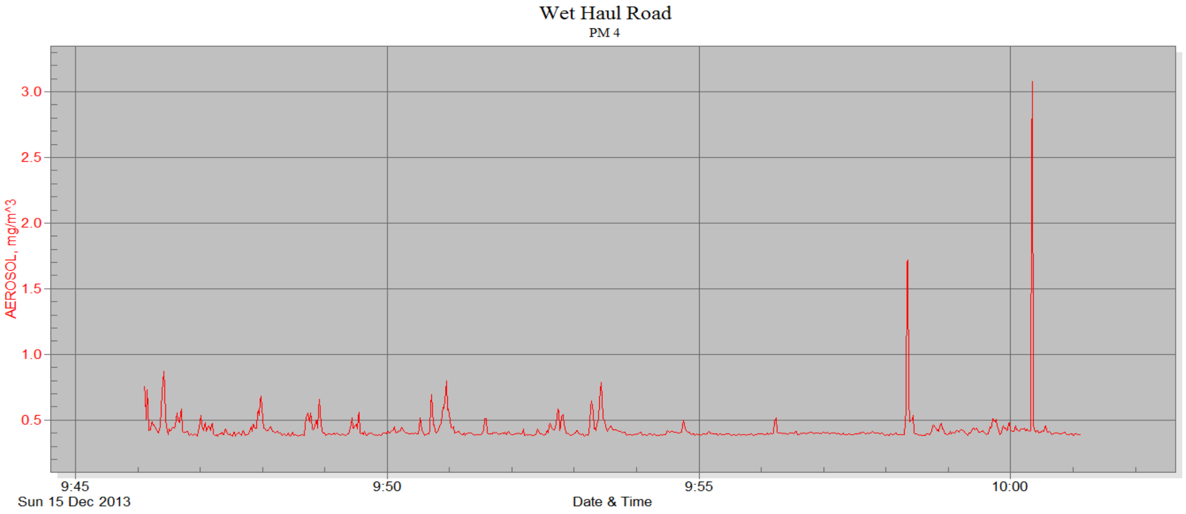

Figure 4.21 Concentration vs Time graph for dust at wet haul road in PM_4

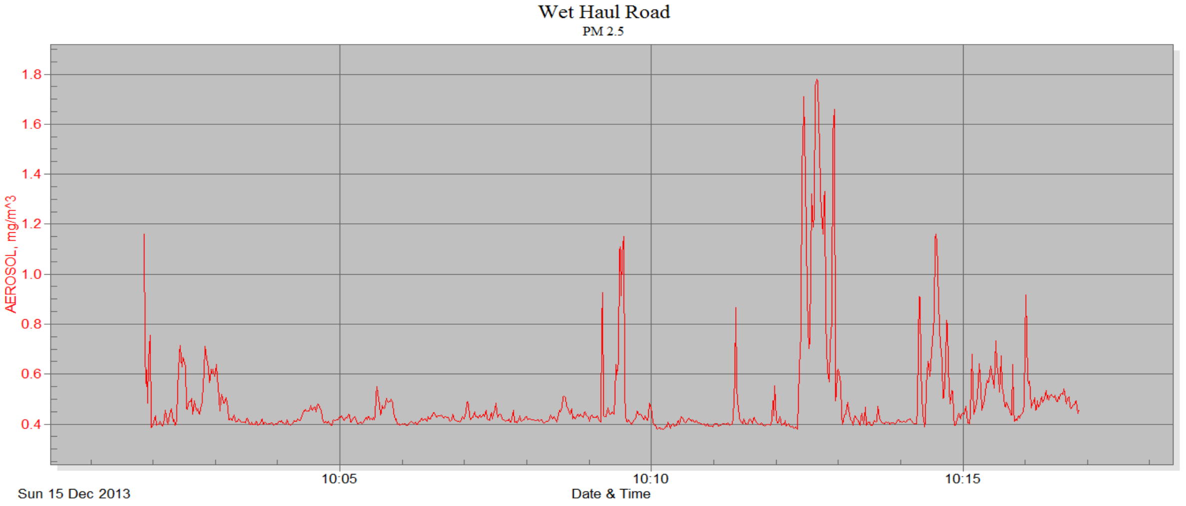

Figure 4.22 Concentration vs Time graph for dust at wet haul road in $PM_{2.5}$

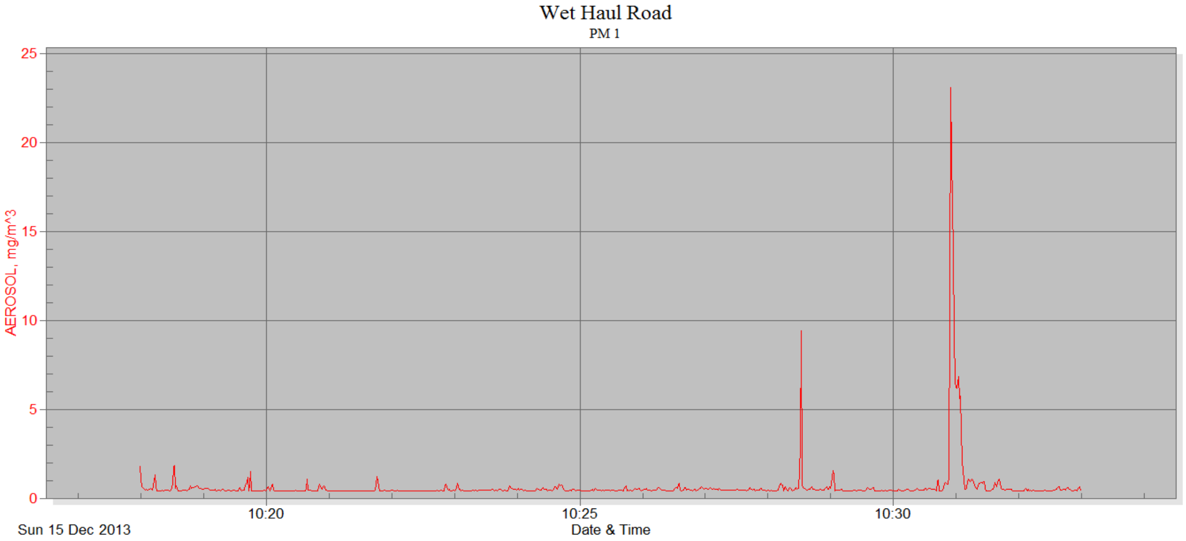

Figure 4.23 Concentration vs Time graph for dust at wet haul road in PM$_1$

The peaks of the graph represent high concentration level at the time of movement of dumpers near monitoring location. Fewer peaks were obtained as effective dust suppression methods were in place. For most of the time concentration remained low.

4.1.1.5 Dust Monitoring at Transportation Road at LOCP

At LOCP Transportation Road was used for transporting coal from stockyards to different customers nearby the mine and for road side selling. A large number of small size dumpers were used for transporting coal. The road as such was not suitable for heavy vehicular movements. Effective dust suppression measures were also not regularly carried out which results in higher concentration of dusts at transportation road comparing to wet haul road. Fig.4.24 shows the transportation road of LOCP. Variation of concentration of dust with respect to time was plotted for different particle range in Figs 4.25, 4.26, 4.27 and 4.28.

Figure 4.24 Transportation road at LOCP

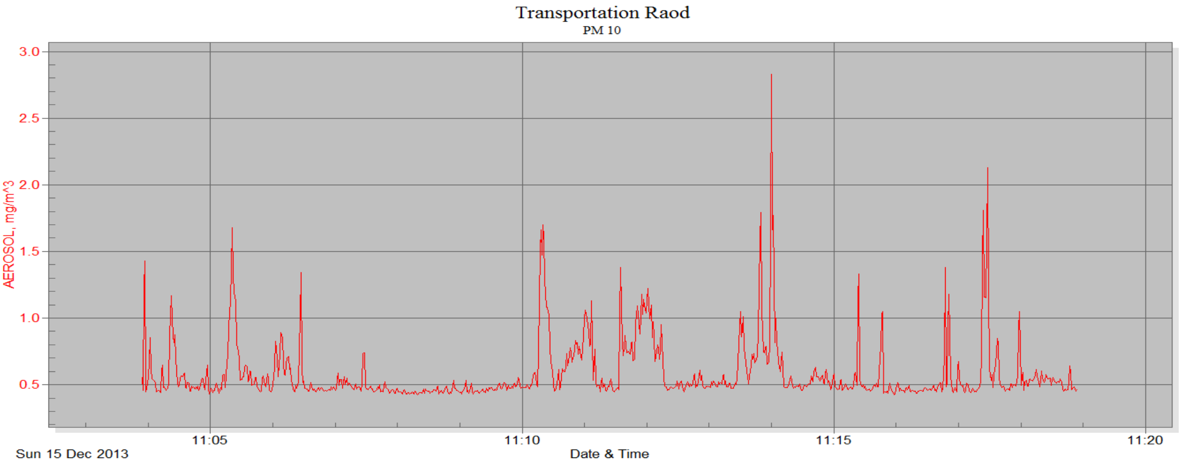

Figure 4.25 Concentration vs Time graph for dust at transportation road in PM_{10}

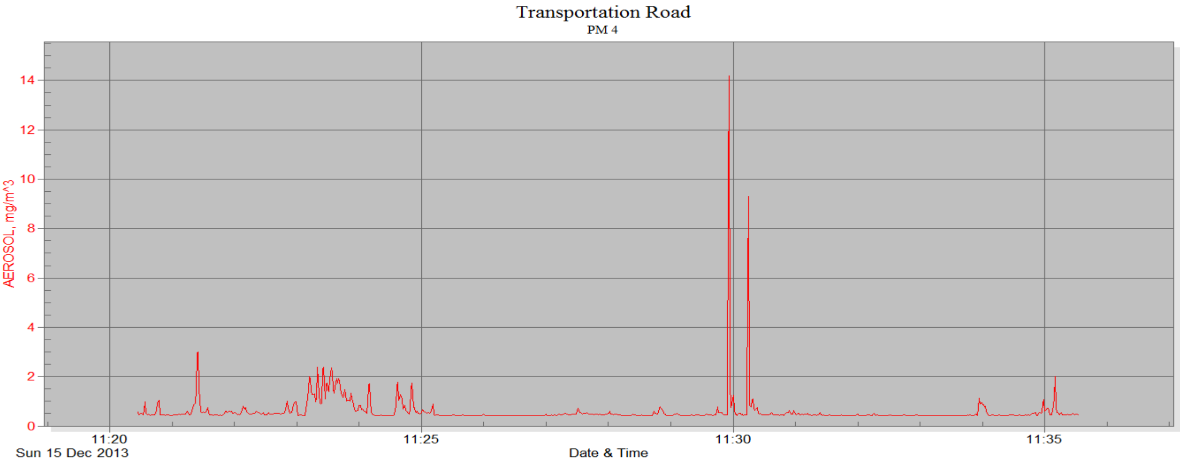

Figure 4.26 Concentration vs Time graph for dust at transportation road in PM_4

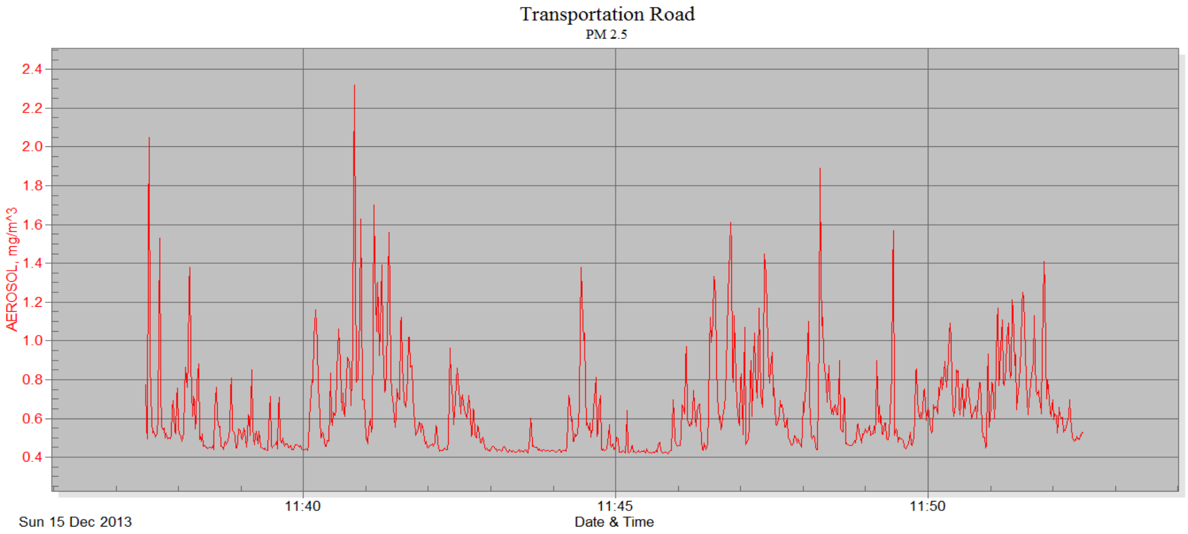

Figure 4.27 Concentration vs Time graph for dust at transportation road in $PM_{2.5}$

