

INFLUENCE OF ENHANCED PRODUCTION AND PIT DIMENSIONS OF OPENCAST COAL MINES ON DUST CONCENTRATION

Thesis

Submitted in partial fulfillment of the requirements for the
degree of

DOCTOR OF PHILOSOPHY

by

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September, 2024

DECLARATION

by the Ph.D. Research Scholar

I hereby *declare* that the Research Thesis entitled “**Influence of enhanced production and pit dimensions of opencast coal mines on dust concentration**” which is being submitted to the National Institute of Technology Karnataka, Surathkal in partial fulfillment of the requirements for the award of the Degree of Doctor of Philosophy in **Mining Engineering** is a *bonafide report of the research work carried out by me*. The material contained in this Research Thesis has not been submitted to any University or Institution for the award of any degree.



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CERTIFICATE

This is to certify that the Research Thesis entitled "**Influence of Enhanced Production and Pit Dimensions of Opencast Coal Mines on Dust Concentration**" submitted by **Mr. Podicheti Ravi Kiran** (Register Number: 135002MN13P01R) as the record of the research work carried out by him, is *accepted as the Research Thesis submission* in partial fulfillment of the requirements for the award of degree of **Doctor of Philosophy**.



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Dedicated to the Almighty

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ABSTRACT

Opencast coal mines play a crucial role in meeting the energy demands of a country. With significant availability of indigenous coal reserves and its affordability, coal is likely to continue as primary source of energy to meet the developmental needs of rising economy. However, the operations will result in deterioration of ambient air quality, particularly due to emission of particulate matter (PM), PM₁₀ and PM_{2.5}. PM₁₀ consists of PM size less than 10 microns and PM_{2.5} consists of PM size less than 2.5 microns. The PM disperses to different directions with varying concentrations based on the quantum of mining operations and local meteorological parameters. Monitoring of PM dispersion is essential due to its associated health impacts. These particles can penetrate deep into lungs, potentially triggering respiratory and cardiovascular illnesses. Prediction of ambient dispersion of PM helps in taking mitigation measures for reducing the dispersion and thus exposure. Development of region-specific dispersion models with respect to changing mine parameters and local meteorological conditions for PM₁₀ and PM_{2.5} emanating from opencast coal mines are necessary for accurate prediction of PM dispersion.

Though number of techniques exists for prediction of dust concentration due to opencast mining, machine learning offers several advantages over traditional modeling techniques in terms of data driven insights, non-linearity, flexibility, handling of complex interactions, anomaly detection, etc.

An approach is made in this research to analyze the concentration of PM in and around 6 opencast coal mines of the Singareni Collieries Company Limited located in Godavari Valley Coal Field, Telangana State of India and to predict the PM concentrations in core and buffer zones using machine learning techniques. The study involved collection of 10 years historical data comprising of 31,680 observations related to mine operating parameters, meteorological and PM data for processing and subsequent dust predictions.

Data has been analyzed using multivariate regression and different machine learning techniques like Decision Tree, Bagging and Random Forest (RF).

The performance metrics of test data compared in order to find the best fit model among these techniques. It has been found that RF method has given better accuracy.

A software program PMPOM (Particulate Matter Prediction in Opencast Mines), has been developed using Python with RF algorithm to predict PM_{10} and $PM_{2.5}$ values at select locations in each mine. Further, contour plots have been developed using Quantum Geographic Information System (QGIS), a geospatial modelling application, for visualization and spatial analysis of PM dispersion patterns within and surrounding the mine. This comprehensive approach has been instrumental in creating more accurate and robust dust dispersion model for the entire region.

The study also aimed at determining the ratio of $PM_{2.5}/PM_{10}$ which is helpful in arriving at the concentration of $PM_{2.5}$ from PM_{10} or vice-versa in case of non-measurement of any one parameter. It has been concluded that a relationship is not possible to establish between $PM_{2.5}$ and PM_{10} in the core zone, whereas in the buffer zone is feasible.

Key words: Opencast coal mines, dust dispersion, machine learning, statistical analysis, prediction, contour plots

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CHAPTER 1

CHAPTER 1

1.INTRODUCTION

This chapter provides an overview of the anticipated rise in coal demand in the future, sources to meet this demand, and the resulting consequences of air pollution. It also explains the importance of predicting particulate matter concentration in and around opencast coal mines. Finally, it outlines the research objectives and describes the methodology used in the research study.

1.1 General

Mining of minerals is being done for the past few centuries for the benefit of mankind and coal has been the primary source of energy in India, despite its environmental impacts. With significant availability of indigenous coal reserves and its affordability, coal is likely to continue as primary source of energy to meet the developmental needs of rising economy. The Economic Survey 2022-23 predicts a robust trajectory for the coal demand, with an annual increase of 6-7% and is expected to push production to 1 billion tones by the end of financial year 2026 and a staggering 1.5 billion tones by 2030. A 2023 report by Inter-Ministerial Committee on transition from coal indicates that NITI Aayog expects the share of coal in India's primary energy mix to decline by 10% by 2035. However, despite this decrease in proportion, the total demand for coal is projected to rise by 40% due to growing energy needs fueled by economic expansion.

