Modeling the dispersion of dust generated from open pit mining activities.

A Thesis Submitted in Partial Fulfillment
Of the Requirements of the Degree of
Bachelor of Technology

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CERTIFICATE

This is to certify that the thesis entitled "Modeling the dispersion of dust generated from open pit mining activities" submitted by Avinash Choudhury bearing Roll No. 111MN0004 in partial fulfillment of the requirements of the award of Degree of Bachelor of Technology in Mining Engineering at National Institute of Technology, Rourkela, is an authentic work carried out by him under my supervision and guidance.

To the best of my knowledge, the matter included in this thesis has not been submitted to any other University or Institute for the award of any degree.

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ABSTRACT

Mining industry is a major source of fugitive dust mostly due to activities which involve handling of large volume of fragmented earth by the HEMMs. The repairable fraction of this dust (size less than 10 microns) is a health hazard, as they have the potential of causing chronic health disorders. Due to this high concentration of repairable dust generated from mining activities, the population directly involved in mining as well as the living in close proximity suffers from a wide variety of respiratory disorders.

If the dust concentration at different location in and around the mining area can be measured then the places with the potential of high concentration build-up can be identified and appropriate protective measures can be taken. This project is a step in that direction.

In this project, the concentrations PM_{10} particles generated from a hypothetical opencast mine having seven dust generation sources has been modeled within an area having a radius of 10 kilometers. The 24-h average concentrations of the PM_{10} particles within the area has been modeled using the AERMOD modeling package and the corresponding concentration plots of the area is plotted. Further analysis of the plots has been done to find the point having maximum concentration of dust.

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CHAPTER 1

INTRODUCTION

1.1 Sources of Air Pollution:-

The atmosphere contains a broad spectrum of air pollutants and these are released from the following two main sources:-

i) Natural: - Some common natural sources of air pollution are volcanoes, forest fires, desert storms, high winds and cyclones, salt sprays from oceans and seas, decomposition of organic matter in swamps and emissions from animals and plants.

ii) Anthropogenic: -The anthropogenic sources of air pollution include industries, modes of transportation, power plants, grinding and cooking operations, household heating, burning of wastes etc.

1.2 Types of Air Pollutants:-

Air Pollution sources, whether natural or anthropogenic produce pollutants of similar nature, and thus, are classified, as under:-

1. Primary Pollutants: - These refer to pollutants that are directly emitted from source, e.g., the exhaust of a car containing oxides of nitrogen. This type of pollutants include:-

    i) Particulate Pollutants: - These refer to finely divided particles that are more than 0.01 micron (micro-meter) in size. These can be fine droplets of liquids as in fogs and mists and solid particles like soot or those suspended in smoke. The different types of particulate pollutants are given in Table 1.1.

    ii) Gaseous Pollutants:-

    a) Sulphur-Containing Compounds:
    Sulphur dioxide, a colorless gas with a pungent smell, for example, gets readily oxidized in the atmosphere to sulphur trioxide which forms sulphuric acid with water. It can have a residence period of 40 days and more in the atmosphere and can therefore, travel over long distances before removal occurs due to atmospheric reactions.

b) Nitrogen-containing compounds:-
The important nitrogen bearing gaseous compounds are nitrous oxides(N_2O), nitrogen oxide(NO), Nitrogen Peroxide(N_2O_2), nitrogen dioxide(NO_2) and ammonia (NH_3). Although about 90% of nitrogen and gaseous compounds are produced by bacterial action, the contribution from anthropogenic sources can be substantial at a local level.

Table 1.1:- Types of Particulate Pollutants

TYPES	DESCRIPTION
Aerosols	Particles dispersed in gases, size<0.01microns
Dusts	Solid Particles, size >1micron
Fog	Dispersion of fine water /ice in air or gas visible to eye
Fume	Solid particles generated by condensation from volatile state, size<1micron
Haze	Combination of water droplets, pollutant gas and/or dust, size<1micron
Mists	Liquids, formed by condensation in process equipment or atmosphere normally obtained when direct contact occurs between a gas containing pollutants or moisture, and liquid/water, size >1 micron
Smog	A term derived from smoke and fog. Now used loosely for other combinations as well.
Smoke	Fine gas-borne particles as a result of incomplete combustion of fuels, size>1 micron.
Soot	Particles of carbon or hydrocarbons or their agglomerates combined with tar formed during incomplete combustion of fuels, usually liquids.

c) Carbon-Containing Compounds:- They are characterized into 3 types:
- Organic Compounds (basically the hydrocarbons).
- Inorganic Compounds (Carbon dioxide and carbon monoxide).
- Halogen Containing Compounds (CFCs).

2) Secondary Pollutants:-
When the primary pollutants react with one another or with other normal constituents present in the atmosphere, secondary pollutants are produced.

1.3 Sources of Pollutants in Mining:-

Mining industry is a source of a large variety of pollutants, which occur in all three states, viz. solids, liquids and gases. The gaseous pollutants include hazardous gases like Carbon Monoxide (CO), Oxides of Nitrogen (NO_X), Sulphur Dioxide (SO_2) which are mainly released by blasting operations. Liquid pollutants affect the environment mostly in the form of slag or acid mine drainage. Among the pollutants produced, Solid dust particles suspended in the air is the most hazardous for mankind. It can cause a wide variety of respiratory disorders. Therefore, control of emission of dust is of paramount importance while working in a mine.

Table 1.2: - Sources of dust and their contribution (New South Wales (NSW) State Pollution Control Commission, 1983):

Sources	**Truck and Shovel operation (Percentage of total dust emission)**	**Dragline Operation (Percentage of total dust emission)**
Dragline	NA	27
Haul Roads		
Overburden	35	NA
Coal	7	42
Loading		
Overburden	12	NA
Coal	4	5
Drilling		
Overburden and Coal	1	2
Blasting		
Overburden and Coal	5	1
Truck Dumping	7	5
Topsoil Removal	18	10
Exposed Areas	6	7
Haul Road Repairs	5	1
TOTAL	100	100

1.4 Objectives:-

Hence, this study has been focused on estimating the emissions and modeling the dispersion of dusts generated from opencast mining. The objectives of this work are mentioned below:

- To study the sources and emission dust from an opencast mining project.
- Simulation of the dispersion of dust generated in a hypothetical mine using AERMOD.
- Analysis of the results obtained after modeling the dispersion of fugitive dust.

CHAPTER 2

LITERATURE REVIEW

Pasquill (1961) was the first to propose a classification system for atmospheric stability (Table 2.1). The classification proposed by the author, required an estimation of solar radiation and wind speed. This classification system produced inconsistent results and was further improved upon by the author by comparing atmospheric stability classes with Richardson Number and ambient temperature changes as discussed in Section 3.3.

Table 2.1: Pasquill's Stability Class based on solar radiation and wind speed:

Wind Speed (m/s)	Solar insolation (strong)	Solar insolation (moderate)	Solar insolation (slight)	Night time (>1/2 cloudiness)	Night Time (<3/8 cloudiness)
<2	A	A-B	B	-	-
2-3	A-B	B	C	E	F
3-4	B	B-C	C	D	E
4-6	C	C-D	D	D	D
>6	C	D	D	D	D

Turner (1971) worked extensively in the field of dust dispersion modeling. By working extensively on the subject, the author estimated the atmospheric dispersion coefficients as a function of downwind distance from the source (Fig. 2.1 (a) and (b)).The results obtained are still widely used for finding the concentration of dust at a particular distance in an atmosphere of particular stability class.