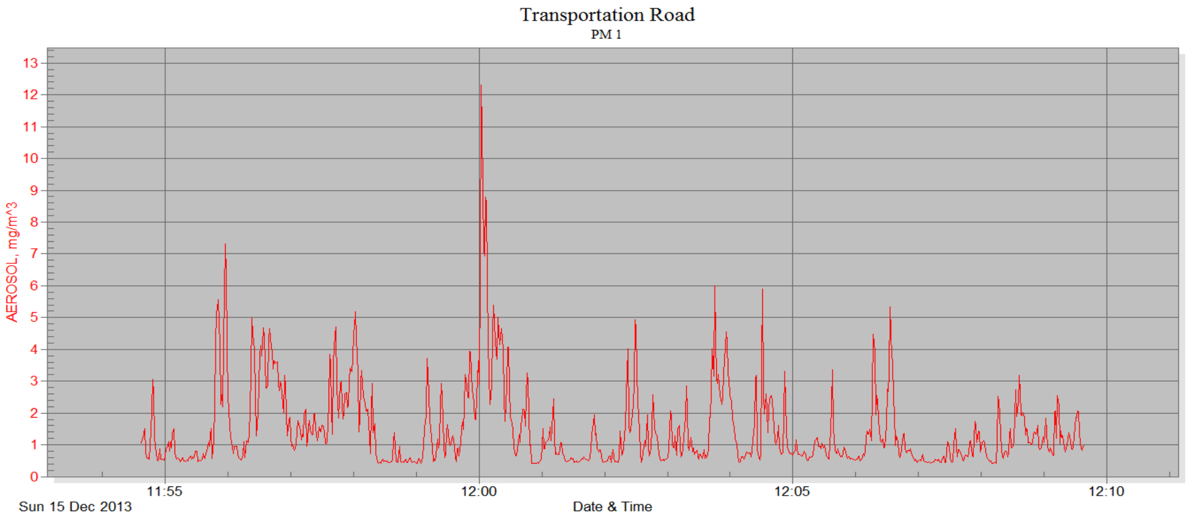

Figure 4.28 Concentration vs Time graph for dust at transportation road in PM_1

The peaks of graph represented high concentration of dust at the time of movement of dumpers near monitoring location. More peaks were obtained which suggests frequent movement of dumpers. The peaks also show higher concentration which shows less effective dust suppression measures.

4.1.1.6 Dust Monitoring at Overburden Bench Before and After Blasting

Blasting involves generation of huge quantities of dust in a small period. Hence monitoring of dust within that period is essential to estimate the contribution of blasting to dust generation. Fig. 4.29 shows the overburden bench of LOCP. At LOCP, blasting was mainly carried out in overburden benches for removal of overburden. After blasting the overburden was removed with combination of shovel-dumper. The explosive used for blasting was site mixed emulsion with nonel detonator. The hole diameter for drilling was kept at 150mm. At the time of monitoring two blasting were carried out in two overburden benches. First blasting involved 1700kg of explosive in 12 numbers of holes. Second blasting involved 1000kg of explosives in 9 numbers of holes. The area was monitored before and after blasting. A variation of concentration of dust before blasting for different size fractions were plotted in Figs. 4.30, 4.31, 4.32 and 4.33. To assess dust generation for the short interval after blasting PM_{10} size selector was used. The concentration of dust with respect to time of first blasting was plotted in Fig. 4.34 and second blasting in Fig. 4.35.

Figure 4.29 Overburden bench at LOCP

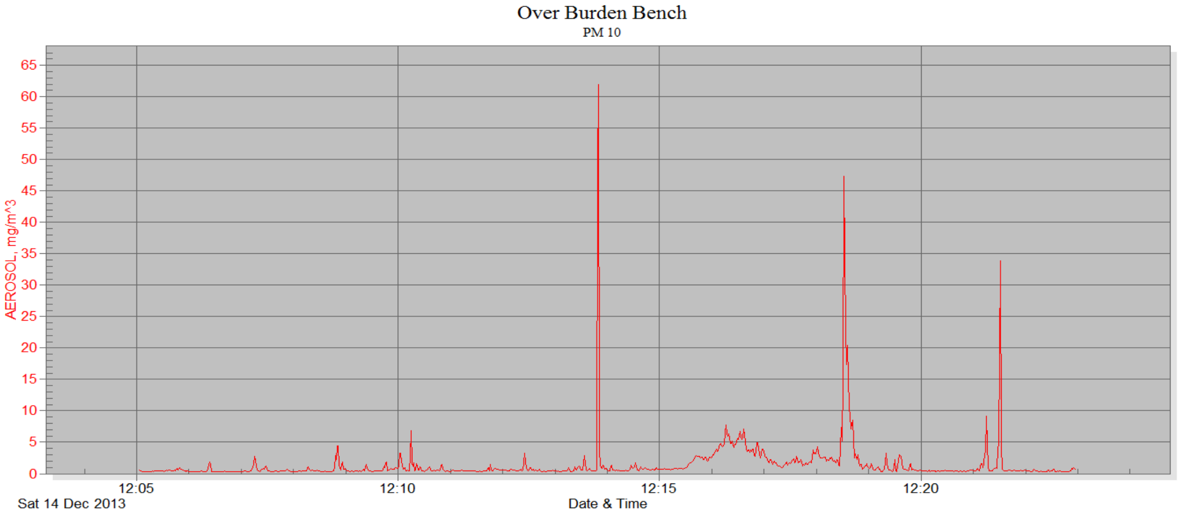

Figure 4.30 Concentration vs Time graph for dust at overburden bench in PM_{10}

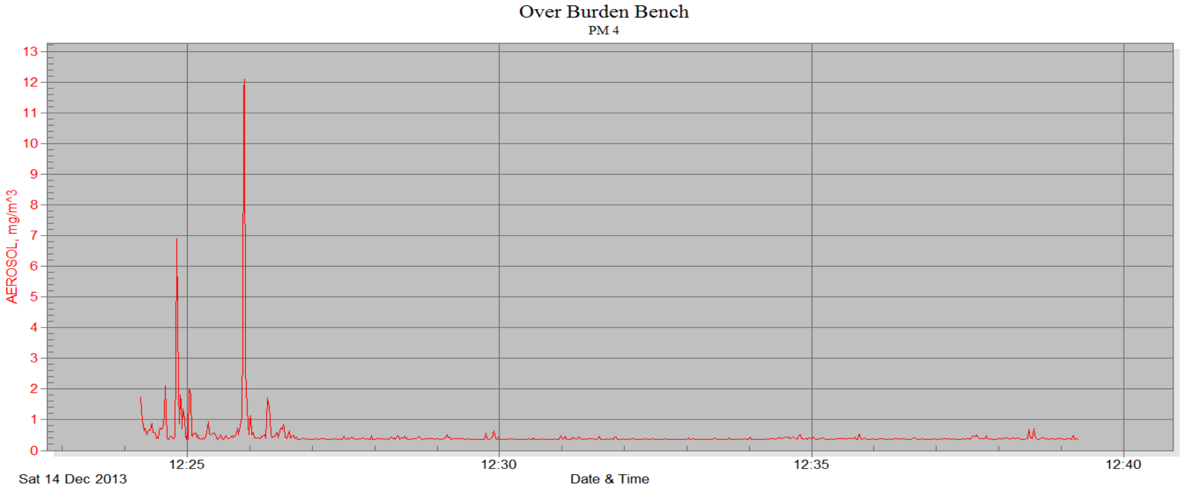

Figure 4.31 Concentration vs Time graph for dust at overburden bench in PM_4

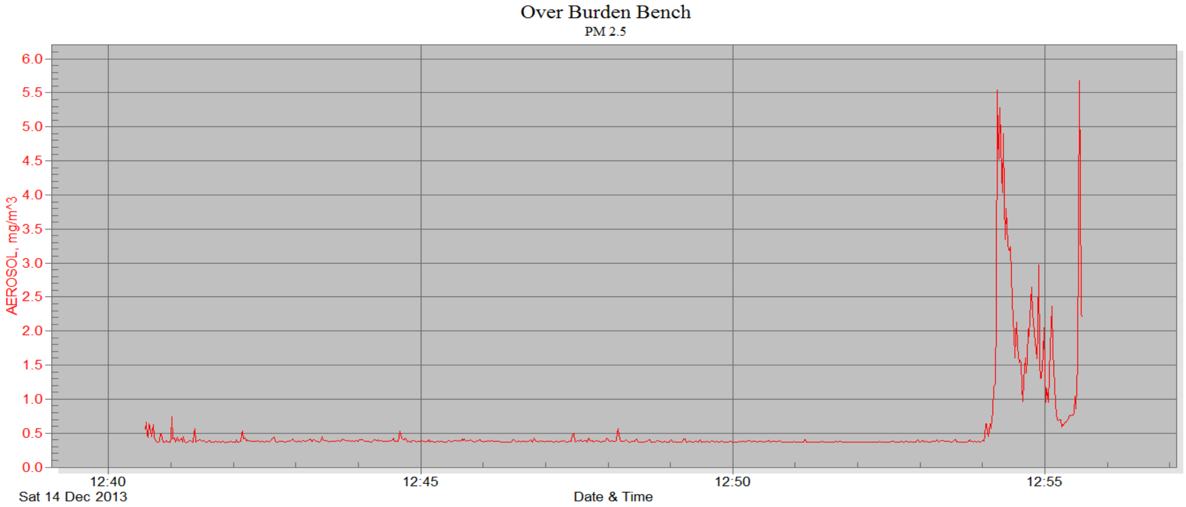

Figure 4.32 Concentration vs Time graph for dust at overburden bench in $PM_{2.5}$