Further, opencast coal mining continues to be the major source of coal supply to thermal power plants for few more decades till there is a gradual shift from coal to renewable energy sources. A number of new coal mines are being opened up and existing mines are under expansion both in public and private sectors in order to meet the growing energy demands of the country. Under this likelihood of consistently increasing coal demand, it becomes even more imperative to curb the dust pollution from coal mining and production activities to limit its environmental impact.

Opencast coal mining involves various operations like drilling, blasting, loading, transporting, unloading and crushing resulting in air pollution and more significantly, discharge of fine dust particularly, PM_{10} and $PM_{2.5}$. PM_{10} consists of PM (Particulate Matter) size less than 10 microns and $PM_{2.5}$ consists of PM size less than 2.5 microns. Air pollution is one of the most important parameters to be considered in preparing Environmental Impact Assessment (EIA) report of mining projects (Canter, 1983) and the estimation of PM dispersion from a mine at various stages of its operations is vital which aids in taking preventive measures against pollution.

Air pollution is primarily due to the ongoing opencast mining operations and prevailing meteorological conditions. Monitoring of these parameters is very much essential due to various health impacts associated with such environmental pollution. Prediction of ambient dispersion helps in taking mitigation measures for reducing the dispersion and thus exposure.

The emission factors being implemented are required to adapt to the local conditions of each mine (Huertas et al. 2012). The same empirical formulae cannot be considered for all Indian mines (Chakraborty et al. 2002). Development of region-specific dispersion techniques with regard to changing mine parameters and local meteorological conditions for PM_{10} and $PM_{2.5}$ emanating from opencast coal mines are necessary to allow accurate prediction of PM dispersion (Richardson et al. 2018; Cooper et al. 2017).

Considering the above, an approach is made in this research to analyze the concentration of PM at different locations in and around some of the opencast coal mines based on coal produced, overburden extracted, project area, meteorological conditions, silt and moisture content of overburden. Instead of manually driven rules and build models from analyzing large amounts of data, ML offers a more efficient alternative for complex data analysis. Machine learning has evolved as a subfield of Artificial Intelligence that involves the development of self-learning algorithms in order to make more accurate predictions. Hence, machine learning techniques have been used for analyzing the data and further processing.

The study also aimed at determining the ratio of $PM_{2.5}/PM_{10}$ which is useful in arriving at the concentration of $PM_{2.5}$ from PM_{10} or vice-versa in case of non-measurement of any one parameter.

1.2 Research Gap and Motivation

Many studies by various researchers have revealed that there is considerable difference between the predicted dust concentration values using different models and actual measured values. So, development of region-specific dispersion techniques with regard to changing mine parameters and local meteorological conditions for PM_{10} and $PM_{2.5}$ emanating from opencast coal mines are necessary for prediction of PM dispersion. Traditional deterministic models cannot accurately assess the non-linear relationship between the concentration of air pollutants and their sources of emission and dispersion. To tackle such a limitation, the most promising approach is to use statistical models based on machine learning techniques. Considering the above, an approach is made in this research to analyze and predict the concentration of PM at different locations in and around some of the opencast coal mines.

1.3 Problem Statement

Though number of dispersion models exists for prediction of dust concentration due to opencast mining, machine learning offers several advantages over traditional modeling techniques in terms of data driven insights, non-linearity, flexibility, handling of complex interactions, anomaly detection, etc. To integrate the mine working parameters with meteorological conditions and historical data of particulate matter and develop a more accurate and robust dust prediction model using machine learning techniques.

1.4 Objectives of Research Study

The objectives of the research work are as follows:

- a. To assess the influence of mining and meteorological parameters on dust dispersion in core and buffer areas of opencast coal mines.
- b. To develop dust dispersion prediction models using machine learning techniques.
- c. To develop dust contours using geo-spatial modeling application.

1.5 Research Methodology

The following methodology is followed to attain the objectives of research work. The study involves collection and analysis of data related to mining, meteorological and particulate matter.

- a. In total, 6 case studies are considered for the research study with 31,680 data sets of 10-year period. Prediction models have been developed using Multivariate Regression (MVR) technique and different Machine Learning (ML) techniques like bagging, decision tree and random forest. 80% of the data is used for training and 20% of the data is used for testing. Further, these models are evaluated based on the performance evaluation metrics such as Mean Square Error (MSE), Root Mean Square Error (RMSE) and Co-efficient of determination (R^2).
- b. The performance metrics of test data are compared for different models in order to find the best model among the above. For the given data, the response variables are Coal Handling Plant (CHP), Base Workshop (BWS) and 4 villages. The remaining features i.e., project parameters, particulate matter and meteorological data are the independent variables.
- c. A software named PMPOM (Particulate Matter Prediction in Opencast Mines) has been developed using Python with RF algorithm to predict PM_{10} and $PM_{2.5}$ values at select locations in and around each mine to predict the dust concentrations.
- d. Contour plots have been developed to predict the dust concentrations at non-monitored locations in and around the mines using Quantum Geographic Information System (QGIS), a geospatial modelling application.