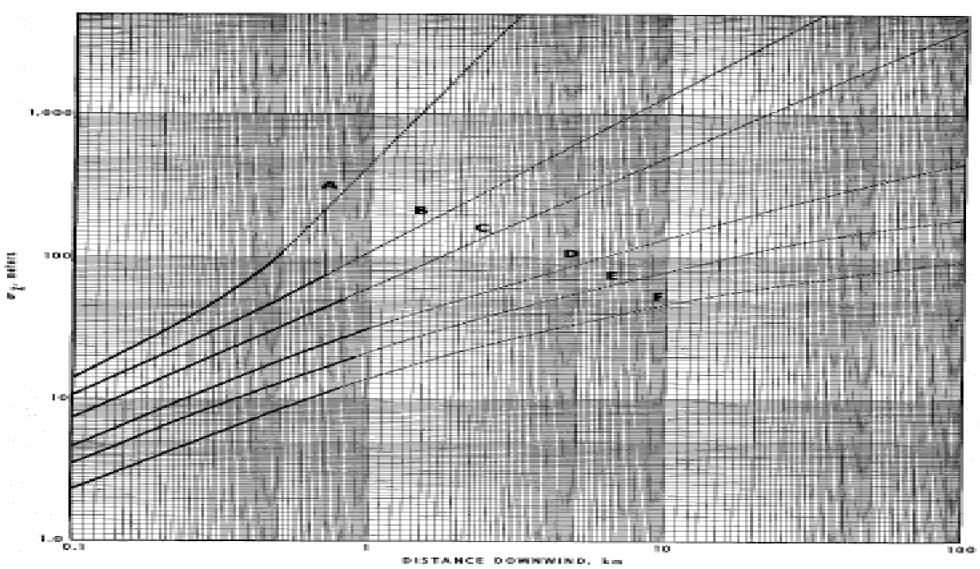

Figure 3-3. Vertical dispersion coefficient as a function of downwind distance from the source.

Figure 2.1 (a):- Values of dispersion coefficient σ_z in atmosphere for different stability class (Turner, 1971)

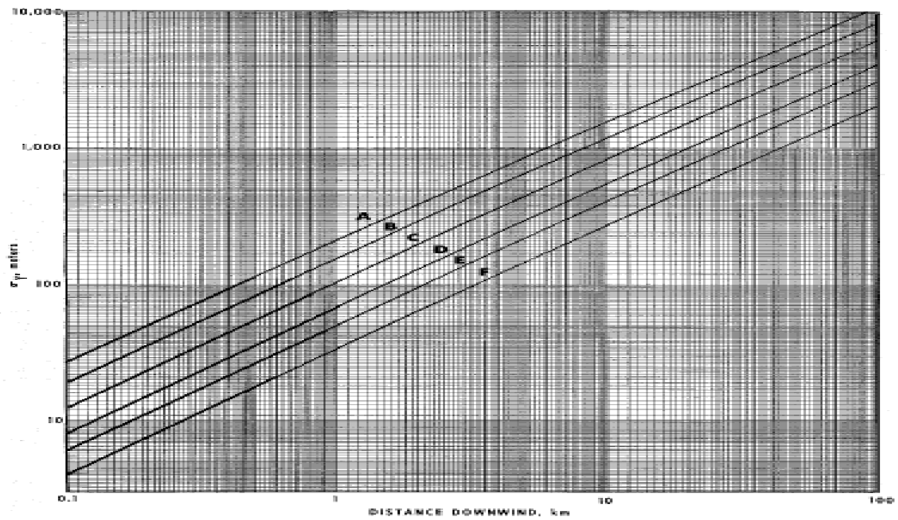

Figure 2.1 (b):- Values of dispersion coefficient σ_y in atmosphere for different stability class (Turner, 1971)

Chaulya (1999) studied the quality of air in the opencast mining projects of Lakhanpur area of Ib valley coalfields, Orissa. The study was conducted for 1 full year and the 24-h average concentration of the total suspended particulate (TSP) matter, respirable particulate matter (PM_{10}), sulphur dioxide and oxides of nitrogen (NO_X) were measured. The author developed a relationship between TSP and other pollutants based on linear regression to estimate the concentration of other pollutants based on the knowledge of TSP concentration. In residential areas (buffer zone) sampling and analysis was done bi-monthly and in industrial areas (core zone/mining area) it was done six times a month from September 1998 to August 1999.

The author discussed various effective measures for the control and mitigation of the dangerous suspended particulates produced during the opencast mining activities.

Chakraborty et al. (2001) carried out a detailed study to predict the emission rates of various mining activities in opencast mines. Seven different coal mines and three iron mines were selected by them based on different parameters like geographical location, accessibility, working conditions etc. to study the emission rates. 12 empirical formulae were developed to estimate the NO_x and SO_2 emission rates for different opencast mining activities. Results were validated at the Rajpura opencast mine and the data obtained were found to be of good accuracy ranging from 77.2% to 80.4%. The authors also found that suspended particulates have the highest contribution to the total pollution created in the mine and the contribution of NO_x and SO_2 was negligible in that respect. The results obtained by the authors proved to be of great significance to environment engineers for air quality monitoring.

Ghose and Majee (2007) during the study successfully quantified the amount of dust generated from various opencast mining projects. The assessment carried out by the authors involved usage of emission factor data for the quantification of the amount of dust generated. The results obtained showed that wind erosion and coal handling activities are the major sources of dust in opencast mining projects which contributes around 7.8 tons every year. The authors also showed that the heavy mechanization of the opencast mines, under high productivity demands, is the major source of air pollution in those mines. The emission factor suggested in this work could be used for the accurate estimation of dust generated by various activities in an opencast mining project.

Trivedi et al. (2009) studied the dust dispersion in an opencast project in the Western Coalfields, India, and modeled the dispersion using Fugitive Dust Model. The results obtained showed that the contribution of various mining activities in an opencast project to the overall dust emission was negligible beyond a certain distance of around 500m. The results obtained were validated and found to have a good accuracy range of around 68%-92%. The authors also suggested various methods for the control and mitigation of the dust generated by the opencast mining activities.

CHAPTER 3
DISPERSION MODELING

3.1 Plume Rise

Plume Rise essentially involves four phases;

I. Initial Phase
II. Thermal Phase
III. Breakup Phase
IV. Diffusion Phase

Initial Phase is very important as the pollutant concentration in the area is determined by the height to which the plume rise occurs. Consequently the ground level concentration gets reduced. The height of rise will depend on:-

a) The emission temperature,
b) The cross-sectional area of the stack,
c) The velocity of the emission,
d) The horizontal wind speed, and
e) The vertical temperature gradient.