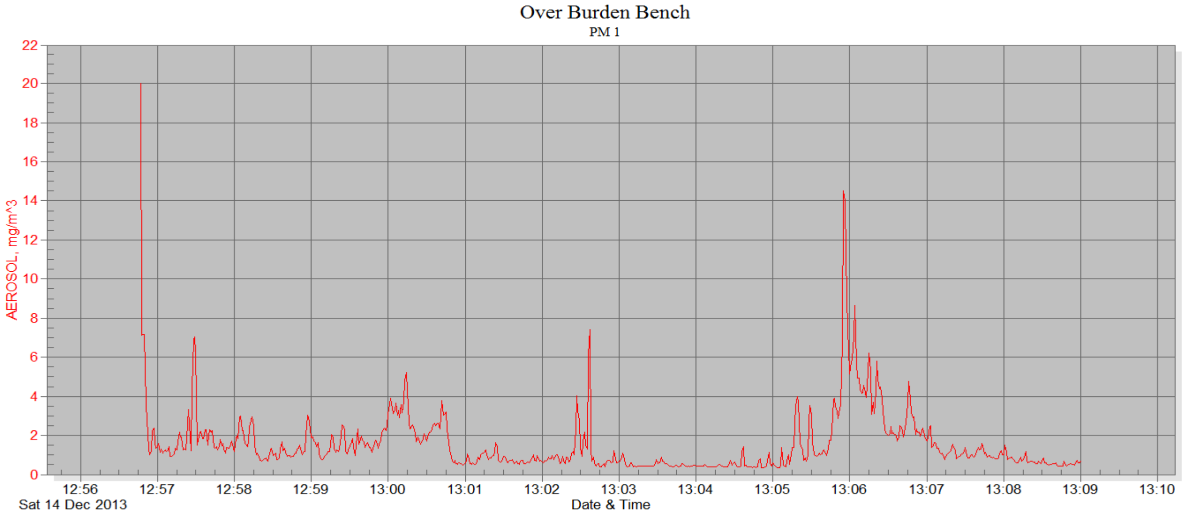

Figure 4.33 Concentration vs Time graph for dust at overburden bench in PM_1

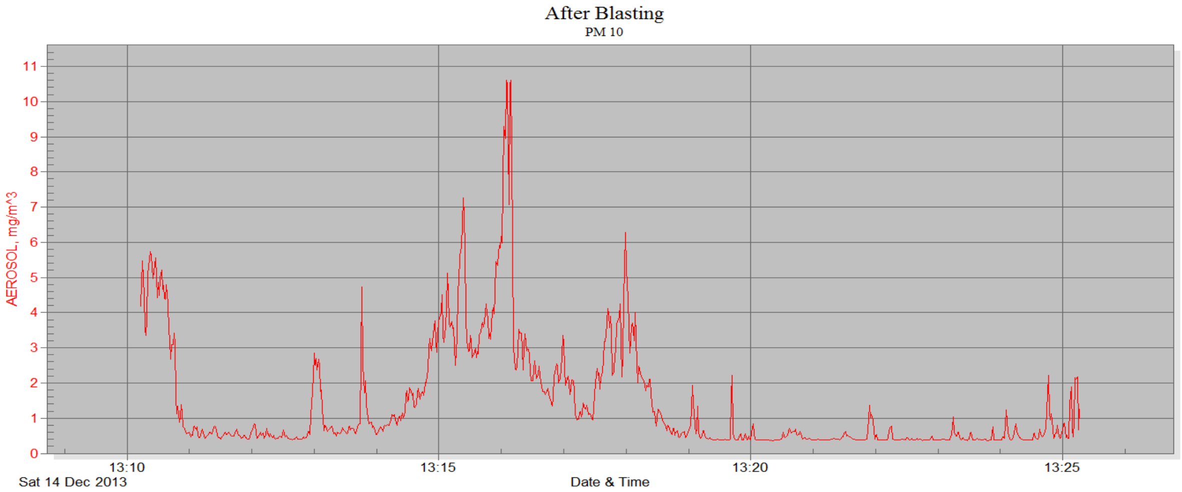

Figure 4.34 Concentration vs Time graph for dust after first blasting in PM$_{10}$

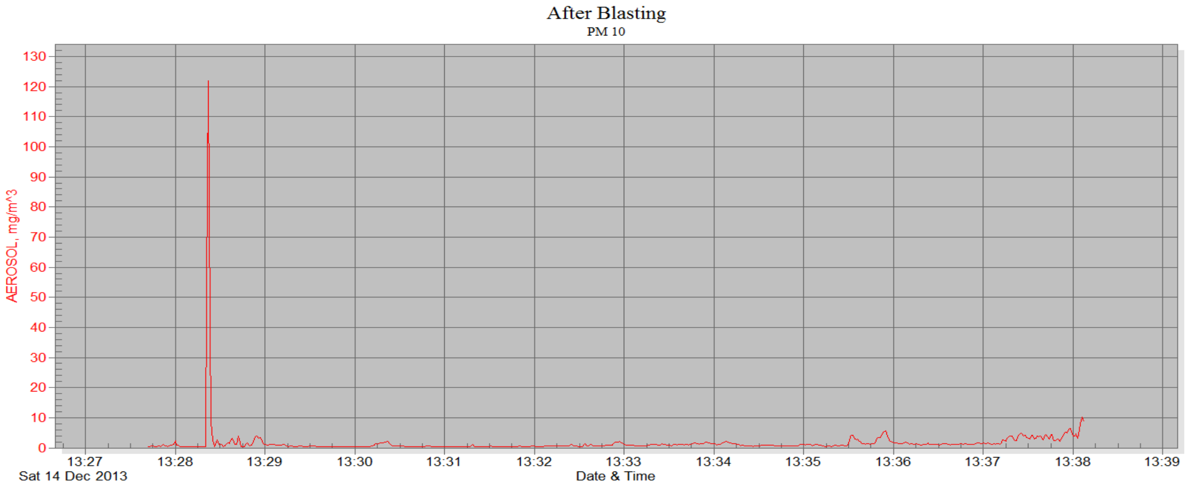

Figure 4.35 Concentration vs Time graph for dust after second blasting in PM$_{10}$

Blasting generated of huge quantities of dust in a short duration. The peaks with high concentration depicted the concentration of just after blasting. These were short lived and for most of the time the concentration was low.

The summary of dust concentrations at different locations of Lakhanpur Opencast Project was tabulated in Table .

Table 4.1 Summary of Dust Monitoring at LOCP

Sl no	Location	Particle Size	Avg. Conc. (mg/m^3)	Min. Conc. (mg/m^3)	Max. Conc. (mg/m^3)
1	Loading point Shovel-dumper (MCL)	1µm	1.800	0.379	39.400
		2.5µm	0.958	0.372	62.600
		4µm	0.787	0.364	13.700
		10µm	0.474	0.326	4.350
2	Surface Miner (MCL)	1µm	13.300	0.311	150.000
		2.5µm	8.350	0.306	146.000
		4µm	4.860	0.284	103.000
		10µm	2.470	0.402	110.000
3	Drilling (MCL)	1µm	8.730	0.412	150.000
		2.5µm	11.100	0.399	150.000
		4µm	30.500	0.328	150.000
		10µm	26.800	0.293	150.000
4	Wet Haul Road (MCL)	1µm	0.631	0.386	23.100
		2.5µm	0.487	0.379	1.780
		4µm	0.428	0.376	3.080
		10µm	0.483	0.389	4.080
5	Transportation Road (MCL)	1µm	1.500	0.410	12.300
		2.5µm	0.642	0.417	2.320
		4µm	0.604	0.411	14.200
		10µm	0.587	0.424	2.830
7	OB Bench (Before blasting) (MCL)	1µm	1.550	0.358	20.000
		2.5µm	0.538	0.360	5.680
		4µm	0.467	0.353	12.100
		10µm	1.420	0.325	62.000
8	OB Bench (After first blasting) (MCL)	10µm	1.420	0.367	10.600
9	OB Bench (After second blasting) (MCL)	10µm	1.590	0.369	122.000

4.1.2 Personal Dust Exposure Sampling

Personal Dust Exposure of different workers associated with mining operations was measured using Personal Dust Sampler (Model No- APM-800). The flow rate was maintained at 1.7l/min for the duration of the exposure. Cyclone was used to measure dust within the respirable zone i.e. within 5 µm. Table shows the exposure of dust of different workers of the mine. As per CMR 123, a place shall be deemed to be in a harmless state for person to work if the weighted average concentration of airborne respirable dust during 8 hour shift is less than three.

Table 4.2 Personal Dust Exposure of Different Persons

Person	Initial Weight of Filter Paper (mg)	Final Weight of Filter Paper (mg)	Flow rate (l/min)	Duration (hr)	Concentration (mg/m^3)
Traffic controller	59.7	61.7	1.7	3.33	5.89
Dozer Operator	59.5	61.8	1.7	4.33	5.21
Explosive Carrier	58.7	67.7	1.7	3	29.41
Dumper Operator	58.4	60.1	1.7	3.66	4.55

4.1.3 Dust Characterisation

The WHO/ILO international programme (1995) [16] on the global elimination of silicosis puts emphasis on characterisation of dust and its sources which involves determination of quartz content in respirable air borne dust.

Fourier Transform Infra-Red technique was used for the determination of quartz content of mine dust. Dust samples were collected from different locations of the mine to measure quartz content of dust through FTIR. FTIR was selected over XRD due to their enhanced efficiency at lower particle sizes. The dust samples were sieved with 200 mesh size and then heated at 105°C for one and half hour for removal of moisture. Then a known weight of dust was mixed with 200 mg of KBr. The mixture was finely mixed with a pestle and a pellet is made using pellet maker. FTIR of the pellet was carried out at from 4000cm^{-1} to 400cm^{-1} at a resolution of 4cm^{-1} with 4 scans per samples. The absorbance peaks at 800cm^{-1} was compared with standard quartz to determine quartz content of the sample. The whole experiment was carried out as per the guidelines of NIOSH-7602 (Silica, Crystalline by IR) [18]. Quartz content of dust from different location was tabulated in Table . A sample FTIR spectra of dust was plotted in the Fig. 4.36.

Table 4.3 Quartz Content of Dust Different Locations of LOCP

Sl no	Location	Quartz Content(%)
1	Mine Road MCL	0.44
2	Wet Haul Road-1 MCL	0.49
3	Wet Haul Road-2 MCL	0.34
4	Wet Haul Road- 3 MCL	0.37
5	Wet Haul Road-4 MCL	0.36
6	O/B Bench Road MCL	0.34
7	Coal Transport Road-1 MCL	0.36
8	Coal Transport Road-2 MCL	0.27
9	Coal Transport Road-3 MCL	0.23
10	Drilling MCL	0.29

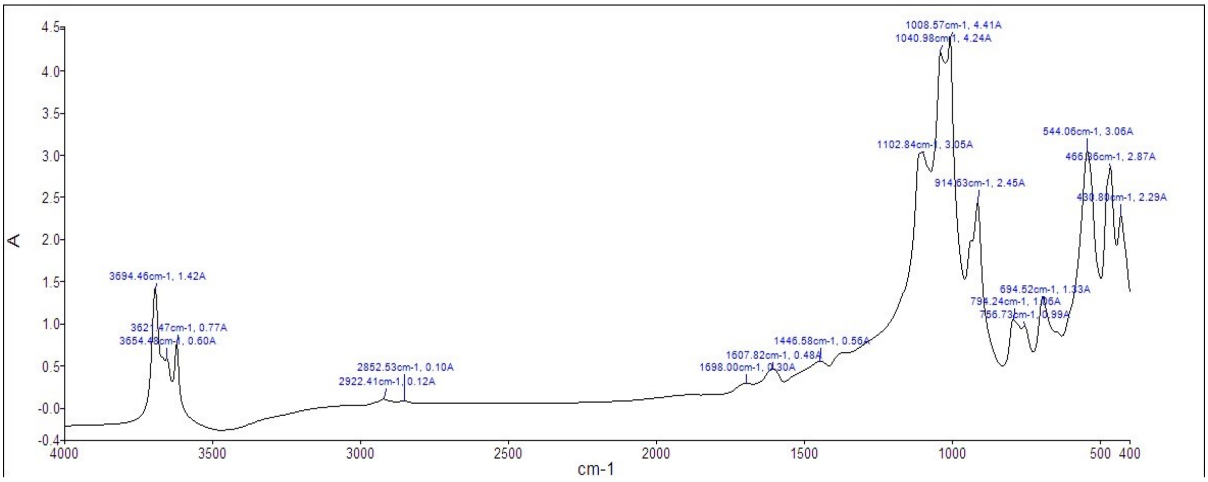

Figure 4.36 Absorbance vs. Wavenumber for MCL Mine Road Dust

4.1.4 Dust Dispersion Modelling using AERMOD for LOCP

Dust dispersion models are generally used to determine the dust concentrations in the surrounding area so as to ensure dust levels don’t exceed the permissible limits. It is most essential that the modelling technique precisely estimates the emission and dispersion of dust from a mining site. In this project work dust dispersion modelling was carried out for Lakhanpur opencast mining project of MCL.