For a given set of these conditions the plume will rise to some height (Δh). The height of the stack plus the plume rise (Δh) is called effective stack height (Fig 3.1).

$$H = h_s + \Delta h$$

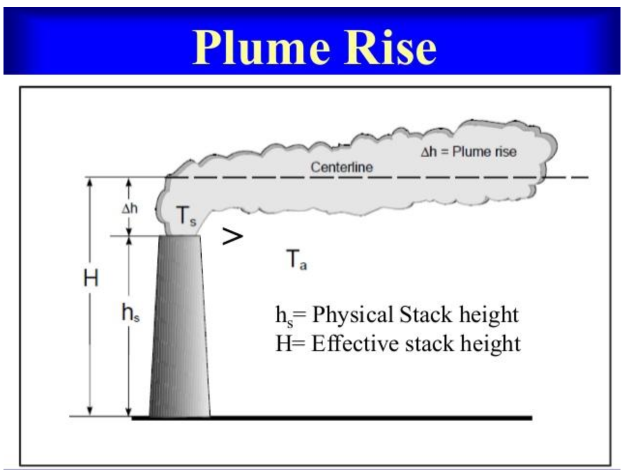

Figure 3.1:- Stack Height and the Plume Rise in a chimney. (Jahagirdar, 2013)

For the measurement of plume rise there are two main equations:-

I. Holland Plume Rise (Schnell, 1999)

$$\Delta h = \frac{V_s . D}{u}\left(1.5 + 2.68 \times 10^{-3} . P . D . \frac{(T_s - T_a)}{T_s}\right) \ldots \ldots \ldots \ldots \ldots (3.1)$$

Δh= Plume Rise, in meters.

V_s= Stack exit Velocity, m/s.

D= Stack Diameter, meters.

u= wind speed, m/s.

P= Pressure, mBars.

T_s= Stack Gas Temperature, in Kelvin.

T_a= Atmospheric Temperature, in Kelvin.

II. Brigg (1969) Plume Rise

This is the standard plume rise model used in most EPA air dispersion models. Brigg divided air pollution plumes into four general categories:-

i. Cold jet plumes in calm ambient air conditions,
ii. Cold jet plumes in windy ambient air conditions,
iii. Hot, buoyant plumes in calm ambient air conditions,
iv. Hot, buoyant plumes in windy conditions.

Logic Diagram for using the Brigg's equations to obtain the plume rise trajectory of bent-over buoyant plumes is presented in Figure 3.2.

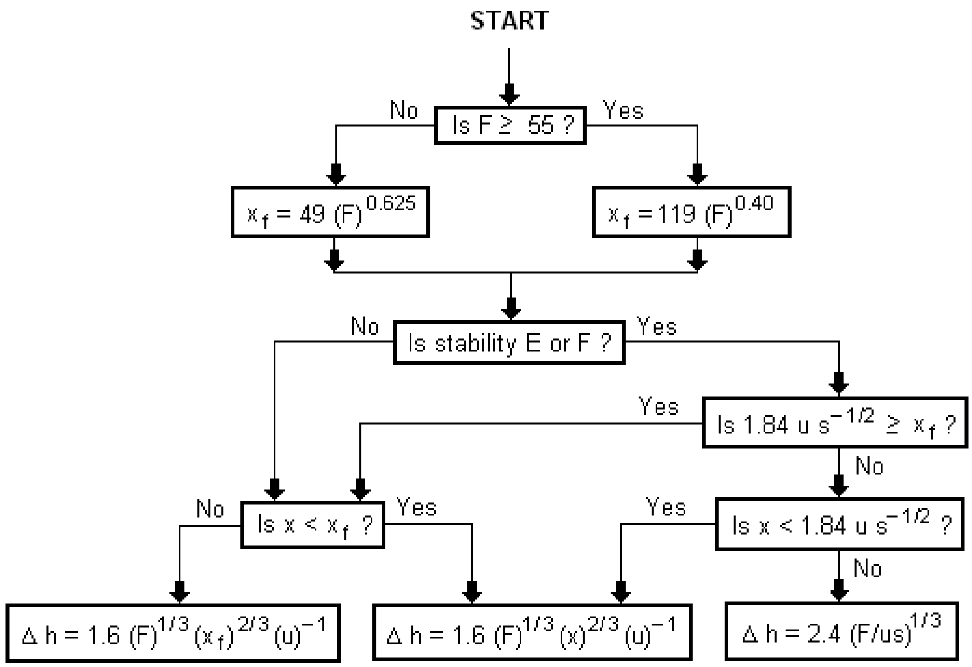

Figure 3.2:- Logic Diagram of Brigg's Equations (Source:-Beychok, 2010)

Δh= plume rise in meters

F= Buoyancy Factor, in m^4/s^3

x= downwind distance from plume source, in meters

x_f= downwind distance from plume source to

point of maximum plume rise, in meters

u= wind speed at actual stack height, in m/s

s= stability parameter, in s^{-2}

3.2 Gaussian Plume Model

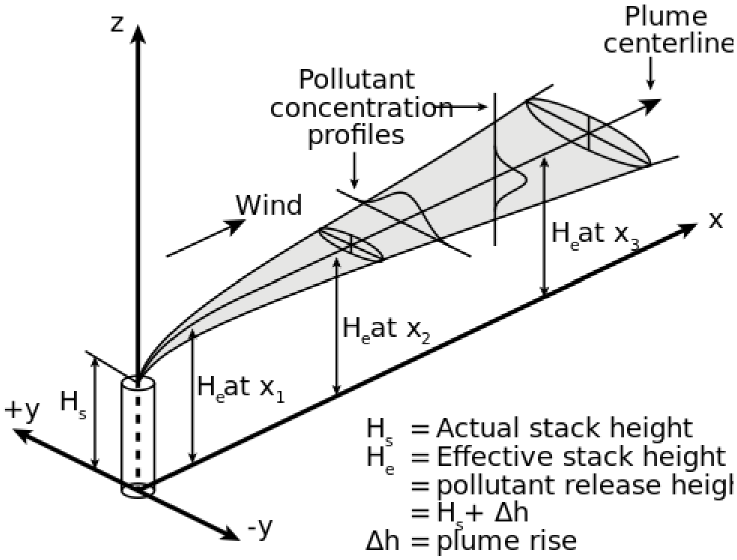

Figure 3.3:- Details of the Gaussian Plume Model (ELTE Prompt Portal, 2012)

The gas stream, also called as plume, rises from the stack well above the top end of the stack/chimney (Fig. 3.3). Such gas plumes generally rise a considerable distance above the stack due to high temperature and large velocity of the gases.

Using the Gaussian Plume Model (Equation 3.2), we can calculate the air pollutant concentration at any point along the direction of air flow.

$$C = \frac{Q}{u} \cdot \frac{1}{2\pi\sigma_z\sigma_y} \cdot e^{-\left[\left(\frac{y^2}{2\sigma_y^2}\right)\right]} \cdot e^{-\left[\left(\frac{(z-H)^2}{2\sigma_z^2}\right)\right]} \ldots\ldots\ldots\ldots\ldots (3.2)$$

C= Concentration of the air pollutant, in the plume, kg/m^3

Q= emission rate of pollutant, kg/s.

u= average wind velocity, m/s.

y, z= distances from the center line of the plume, m.

σ_y, σ_z = horizontal and vertical dispersion coefficients.

H= effective stack height, m.

3.2.1 Dispersion Coefficients:-

The values of the dispersion coefficients are based on atmospheric stability classes. Turner (1971) developed the most widely accepted approach based on work by Pasquill (1961) and Gifford (1959) and these are commonly known as Pasquill-Gifford-Turner (PGT) Diffusion.

3.2.2 Point Of Maximum Concentration:-

The maximum concentration downwind occurs along the plume centerline. For points on the plume centerline, equation of Gaussian Plume Model reduces to Equation 3.3.

$$X = \frac{Q \times 10^6}{\pi \times \sigma_y \times \sigma_z \times u} \times e^{\left[-\frac{1}{2}\left(\frac{H}{\sigma_z}\right)^2\right]} \ldots\ldots\ldots(3.3)$$

3.2.3 Wind Speed:-

In the lower layers of the atmosphere, wind speed normally increases with height. The wind speed at stack height has the greatest effect on the plume. Wind speed may be adjusted to stack height with the Equation 3.4.

$$U_z = U_o \left(\frac{z}{z_o}\right)^p \ldots\ldots\ldots(3.4)$$

Where,

U_z= wind speed at height z, m/s.

U_o= wind speed at anemometric height, m/s.

z= desired height, m.

z_o = anemometric height, usually 10 m.

3.3 Atmospheric Stability:-

Atmospheric Stability is defined in terms of the tendency of a parcel of air to move upward or downward after it has been displaced vertically by a small amount. Essentially, unstable atmospheres of stability class A tend to develop vertical updrafts which increase boundary layer turbulence intensity. Stable atmospheres (Stability Class F) tend to suppress vertical updrafts and reduce turbulence intensity. Since it is difficult to measure turbulence intensity directly, correlations are sought to indicate stability class as a function of readily available and measurable variables.

The earliest classification scheme is attributed to Pasquill (1961), which is summarized in the Table 2.1. This simply requires an estimate of solar radiation and wind speed. It has been shown to produce inconsistent classifications in comparison to other classifications and was thus improved upon by Pasquill (1961) by comparing atmospheric stability classes with Richardson Number and ambient temperature changes.

Richardson No.:- It is the ratio of vertical temperature gradient to the squared vertical gradient of wind speed which is given by Equation no. 3.5.

$$R_i = \frac{\left[\frac{T(z_1)-T(z_2)}{z_1-z_2}\right]}{\left[\frac{u(z_1)-u(z_2)}{z_1-z_2}\right]^2} \ldots\ldots\ldots\ldots (3.5)$$

Where,

R_i = Richardson Number

$T(z_1)$ = Temperature at height Z_1

$T(z_2)$ = Temperature at height Z_2

$u(z_1)$ =Wind velocity at a height Z_1

$u(z_2)$ =Wind velocity at height Z_2

z_1, z_2 = Heights at points 1 and 2

Atmospheric stability classes were correlated with Richardson No. as per Table 3.1.

Table 3.1:- Pasquill's Stability Class based on Richardson's No. (Pasquill, 1961):

Pasquill Stability Class	Ri
A	$Ri<-0.86$
B	$-0.86\leq Ri<-0.37$
C	$-0.37\leq Ri<-0.10$
D	$-0.10\leq Ri<0.053$
E	$0.053\leq Ri<0.134$
F	$0.134\leq Ri$

Atmospheric stability classes were correlated with ambient temperature change as per Table 3.2.

Table 3.2:- Pasquill's Stability Class based on Ambient Temperature Changes (Pasquill, 1961):

Stability Classification	**Pasquill Stability Category**	**Ambient Temperature Change with Height (^oC/100m)**
Extremely Unstable	A	$\Delta T \leq -1.9$
Moderately Unstable	B	$-1.9 < \Delta T \leq -1.7$
Slightly Unstable	C	$-1.7 < \Delta T \leq -1.5$
Neutral	D	$-1.5 < \Delta T \leq -0.5$
Slightly Stable	E	$-0.5 < \Delta T \leq 1.5$
Moderately Stable	F	$1.5 < \Delta T \leq 4.0$
Extremely Stable	G	$\Delta T > 4.0$

3.4 Wind Rose Diagram:-

Pollutant dispersion is significantly affected by the changes in the wind speed and direction. If the wind direction is relatively constant, then the same area will be continuously exposed to air pollution. On the contrary, if the wind direction shifts continuously, the air pollutants get dispersed over a larger area and the concentrations over any given exposed area will be lower. Larger changes in wind direction may also occur over short periods of time.

A wind rose diagram summarizes wind direction frequency and the wind velocity for a given period of time.

The data on direction frequency wind velocity in a wind rose diagram are generally given for eight primary and eight secondary directions of the compass.

- Wind velocity is divided into wind classes as in the figure below,
- The length of spokes indicates the direction frequency,
- Starting from the center that represents the frequency of calm periods(when wind velocity<1 m/s); each circular segment represents the frequency of average wind velocity or its range (Fig. 3.4)

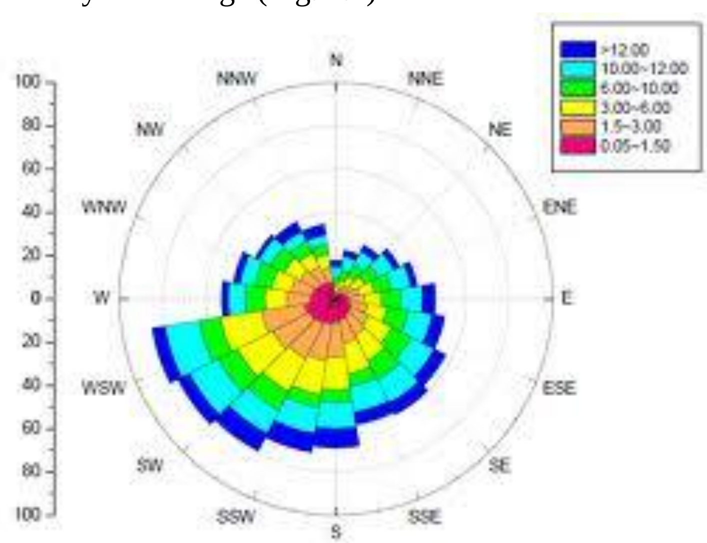

Figure 3.4:- An example of a Wind Rose Diagram (Wind Rose Plot, Originlab Corporation)

CHAPTER 4

CASE STUDY

This project is a case study based on a hypothetical data set created in manner that it mirrors the conditions in an opencast mining project. The data set generated was fed into the AERMOD software for modeling the dispersion of the dust particles generated from the various mining activities in the opencast mine. The terrain and geological conditions were taken from the sample dataset of Rosemont Copper Mine located at Tucson in the state of Arizona, USA.

The input data fed into the AERMOD software were:-

1. Hourly Surface Data File:- this data file was generated by a nearby weather station or airport. This sort data file contained composite surface map, weather report at the surface level etc. taken on an hourly basis. The data file input into the software was of ".ish" format.

2. Upper Air Data: - This data set was also generated from a nearby weather station or airport. This data set contained wind conditions i.e. wind direction, temperature etc. of the upper air at a particular location, taken by an anemometer (12 meters above ground). This file was in ".fsl" format.

3. Land Use Land Cover (LULC):- This data set contained the land cover data which was a well classified and tabulated data of the land use pattern of a certain area and the land cover data was transformed into a grid system or raster system.

4. Mine Sources: - It was a manually generated excel file that contains the different sources in a mine and also contained the coordinates of the positions of the sources. This file was in ".xls" format.

5. Gas Particle Data: - This was also a manually generated excel file that contained the different types of particles present in the dust generated by the various sources of dust generation in a mine along with their sizes and mass fraction. It was in ".xls" format.

6. Boundary Data: - Boundary data was also a manually generated excel file that contained the coordinates of the boundary of the mine.

The project involved two main processes:-

i. Processing of the surface data and upper air data using AERMET.
ii. Using the processed data generated by AERMET to model the dispersion of the in AERMOD software.

4.1 AERMET:-

At first the AERMET results were generated, using the hourly surface data and the upper air data and these data based on wind rose diagrams were further used in the modeling of the dispersion of dust in the mining area.