4.1.4.1 Input Data to AERMOD

The Input data required for modelling purpose are

- Location of Reference Point (latitude, longitude)
- Location of the mine (latitude, longitude)
- Base Map of the area
- Hourly Micrometeorological Data
- Pollutants to be modelled
- Location of Sources (latitude, longitude)
- Emission Factors for Different Sources
- No of Receptors
- Terrain Features

Location of Reference Point

The latitude and longitude of the reference point was obtained and it was converted into co-ordinates by taking standard UTM as projection and NAD83 as datum. The information about the reference point was tabulated in Table .

Table 4.4 Location of Reference Point

Reference Point	
Latitude	21°45’59”N
Longitude	83°50’16”E
Projection	Standard UTM
Datum	NAD83
Zone	44
Hemisphere	N
Easting	793482.7
Northing	2409666.5

Location of the mine

Lakhanpur opencast Coal Project lies between latitudes 21’43’30” to 21’46’44” and longitudes 83’49’11” to 83’52’38”.

Base Map of the area

Base map of the mine was obtained by exporting the co-ordinates of the reference point and the radius of modelling area to Google Earth. The reference point was taken as centre and the radius of modelling area was taken as 7.5km. Hence an area of 225km^2 can be considered as modelling area. Fig.4.37 shows the base map of the area.

Figure 4.37 Base map showing reference point and area of modelling for LOCP

Hourly Micrometeorological Data

Hourly micrometeorological data for the year of 2013 was obtained from the nearest automatic weather station. 13 parameters like Year, Month, Day, Hour, Cloud Cover (tenths), Dry Bulb Temp (°C), Relative Humidity (%), Station Pressure (mbar), Wind Direction (deg), Wind Speed (m/s), Ceiling Height (m), Hourly Precipitation (1/100 th of inch), Global Horizontal

Radiation (Wh/m2) are required for AERMET. The sample data for a single day was tabulated in Table .

Table 4.5 Sample Micrometeorological data for the year 2013

Year	Month	Day	Hour	Cloud Cover (tenths)	Dry Bulb Temp (°C)	Relative Humidity (%)	Station Pressure (mbar)	Wind Direction (deg)	Wind Speed (m/s)	Ceiling Height (m)	Hourly Precipitation (1/100 th of inch)	Global Horizontal Radiation (Wh/m2)
2013	10	2	0	4	29.3	76	995	133	0.1	3000	0	0
2013	10	2	1	4	28	81	993	138	0.1	3000	0	5000
2013	10	2	2	4	28	85	993	145	0.2	3000	0	0
2013	10	2	3	4	27	87	993	124	0	3000	0	0
2013	10	2	4	4	27	84	992	147	0	3000	0	0
2013	10	2	5	4	27.4	87	993	45	0	3000	0	0
2013	10	2	6	4	27.1	90	994	21	1.4	3000	0	5000
2013	10	2	7	4	27	90	994	24	1.3	3000	0	5000
2013	10	2	8	4	28.6	82	995	28	2	3000	0	5000
2013	10	2	9	4	31.1	69	994	71	0.7	3000	0	5000
2013	10	2	10	4	32	65	996	53	1.1	3000	0	5000
2013	10	2	11	4	34.2	57	996	73	0.7	3000	0	5000
2013	10	2	12	4	34.6	55	994	129	0.7	3000	0	5000
2013	10	2	13	4	35.2	52	994	174	1.5	3000	0	5000
2013	10	2	14	4	34.6	55	993	179	1.1	3000	0	5000
2013	10	2	15	4	34	57	992	180	0.8	3000	0	5000
2013	10	2	16	4	35.5	55	991	133	0.5	3000	0	5000
2013	10	2	17	4	31	68	991	161	0.4	3000	2	5000
2013	10	2	18	4	29.2	83	991	154	0	3000	0	0
2013	10	2	19	4	28	88	992	90	0	3000	2	0
2013	10	2	20	4	28.1	91	992	0	0	3000	2	0
2013	10	2	21	4	28.1	91	993	116	0	3000	0	0
2013	10	2	22	4	28.1	90	993	180	0	3000	0	0
2013	10	2	23	4	27.2	90	993	162	0	3000	0	0

Pollutants to be modelled

For this modelling purpose SPM was considered.

Emission Factors for Different Sources

Emission factors of different sources are calculated based on the empirical formulae proposed by **Chakraborty et al. (2002)** [1]. The whole mine was considered as an area source. The formula for emission factor is

Overall mine (for SPM) $$\mathbf{E = [u^{0.4} a^{0.2} \{9.7 + 0.01p + \frac{b}{4+0.3b}\}]} \ldots\ldots\ldots\ldots\ldots \quad \mathbf{(7)}$$

Where,

u : wind speed (m/s)

p : coal/mineral production (MT/Annum),

b : OB handling (Mm^3/Annum);

E : emission rate (g/s)

For Lakhanpur Opencast Project the values were:

Wind speed, u	: 2.33 m/sec
Area, a	: 4.84 km^2
Coal Production, p	: 15 MT/Annum
Overburden handling, b	: 14.91 Mm^3/Annum

Putting the values, Emission factor (for SPM) was found to be E= 22.2836093895 g/s

No of Receptors

The whole modelling area was divided into 31x31 square grids with length of 500m. Hence the total modelling area was 225km^2 and area each grid was 0.25km^2. There were total 961 receptors in the modelling area.

Terrain Features

AERMAP was used to extract digital terrain data from WebGIS server for the area. SRTM3/SRTM1 map was selected for this purpose. The specifications of SRTM3 map is as follows

Table 4.6 specifications of SRTM3 map

Resolution	~90 m, 3 arc-sec
Coverage	Global
Projection	Geographic
Datum	WGS84
Vertical Units	Meter

4.1.4.2 Output of AERMOD

WINDROSE

First the meteorological data in the excel format was exported to AERMET. Then, by using file maker, the whole data in the excel format was converted to SAMSON format. To find out Windrose plot, the Samson file was processed in WRPLOT View 8.5.1. The direction suggests the direction from which the wind blows. Fig. 4.38 shows the Windrose diagram for the meteorological data with 36 directions. Similarly Fig. 4.39 shows the Windrose diagram for the same data with 16 directions. The results of the Windrose were tabulated in Table . Wind frequency classification was plotted in Fig.4.40. It shows percentage of wind with a different speed ranges. It also shows the time for which calm situation prevailed. The calm state prevailed for 34.17%. The average wind speed for the whole year was found to be 2.33 m/s. The predominant wind direction was from North-East to South-West. The data from WRPLOT View 8.5.1 was exported to Google earth to see the exact direction of wind as experienced in the field itself. It was plotted in Fig.4.41.

Table 4.7 Results of Windrose Plot

Data Period	Start Date: 01/01/2013 - 00:00 End Date: 31/12/2013 - 23:00
Calm Winds	34.17%
Avg. Wind Speed	2.33 m/s
Total Count	8759 hrs.
Directions	36

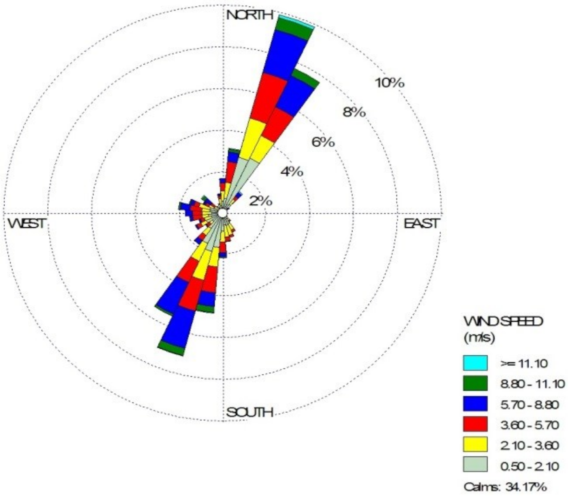

Figure 4.38 Windrose plot with 36 directions

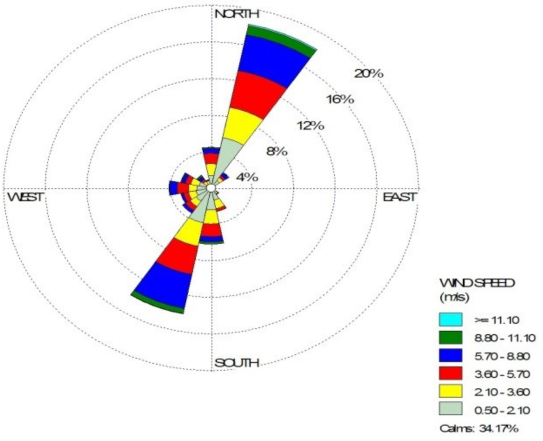

Figure 4.39 Windrose plot with 16 directions

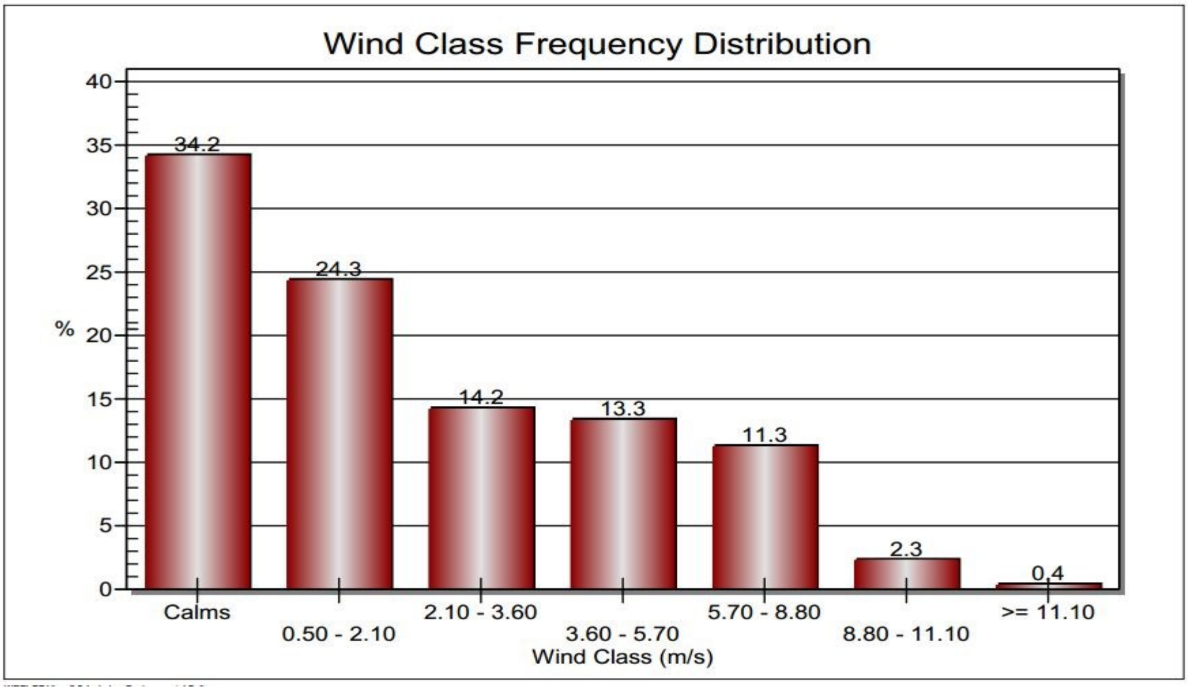

Figure 4.40 Wind class frequency distribution

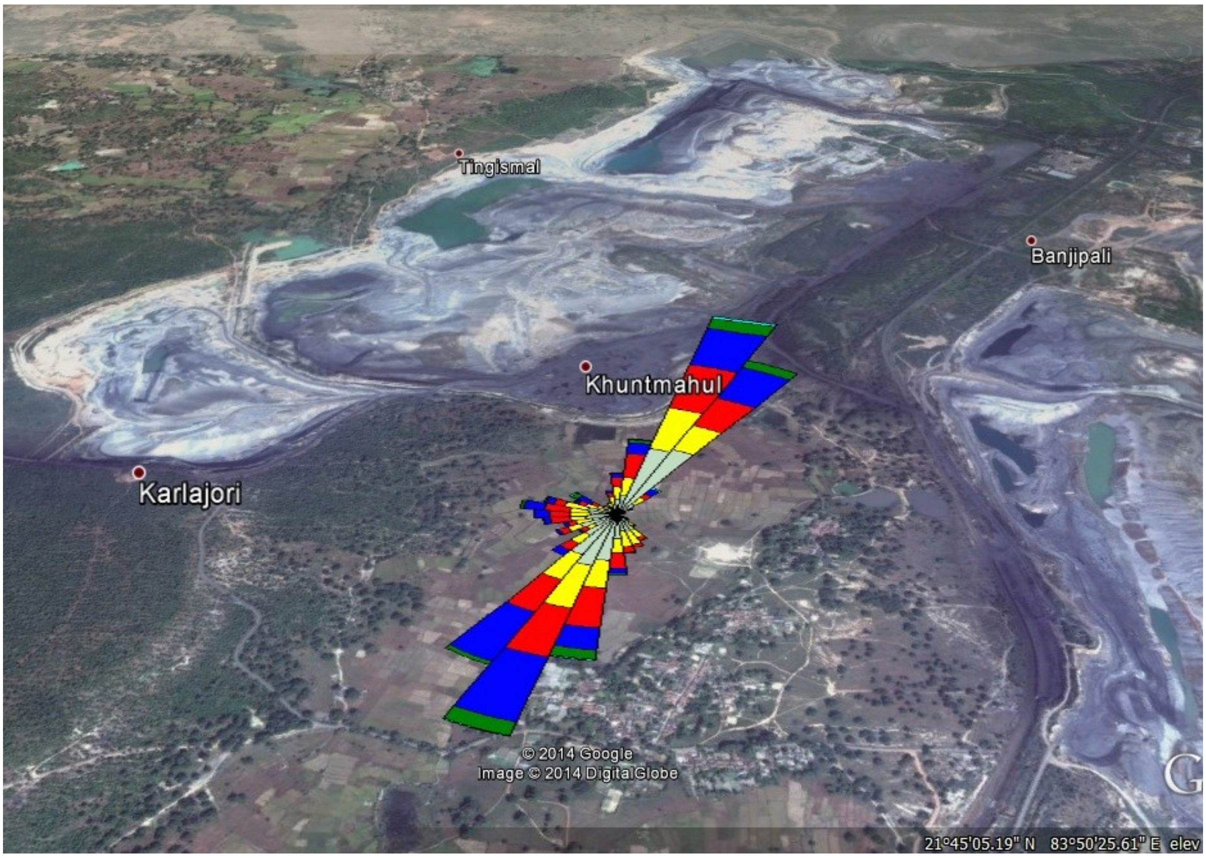

Figure 4.41 Windrose along with the mine as seen in google earth

Isopleths Generated by AERMOD

AERMOD predicted PM_{10} concentrations in and around the mine for different time periods. Plots for highest and second highest concentration levels for 1hour, 3hour and 24 hour period for one year were generated. Isopleths for annual average concentrations were also generated. The isopleths for 24hr period and annual average were plotted in Figs 4.42 and 4.43. The data from AERMOD was also exported to google earth to simulate the predicted concentration level at ground itself. It gives a good interface to determine the concentration levels at any location by just clicking over that location. The highest concentration level for 24 hour for the year as seen in Google earth was plotted in Fig.4.43. Similarly, annual average concentration as seen in the Google earth was also plotted in Fig.4.45. The predicted dust concentrations at different locations are tabulated in Table .