The hourly surface data for one year, in .ish format, was given as input and the location, the local standard time and the base elevation of the point where the data are taken were entered. The point was located at 39.5^{o} N and 119.783^{o} W, the base elevation of the point was taken as 1341 meters, and the local standard time was adjusted to 8 hours ahead of Greenwich Mean Time (GMT)(Fig. 4.1).

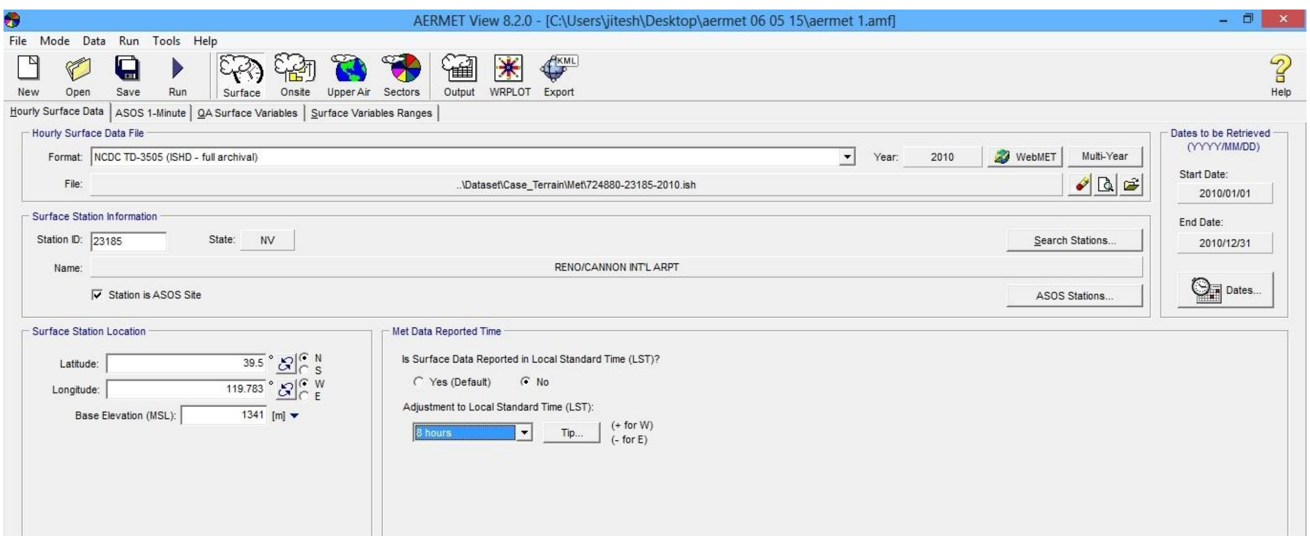

Figure 4.1:- Details of the input data in AERMET (Hourly Surface Data)

The Upper Air data for one year, in .fsl format, was then given as input and the location, the local standard time and anemometric height was specified. The anemometer was located at 39.57^{o} N and 119.8^{o}W, the height of the anemometer was taken as 33 feet above ground, and the local standard time was adjusted to 8 hours ahead of Greenwich Mean Time (GMT).(Fig. 4.2)

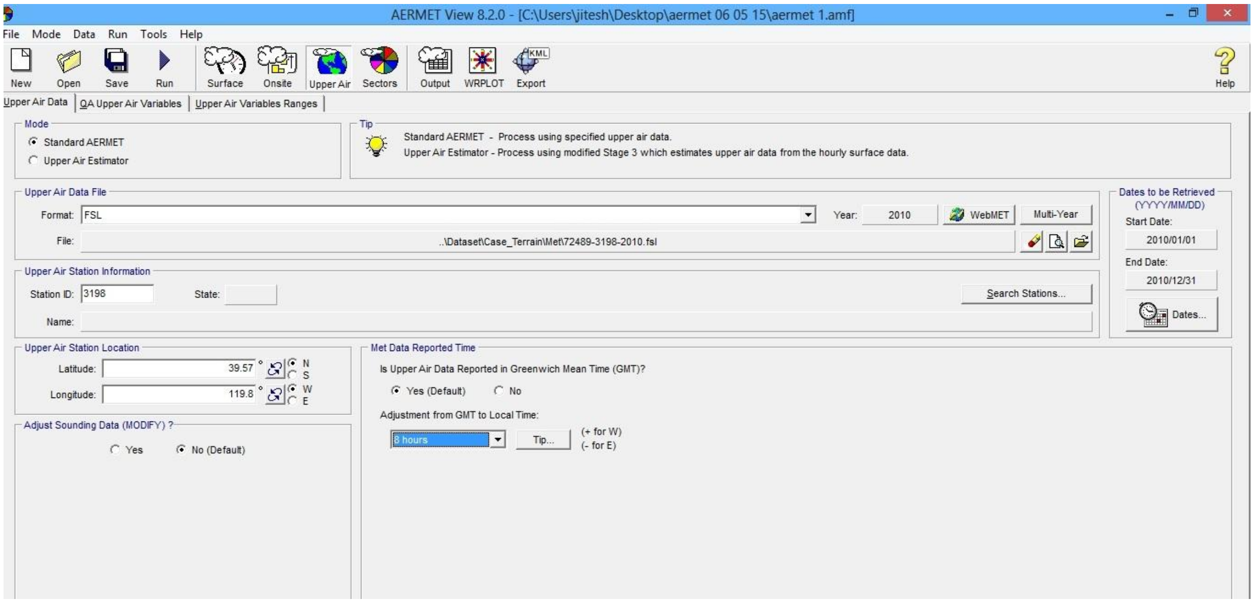

Figure 4.2:- Details of the input data in AERMET (Upper Air Data)

Then the Land Use Land Cover Data, in bin format, was given as input. It contained the Albedo, Bowen's Ratio and the Surface Roughness of the area which have been shown in the Table 4.1. Along with these, the location of the station was specified as 39.5^{o}N and 119.783^{o} W, the site characteristics were specified (Airport site, arid region and average site surface moisture), and the area was divided into 12 sectors (Fig 4.3).

Table 4.1:- Details of the LULC Data:

	Albedo	Bowen Ratio	Surface Roughness
Jan	0.19	1.49	0.07
Feb	0.19	1.49	0.07
Mar	0.18	1.04	0.074
Apr	0.18	1.04	0.074
May	0.18	1.04	0.074
Jun	0.19	1.21	0.076
Jul	0.19	1.21	0.076
Aug	0.19	1.21	0.076
Sep	0.19	1.49	0.076
Oct	0.19	1.49	0.076
Nov	0.19	1.49	0.076
Dec	0.19	1.49	0.07

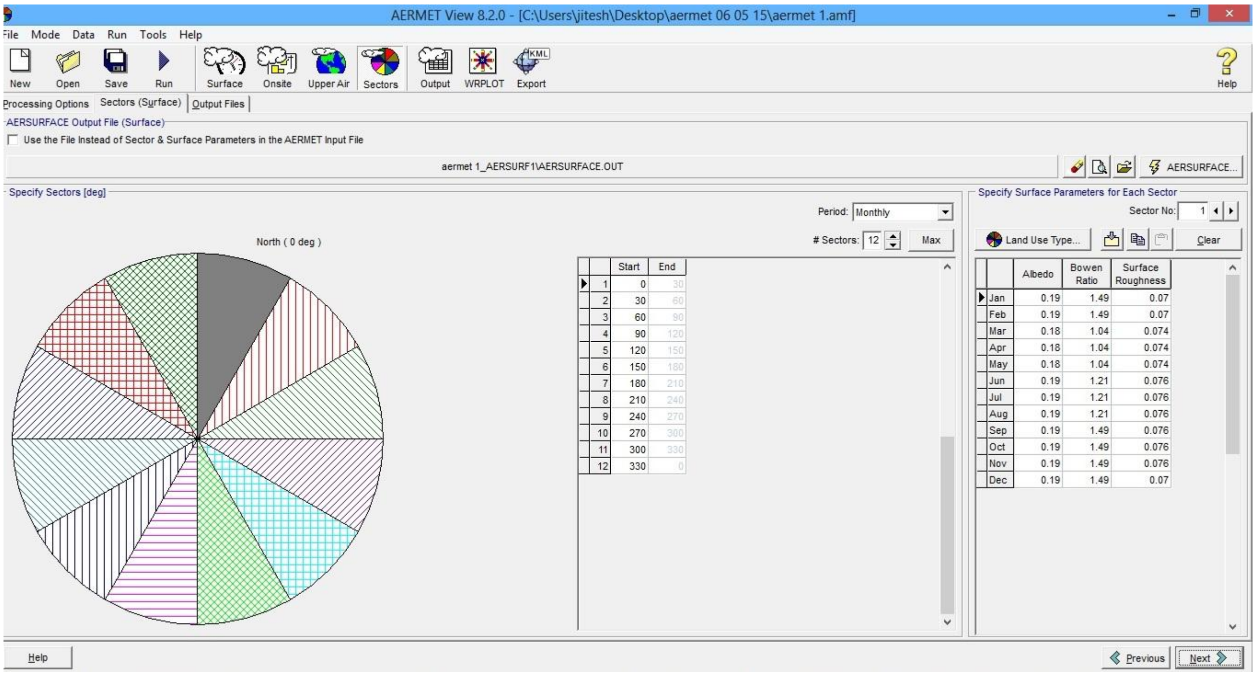

Figure 4.3:- Area is divided into 12 sectors.

Then the data entered was processed using AERMET and two processed files were generated, the preprocessed surface file (.SFC) and the preprocessed profile file (.PFL) after which the wind rose diagrams were generated (Fig 4.4 & 4.5).

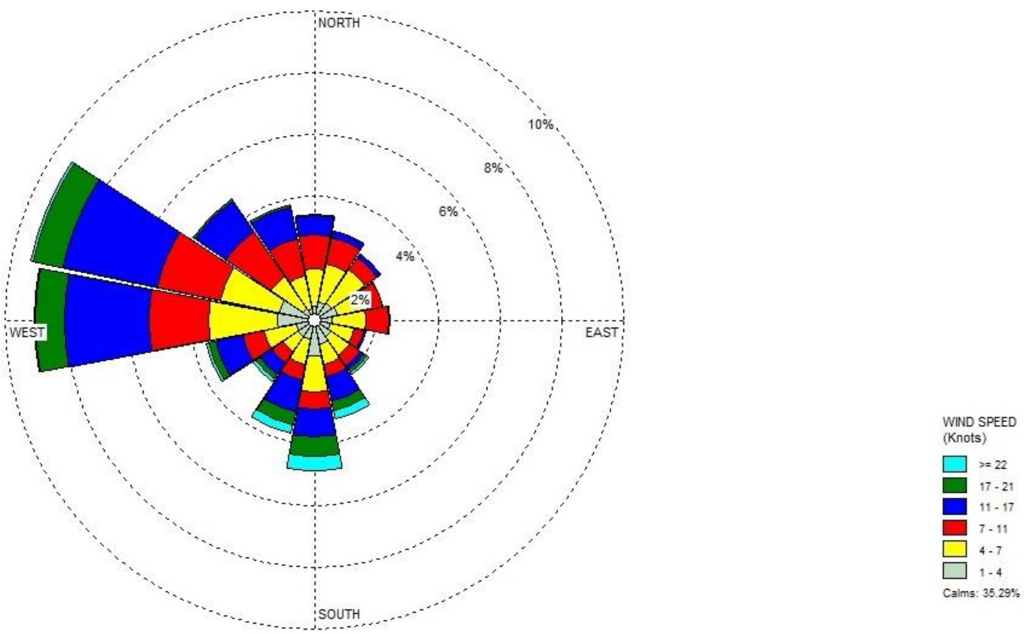

Figure 4.4:- Wind Rose Diagram of the Pre-Processed Surface file.

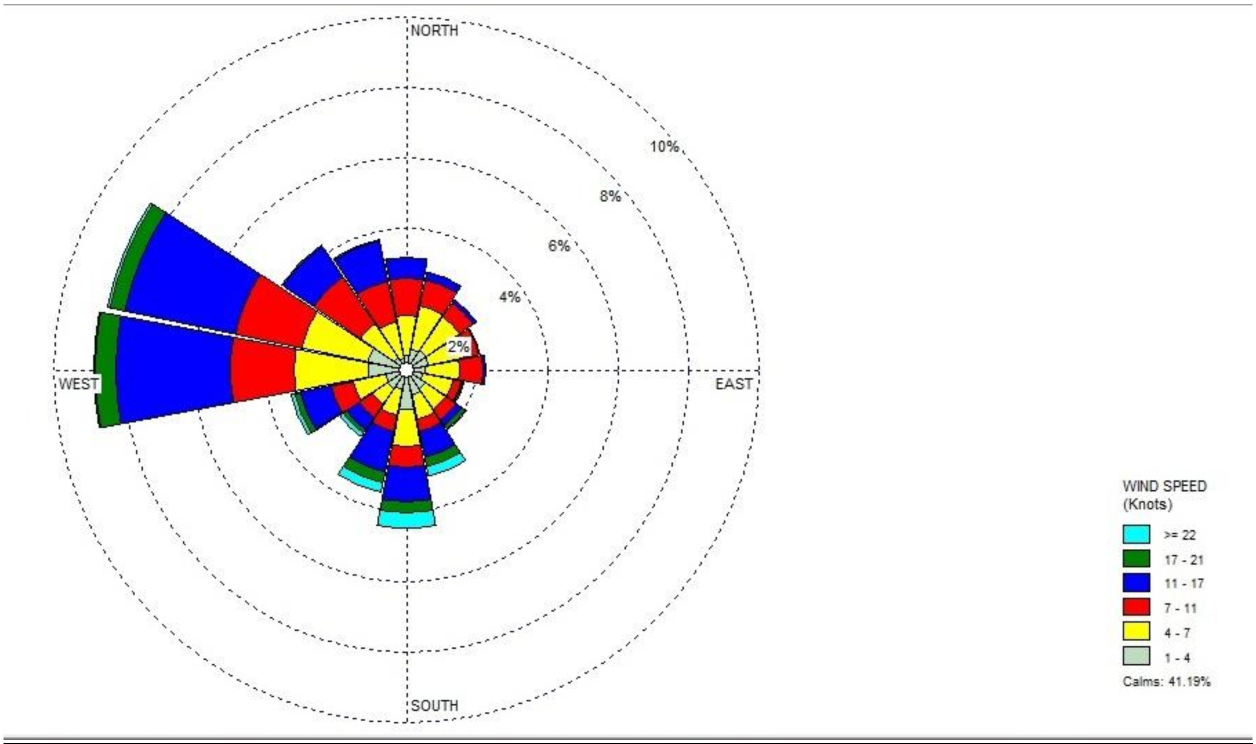

Figure 4.5:- Wind Rose Diagram of the Pre-Processed Profile file.