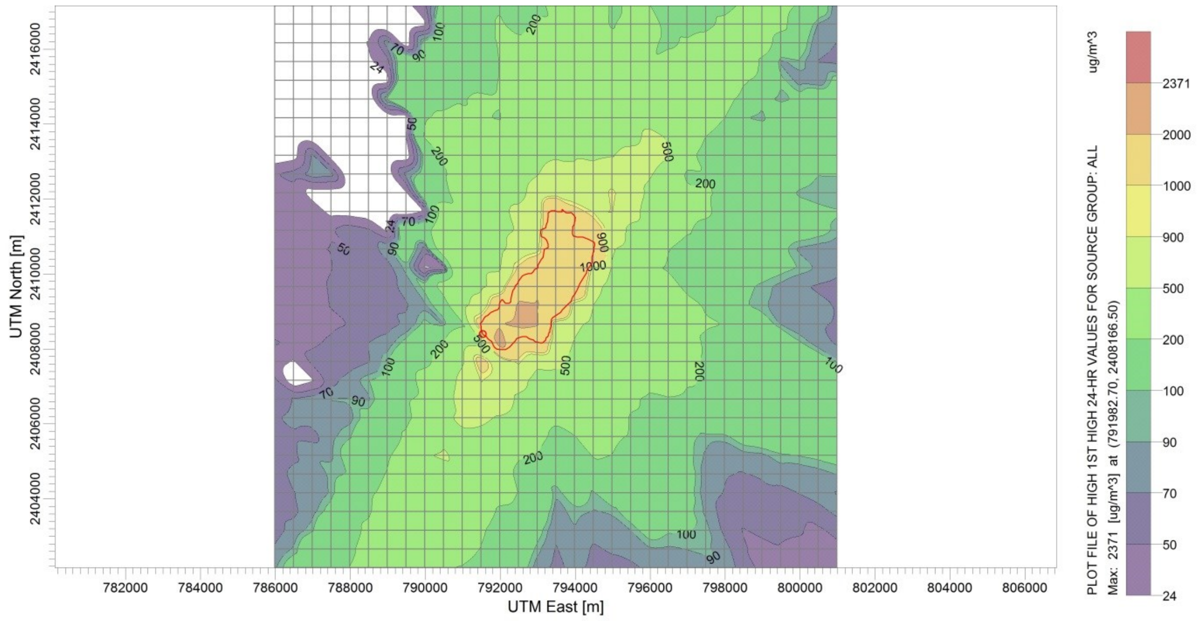

Figure 4.42 Highest 24hour concentration for the year

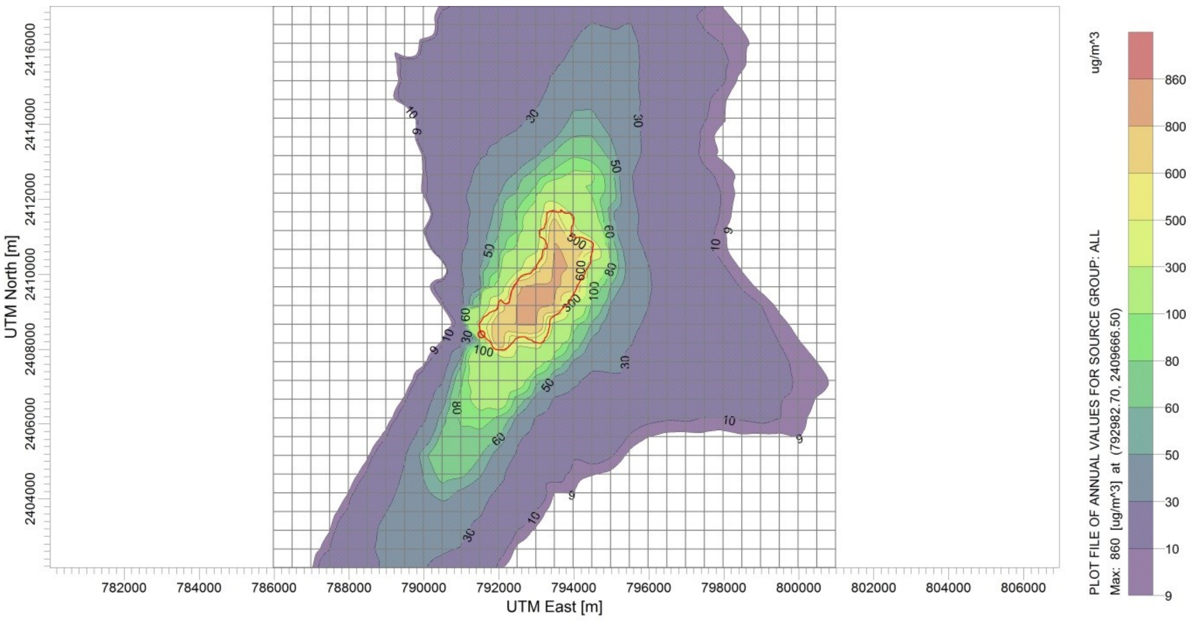

Figure 4.43 Annual average concentrations

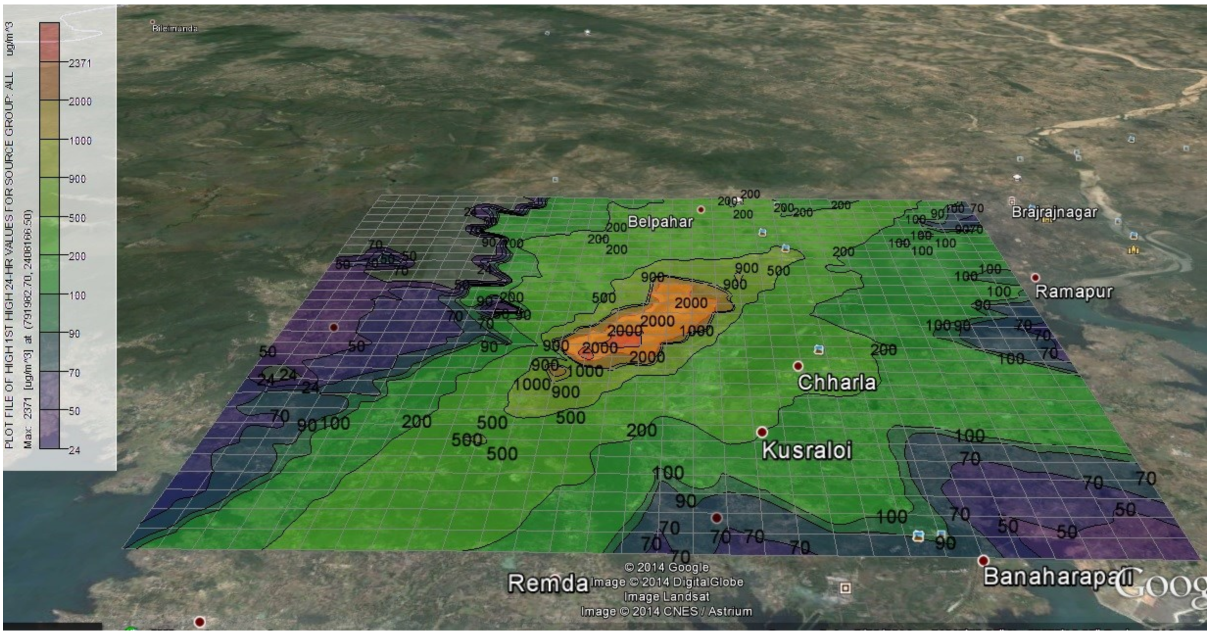

Figure 4.44 Highest 24 hour concentration isopleths as seen in google earth

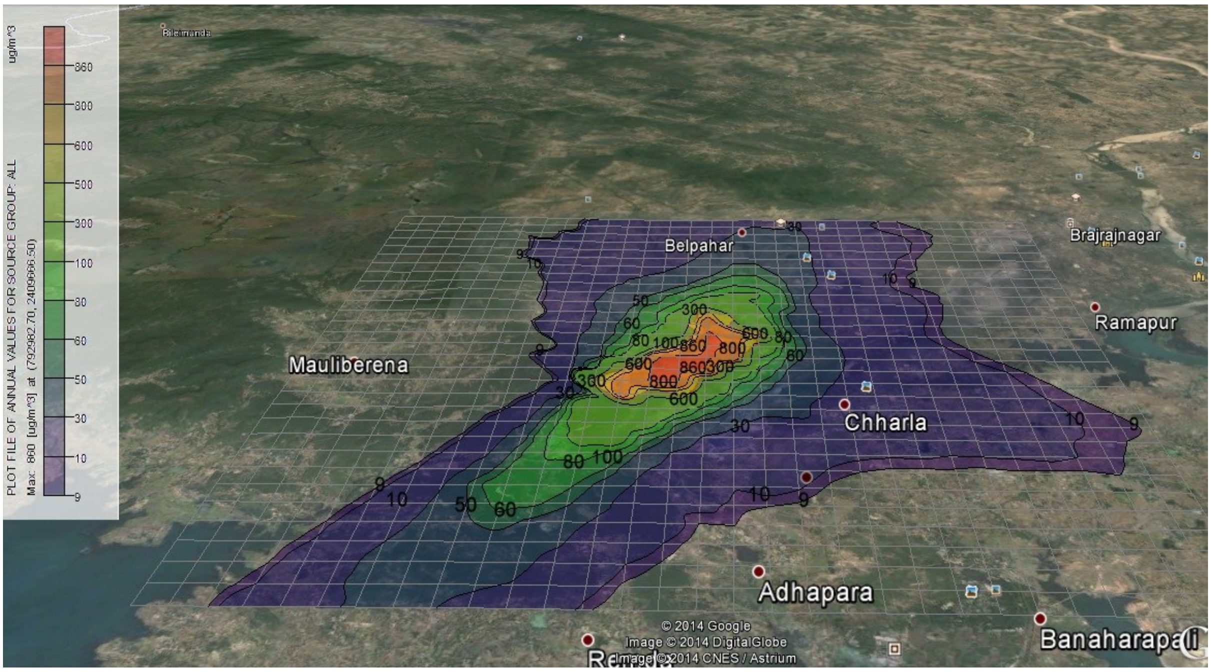

Figure 4.45 Annual average concentration isopleths as seen in google earth

Table 4.8 Prediction of Conc. for PM_{10} at Different Areas at and around LOCP

Sl No.	Location	Predicted Value (µg/m³)				NAAQS Standards (µg/m³)	
		24hr		Annual		24hr	Annual
		Min	Max	Min	Max		
1	Lakhanpur	23.70867	50	0	0	100	60
2	Mauliberena	23.70867	50	0	0	100	60
3	Beheramal	200	500	30	50	100	60
4	Soldia	200	500	30	50	100	60
5	Bartap	100	200	10	30	100	60
6	Banjari	200	500	10	30	100	60
7	Belpahar	200	500	30	50	100	60
8	Samra	200	500	10	30	100	60
9	Piplimal	200	500	30	50	100	60
10	Kudaloi	200	500	50	60	100	60
11	Tingismal	1000	2000	300	500	100	60
12	Khuntmahul	1000	2000	600	800	100	60
13	Karlajori	1000	2000	300	500	100	60
14	Khairkuni	1000	2000	100	300	100	60

15	Khaliapali	500	900	100	300	100	60
16	Adhapara	70	90	0	0	100	60
17	Banjipali	500	900	100	300	100	60
18	Darlipali	200	500	30	50	100	60
19	Kushraloi	100	200	8.59627	10	100	60
20	Ubuda	200	500	30	50	100	60
21	Charla	200	500	10	30	100	60
22	Khadam	100	200	10	30	100	60
23	Bandhbahal	100	200	10	30	100	60
24	Sarandamal	100	200	10	30	100	60
25	Dalgaon	100	200	0	0	100	60
26	Negipali	50	70	0	0	100	60
27	Kirarama	100	200	8.59627	10	100	60
28	Katapali	100	200	0	0	100	60
29	Kudopali	90	100	0	0	100	60
30	Baliput	70	90	0	0	100	60

CHAPTER 5
RESULTS AND DISCUSSIONS

RESULTS AND DISCUSSIONS

Lakhanpur Opencast Project

From the monitoring at various sources of LOCP, a comparison can be made for different dust generating sources. The comparison of average dust concentration in PM_{10}, PM_4, $PM_{2.5}$ and PM_1 at different locations was plotted in Fig.5.1. It can be concluded that drilling was the most polluting source in $PM_{2.5}$, PM_4 and PM_{10} whereas surface miner was the most polluting source in PM_1.

Minimum concentration in PM_{10}, PM_4, $PM_{2.5}$ and PM_1 at different locations was plotted in Fig.5.2. It shows that least concentration was obtained at surface miner for PM_1, $PM_{2.5}$ and PM_4. For PM_{10}, least concentration was obtained at drilling point.

Maximum concentration in PM_{10}, PM_4, $PM_{2.5}$ and PM_1 at different locations was plotted in Fig.5.3. It can be concluded that at drilling point maximum concentration was obtained for PM_1, $PM_{2.5}$, PM_4, & PM_{10} . Surface miner was the second most polluting source at all size range. Insufficient use of water for drilling and cutting purpose at these locations resulted in generation of high quantity of fine dusts.

Personal dust exposure to different workers was plotted in Fig.5.4. Exposure level of explosive carrier was highest whereas exposure level of dumper operator was lowest. However, for most of the workers the exposure was beyond statutory limit of $3mg/m^3$.

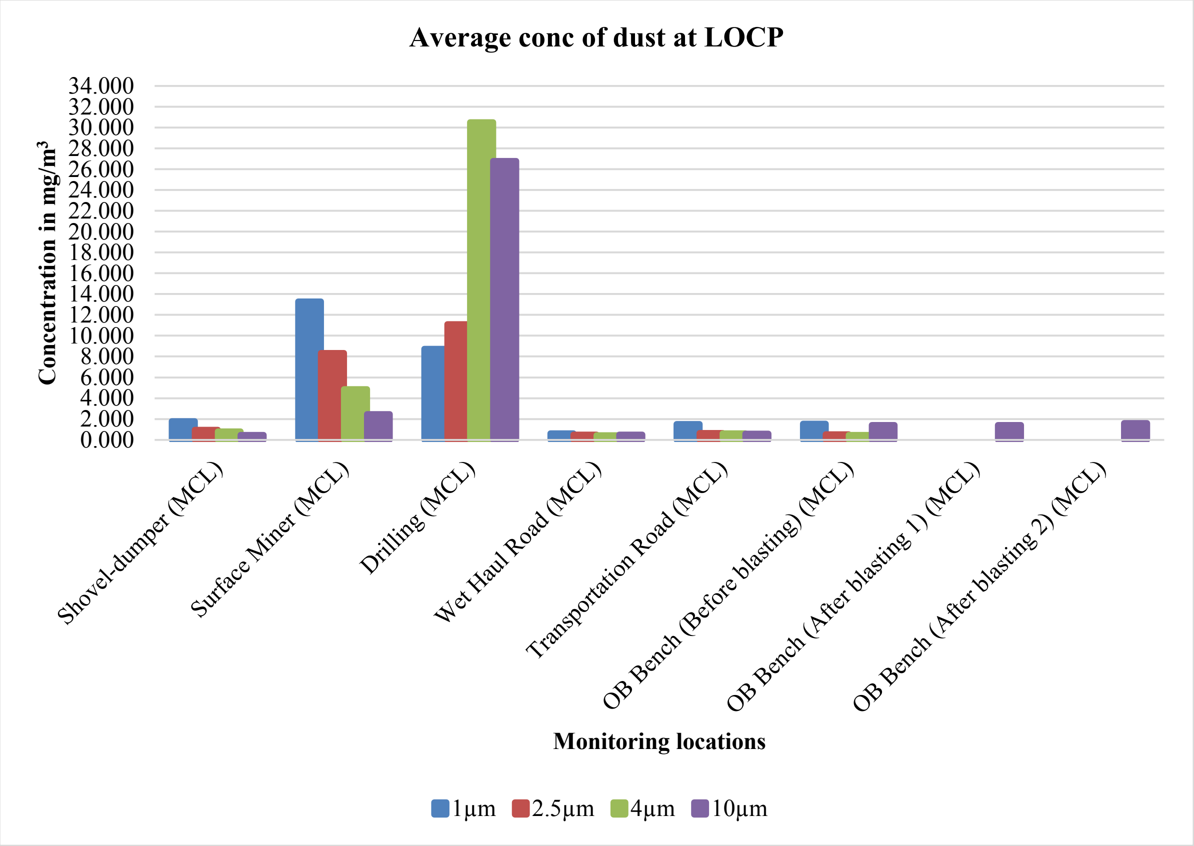

Figure 5.1 Comparison of average concentration of dust at different locations of LOCP

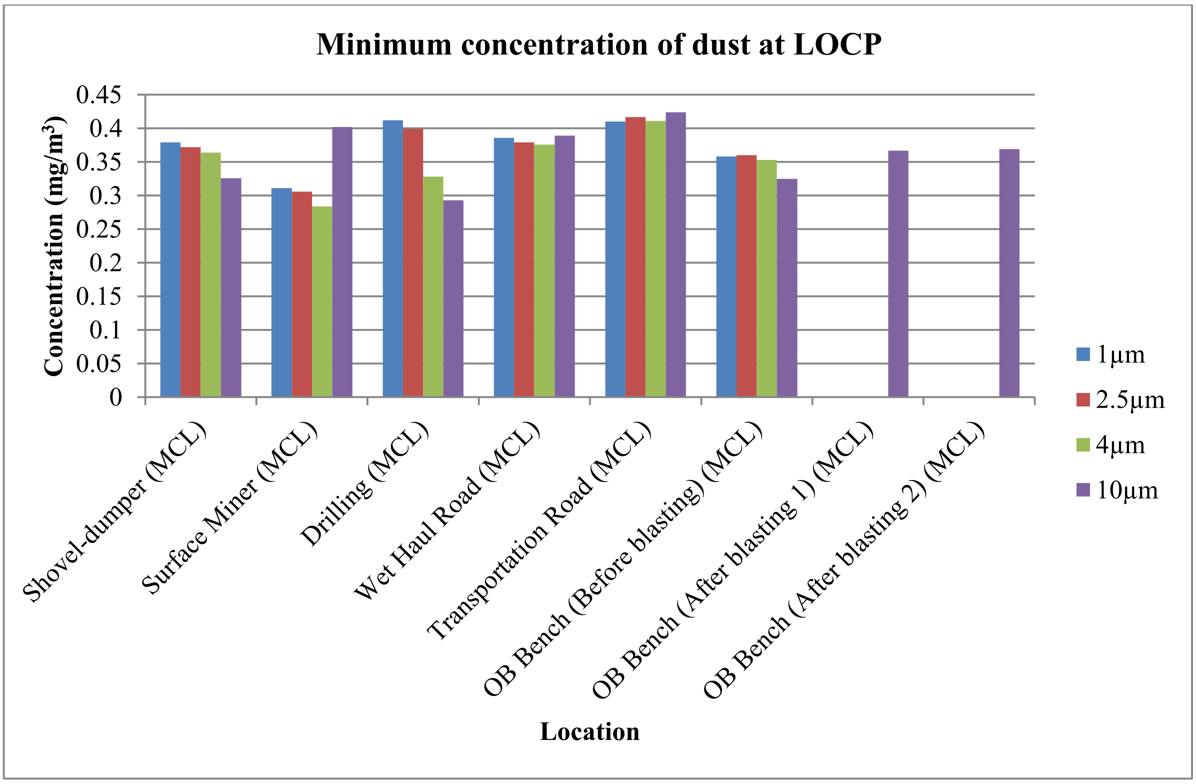

Figure 5.2 Comparison of minimum dust concentration at different locations of LOCP