4.2 AERMOD:-

After the results were processed in AERMET it was used in the AERMOD software to model the dispersion of dust. A Universal Transverse Mercator (UTM) projection was used with WGS84 datum. The UTM zone was taken as 12 N. The centre of the modeling area was taken as the reference point, with an X - coordinate of 523675 m and Y- coordinate of 3521929 m. The radius of the modeling area was taken as 10 kilometers from the centre and terrain height was specified as "elevated".

In this project only PM_{10} emissions were taken into consideration. The 24-h average concentration of the PM_{10} was measured. The mine sources file generated in an excel sheet containing source type, x and y coordinates of their locations, their base elevations and the release height was given as input (Table 4.2).

Then as a seventh source a haul road (which is taken as a line volume source) was created specifying various parameters as follows:-

Vehicle height (VH) = 7.62 m

Factor = 1.7

Plume height (PH) = 12.95 m (PH= factor * VH)

Release height (RH) = 6.48 m (RH = 0.5 * PH)

Initial sigma Z= 6.03 m (Z = PH/2.15)

Lane type = two lane

Road width = 12 m

Plume width = 18 m (PW = RW + 6m)

Emission rate = 19.53 g/s

Table 4.2:- Details of sources of dust entered:

#	Source ID	Source Type	X Coord.(m)	Y Coord.(m)	Base Elevation	Release Height(m)	Description
1	SCRB01	Point	524076.40	3521780.60	1539.69	7.3	Scrubber
2	DC01	Point	524114.23	3521822.86	1528.7	6.1	Dust Collector
3	BLST01	Volume	522517.60	3521978.60	1639.1	10	
4	BLST02	Volume	522753.40	3521978.60	1603.88	10	
5	BLST03	Volume	522510.10	3521788.40	1622.61	10	
6	PIT01	Open Pit	522319.90	3521271.10	1732	0	Open Pit Mine
7	ROAD01	Line Volume	524300.32	3521941.41	0		

After the sources were given as input, the gas particle data was imported. Gas particle data was an excel file containing the particle diameter, mass fraction and the density of the particles as in the Table 4.3.

Table 4.3:- Details of the gas particle data entered:

Sl. No.	*Particle diameter (microns)*	Mass fraction (0 to 1)	Particle density (g/cm^3)
1	*2.20*	0.317	2.44
2	*3.17*	0.103	2.44
3	*6.10*	0.292	2.44
4	*7.82*	0.158	2.44
5	*9.32*	0.13	2.44

Now, the buildings data was entered. Buildings were taken as rectangular shaped having an elevation of 5 meter each. Then the boundary of the mine was specified. The boundary data file which was an excel file containing the coordinates of the boundary of the mine is imported (Table 4.3).

Table 4.4:- Details of the Boundary Data entered:

Point	Coordinates
A	(522173.2, 3522567)
B	(522016.8, 3521593)
C	(522074.2,3521119)
D	(523423.9,3520452)
E	(524492.3,3520665)
F	(525065.5,3521280)
G	(525023.8,3522797)
H	(523960.7,3522990)
I	(522407.7, 3522885)

Now, a three tier grid system was generated to divide the area into grids with the origin at (523675, 3521929) which would be helpful in specifying the maximum concentration of dust in each grid. The details of the grid system were given in the Table 4.4. The result of data entered appeared on the screen as in the Figure 4.6.

Table 4.4:- Details of the 3-tier grid system created:

Tier	Distance From Center(m)	Tier Spacing(m)
1	2500	250
2	5000	500
3	10000	1000

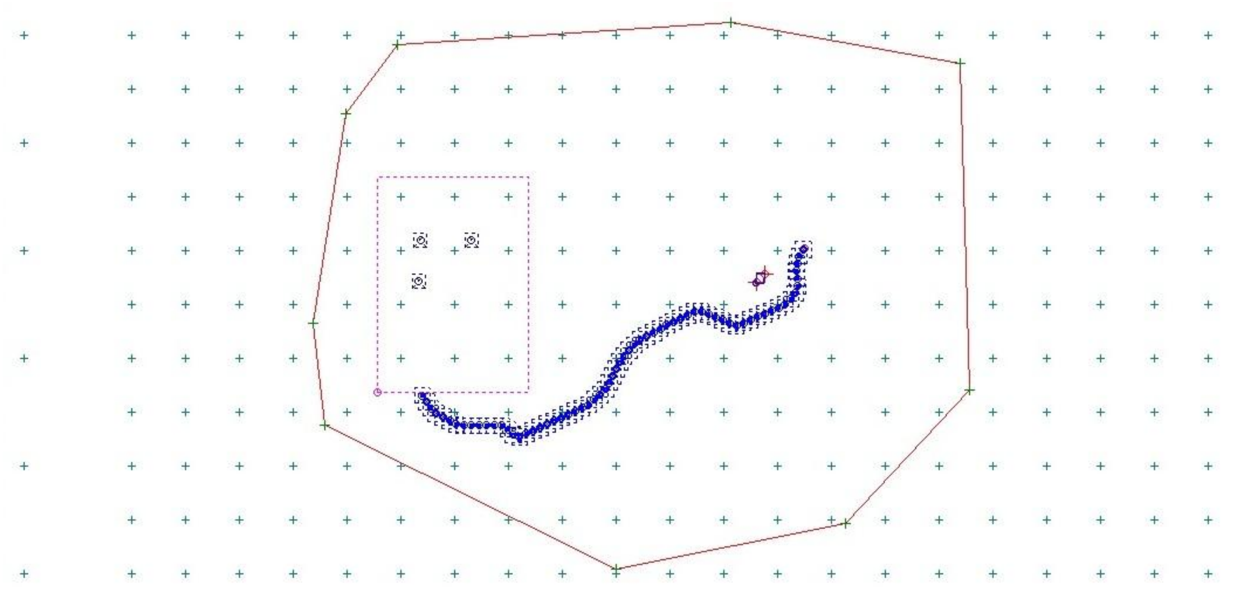

Figure 4.6:- Details of the result after entering the data.

Now the terrain data file which is a Digital Elevation Model (DEM) of the Rosemont Copper Mine was imported. As all the data to be entered have been entered, the mine scenario appeared on the screen as shown in Figure 4.7. The file was ready to be processed to model the dispersion and find the maximum concentration in the area.