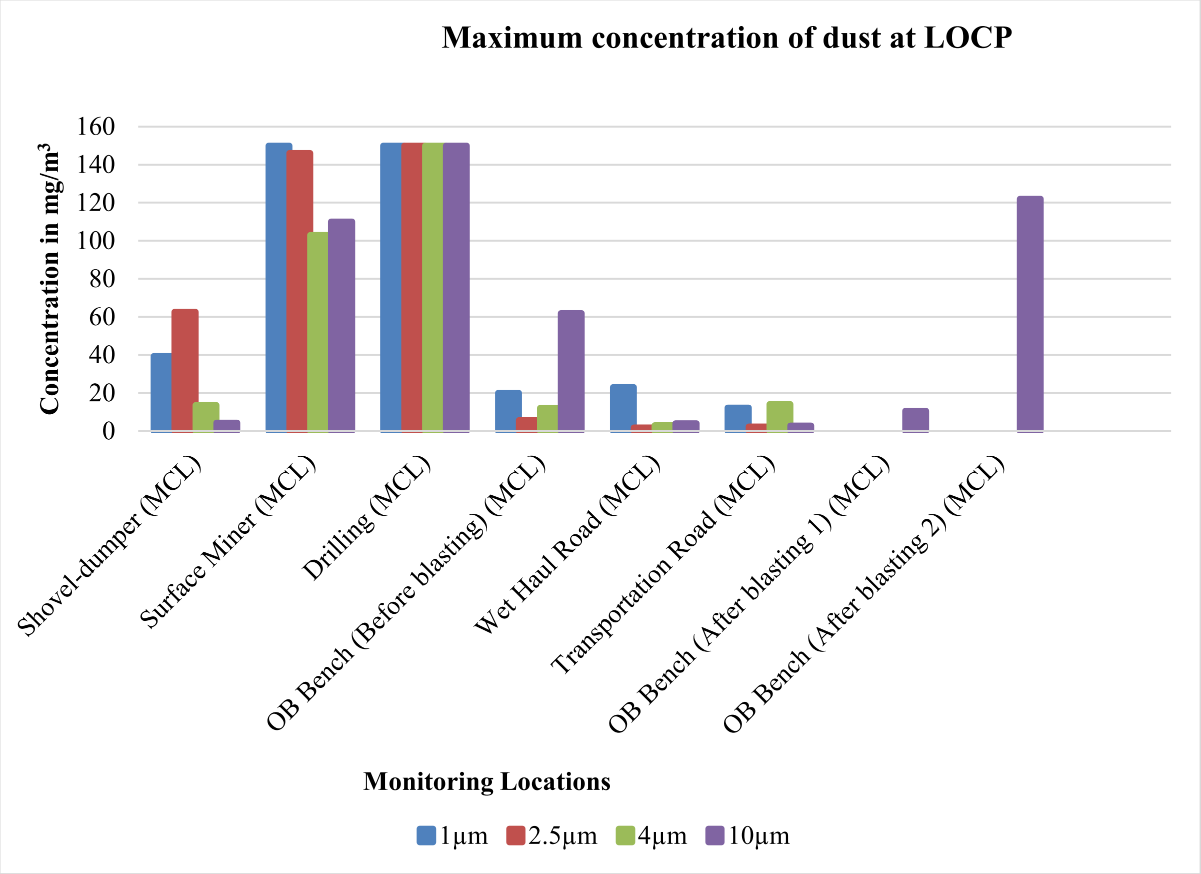

Figure 5.3 Comparison of maximum dust concentration at different locations of LOCP

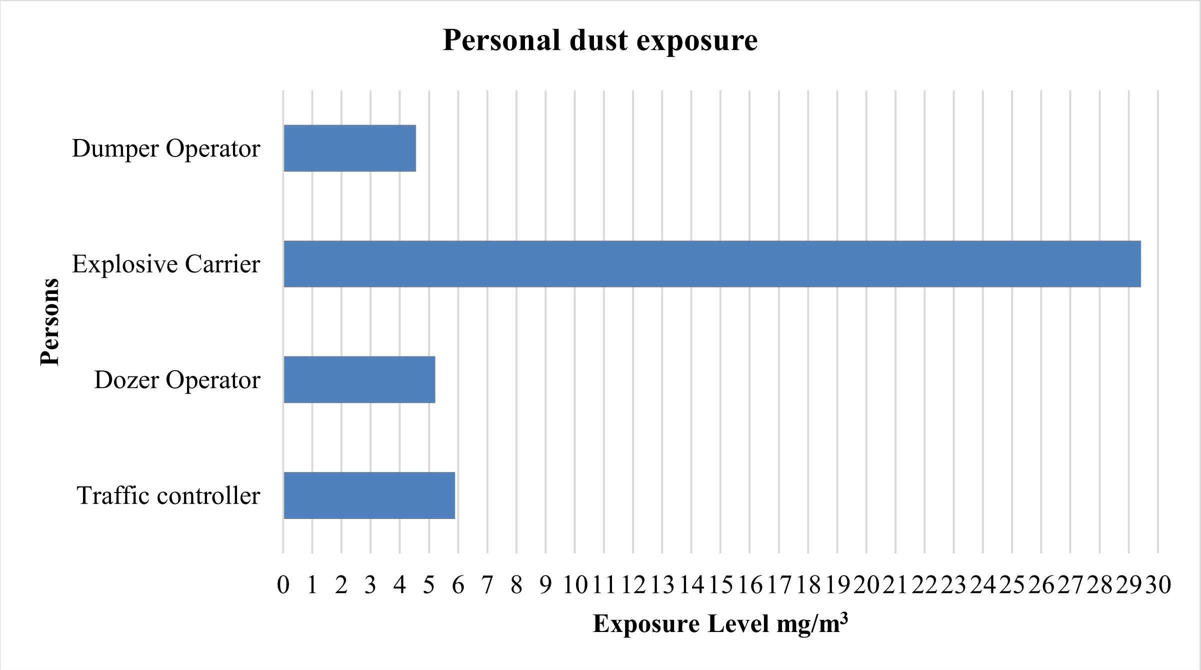

Figure 5.4 Personal dust exposure level of different workers at LOCP

A comparison of quartz content at different locations was plotted in Fig.5.5. Maximum quartz content was obtained at wet haul road-1 whereas minimum quartz content was found at coal transport road-3.

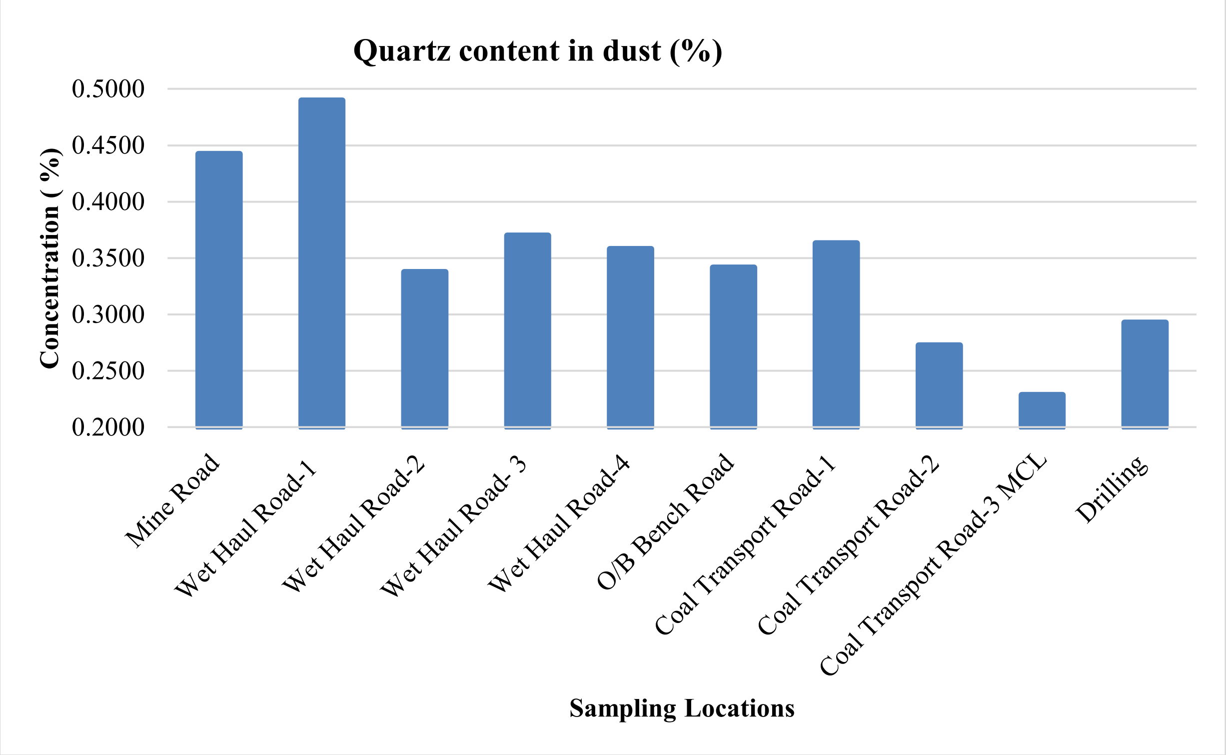

Figure 5.5 Quartz content of dust at different locations of LOCP

The predicted concentration at different locations in and around the mine was obtained from AERMOD. A comparison was made for the highest 24 hour predicted concentration in PM10 for the year at Fig.5.6. At most of the locations the predicted concentration level was higher than NAAQS limit of 100µg/m^3. Similarly another comparison was made for the annual average predicted dust concentration in PM10 in Fig.5.7. It can be seen that debarring a few locations, dust concentration was below the NAAQS limit of 100µg/m^3.

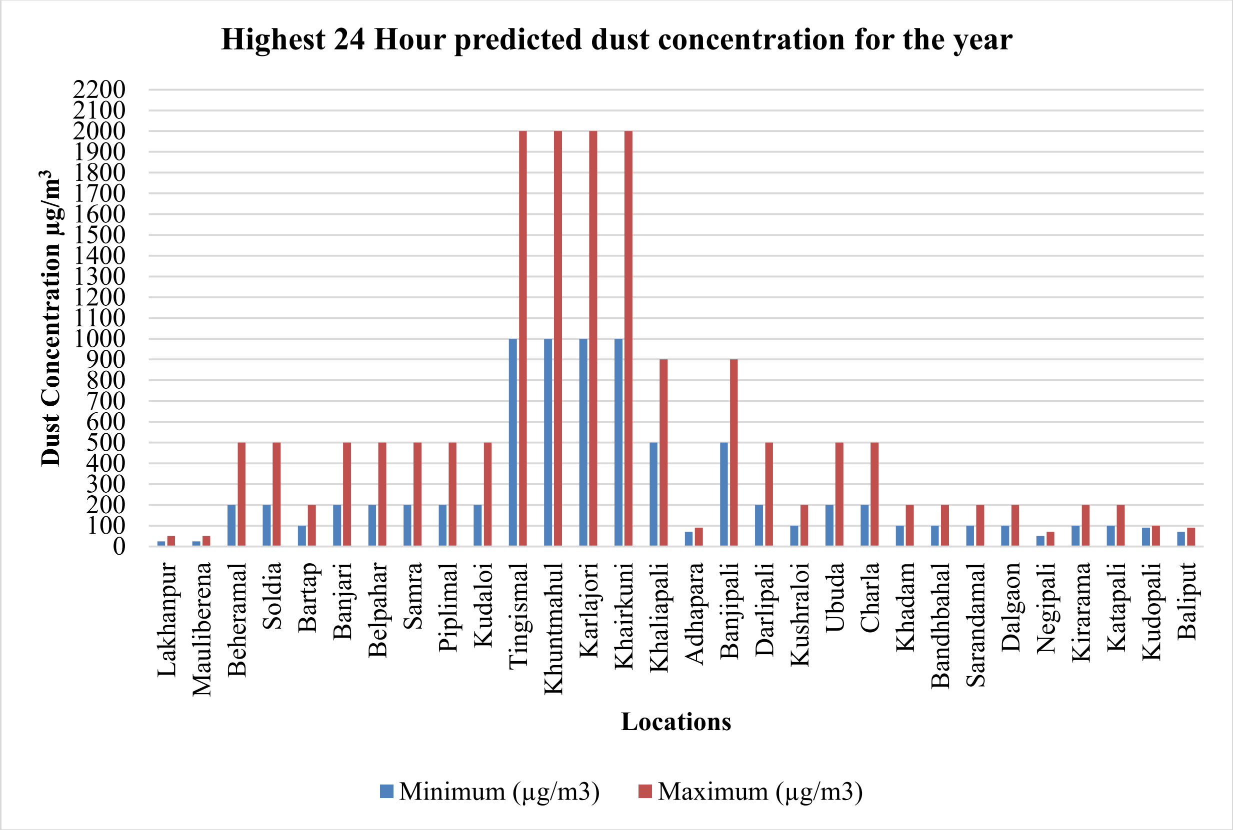

Figure 5.6 Highest 24hour predicted dust concentration in PM10 for the year

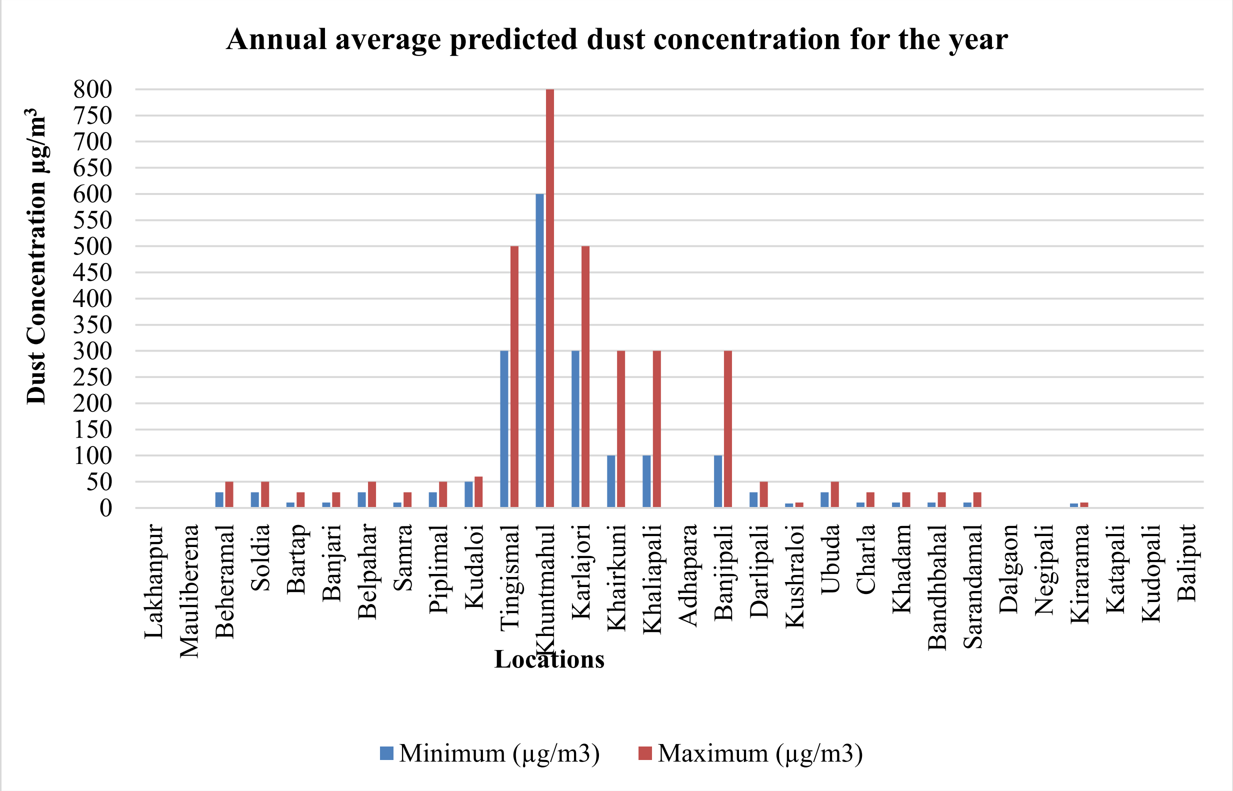

Figure 5.7 Annual average predicted dust concentration in PM10 for the year

CHAPTER 6

CONCLUSION

CONCLUSION

- From the field monitoring of dust concentrations using DustTrak-II at LOCP, it can be concluded that:

  The maximum dust concentration was obtained at drilling point with average concentration of 26.8 mg/m^3 and maximum concentration of 150.0mg/m^3 in PM$_{10}$ range. Minimum mean dust concentration was found at loading point at 0.474mg/m^3 in the PM$_{10}$ range. Drilling and Surface miner operations were found to be the major sources of dust generation.

- From personal dust exposure monitoring of workers using PDS APM-500, it can be concluded that:

  The dust exposure of worker was the maximum for explosive carrier at 29.41mg/m^3 which is much above the regulatory limit of 3mg/m^3. In general, for most of the employees under study, personal respirable dust exposure was found to be beyond the permissible limit.

- From Characterization of dust using FTIR, it can be concluded that minimum quartz content was found at coal transport road at 0.23% and maximum quartz content was found at wet haul road of LOCP at 0.49%.
- From the dust dispersion modelling, it could be observed that:
  - For 24hr period for the year, the highest dust concentration for PM$_{10}$ at all other places except at Lakhanpur, Mauliberena, Adhapara, Negipali, Kudopali and Baliput were found to be above NAAQS limit of 100µg/m^3.
  - For annual average, at most of the places at and around LOCP, the dust concentrations were found to be below NAAQS limit of 60µg/m^3 except at Tingismal, Khuntmahul, Karlajori, Khairkuni, Khaliapali, Banjipali.

REFERENCES

REFERENCES

1. Chakraborty, M.K., Ahmad, M., Singh, R.S., Pal, D., Bandopadhyay, C. & Chaulya, S.K., (2002), Determination of the emission rate from various opencast mining operations, Environmental Modelling & Software, 17, pp. 467–480.
2. Chaulya, S.K., Ahmad, M., Singh, R.S., Bandopadhyay, L.K., Bandopadhyay, C. & Mondal, G.C., (2002), Validation of two air models for Indian Mining conditions, Central Mining Research Institute, Dhanbad, India, Environmental Monitoring and Assessment 82. Pp. 23-43.
3. Chaulya, S.K., (2004), Assessment and management of air quality for an opencast coal mining area, Journal of Environmental Management, 70, pp. 1–14 .
4. Erol, I., Aydin, H., Didari, V. & Ural S., (2013), Pneumoconiosis and quartz content of respirable dust in the coal mines in Zonguldak, Turkey, International Journal of Coal Geology, 116-117, pp. 26-35.
5. Ghose, M.K. & Majee, S.R., (2007), Characteristics of hazardous airborne dust around an Indian surface coal mining area, Environ Monit. Assess. 130, pp. 17-25.
6. Hartman,H.L., Mutumansky, J.M., Ramani, R.V. & Wang, Y.J., Mine Ventilation and Air Conditioning, New York, 3rd ed, Willey-Interscience publication, 1993
7. Kumari, S., Kumar, R., Mishra, K.K., Pandey, J.K., Udaybandhu, G.N. & Bandopadhyay, A.K., (2011), Determination of quartz and its abundance in respirable airborne dust in both coal and metal mines in India, Procedia Engineering, Volume 26, pp. 1810-1819.
8. Mishra, G.B., Mine Environment and Ventilation, Oxford University Press, New Delhi, 2004.

9. Mishra, P.C. & Jha, S.K.,(2010), Dust dispersion modelling in opencast coal mines and control of dispersion in Mahanadi Coal Fields of Orissa, The Bioscan, Vol.2, pp.479-500.
10. Mukherjee, A.K., Bhattacharya, S.K. & Saiyed, H.M., (2005), Assessment of respirable dust and its free silica content in different Indian coal mines, International Health, vol-43, pp. 277-284.
11. Reed, W.R., (2005), Significant Dust Dispersion Models for Mining Operations, Information Circular 9478, DHHS (NIOSH) Publication,138.
12. Sengupta, M., Mine Environment and Ventilation, Vol-I. Alaska, CRC press, 1989.
13. Tripathy, D.P.(2014), Prevention and control of dust pollution in mines, The Indian Mining and Engineering Journal, vol-53, No-03, pp. 10-13.
14. Trivedi, R., Chakraborty, M.K. & Tewary, B.K., (2009), Dust dispersion modelling using fugitive dust model at an opencast coal project of western coalfields limited, India, Journal of Scientific and Industrial Research, vol.68, pp. 71-78.
15. http://www.ilo.org/oshenc/part-i/respiratory-system/item/415-pneumoconioses-definition?tmpl=component&print=1
16. http://www.who.int/occupational_health/publications/newsletter/gohnet12e.pdf
17. http://www.tsi.com/uploadedFiles/_Site_Root/Products/Literature/Spec_Sheets/DustTrak-II-6001987_UK-A4-web.pdf
18. http://www.cdc.gov/niosh/docs/2003-154/pdfs/7602.pdf
19. http://en.wikipedia.org/wiki/Dust
20. http://www.stopajaxmine.ca/files/documents/BPEMDustControl.pdf
21. http://en.wikipedia.org/wiki/Aerosol
22. http://www.businessdictionary.com/definition/aerosol.html
23. http://www.who.int/occupational_health/publications/en/oehairbornedust.pdf

24. https://www.osha.gov/
25. http://www.envirotechindia.com/apm-801.html
26. http://www.perkinelmer.com/CMSResources/Images/44-131248BRO_SpectrumTwo.pdf
27. http://www.ilo.org/oshenc/part-i/respiratory-system/item/415-pneumoconioses-definition
28. http://www.cdc.gov/niosh/docs/2003-154/pdfs/7603.pdf
29. http://www.hse.gov.uk/pubns/mdhs/pdfs/mdhs101.pdf
30. http://www.epa.gov/scram001/7thconf/aermod/aermod_mfd.pdf
31. https://www.osha.gov/dsg/topics/silicacrystalline/dust/chapter_1.html
32. http://cnx.org/content/m45536/latest/?collection=col11487/latest
33. http://www.weblakes.com/guides/aermod/section2/index.html