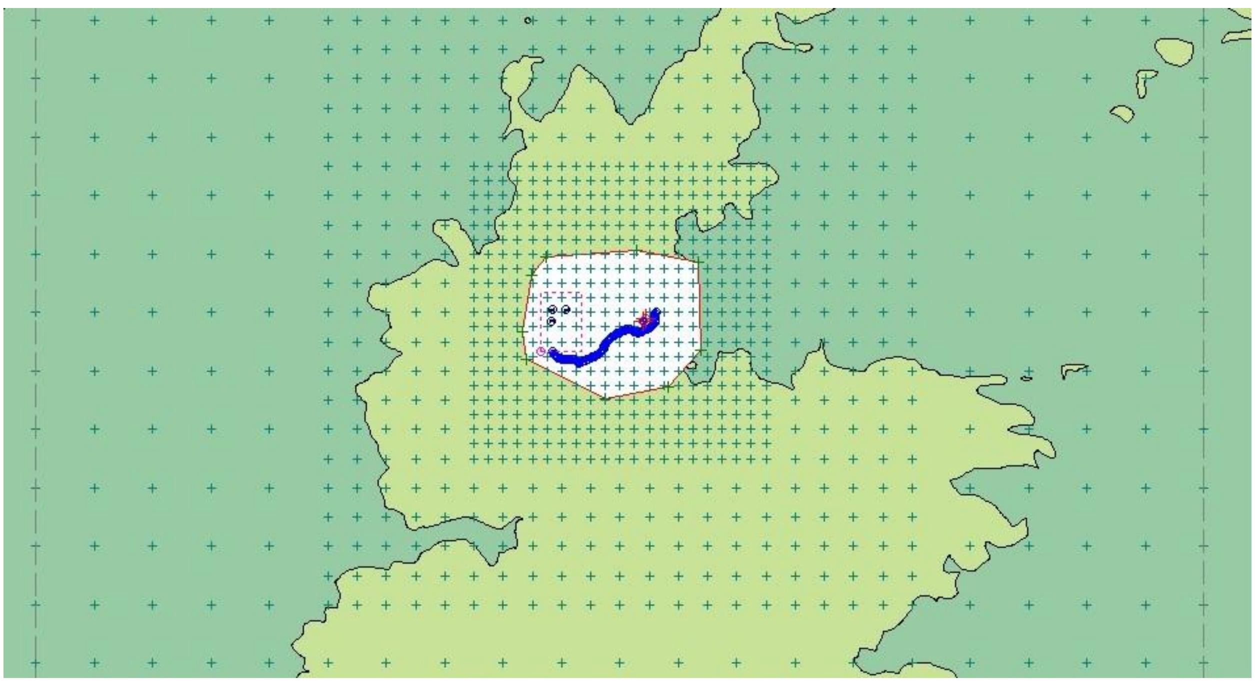

Figure 4.7:- Details of the result after entering the terrain DEM file.

CHAPTER 5

RESULTS

After all the required data was entered, the data were processed. The result obtained appeared as in the figure. The maximum dust concentration in the area was found to be 98.79802µg/m^3; at a location having coordinates (5239925.00, 3521679.00). (Fig. 5.1 & 5.2)

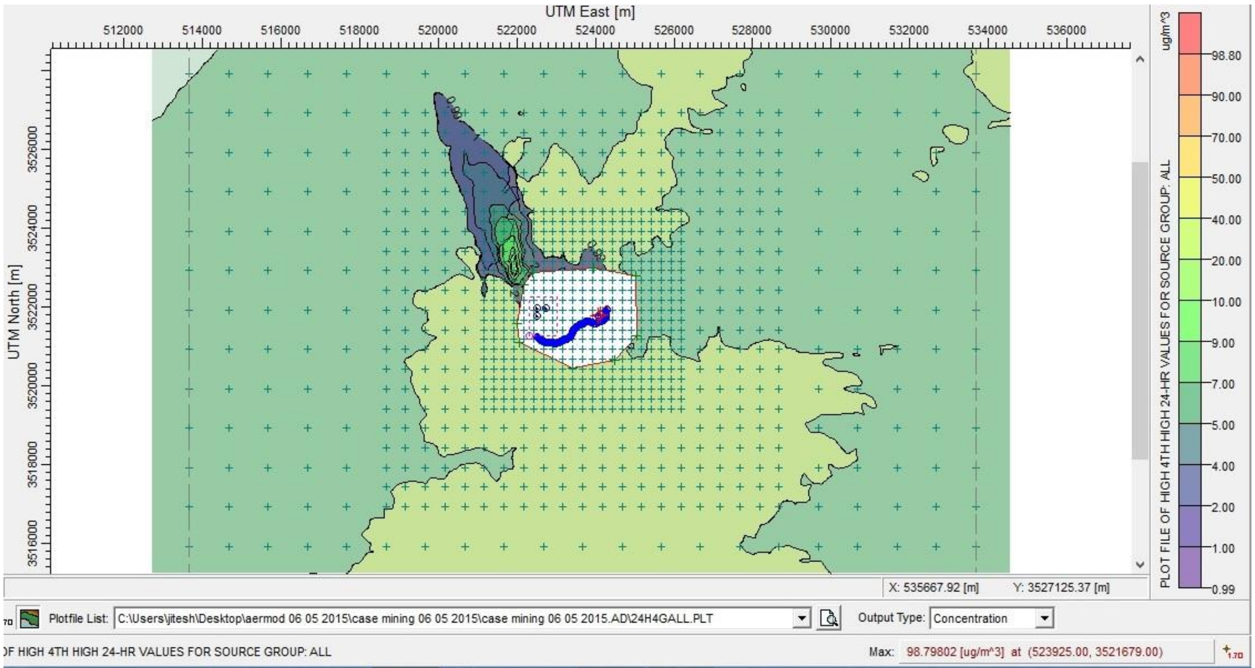

Figure 5.1:- Result after processing (showing contours).

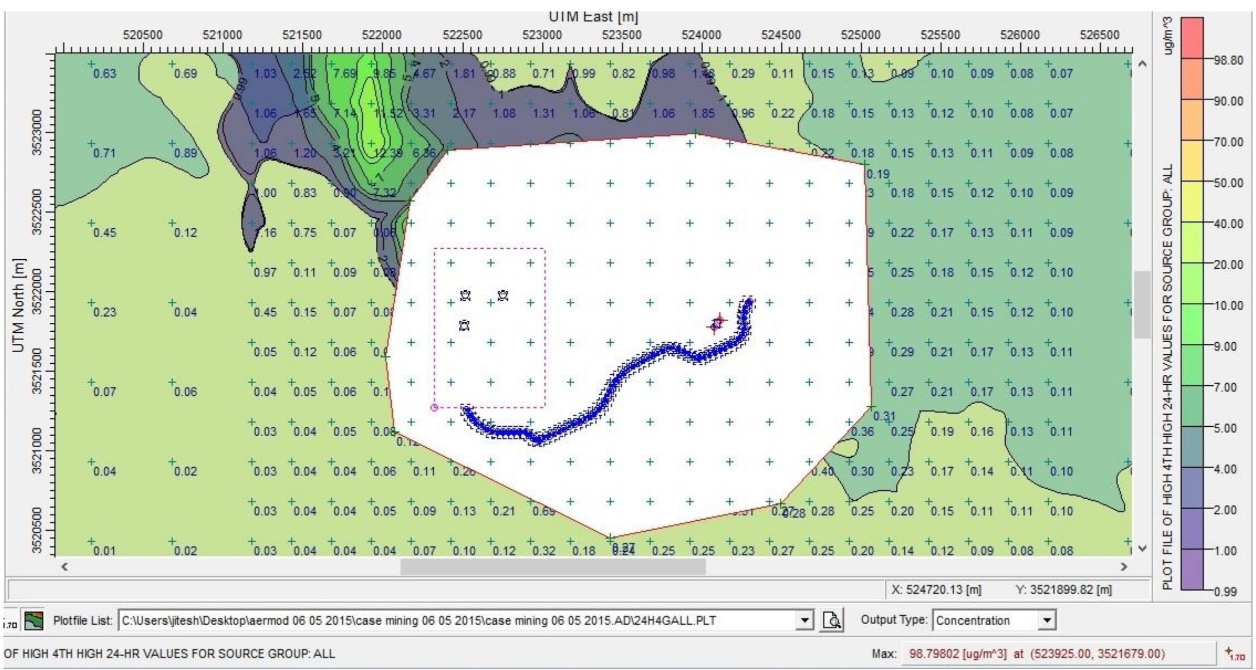

Figure 5.2:- Details of the result (Showing grid-wise maximum concentration)

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