A flow chart showing the methodology adopted in the research study is given in Figure 1.1.

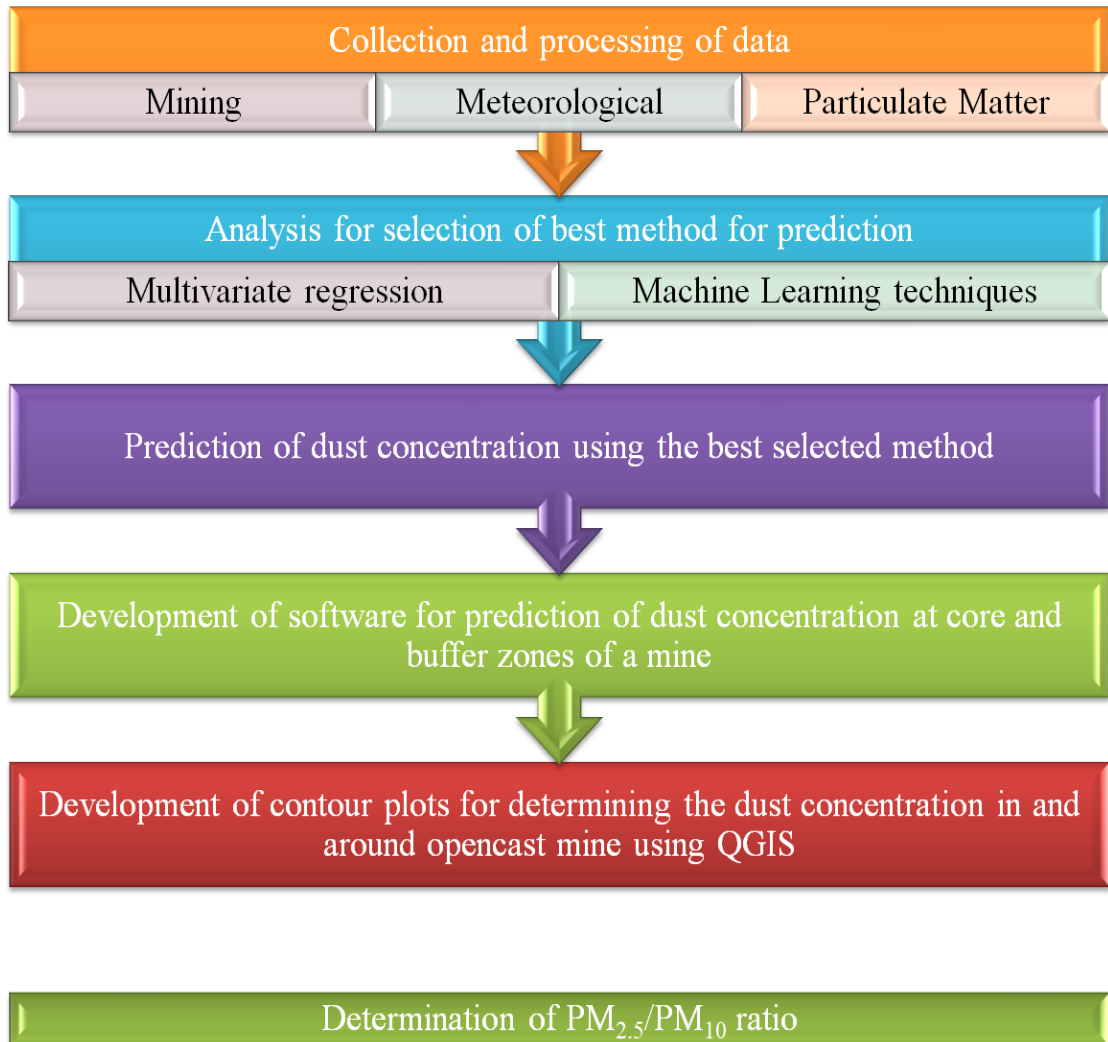


Figure 1.1 Schematic representation of the methodology

1.6 Organization of Thesis

CHAPTER 1

This chapter discusses the necessity of coal mining and the potential for its production enhancement in the near future, along with the impact of environmental degradation caused by PM. The chapter outlines the objectives of the research study and describes the research methodology adopted.

CHAPTER 2

A thorough literature review has been conducted, encompassing studies undertaken by previous researchers in the field of PM_{2.5}/PM₁₀ ratio are given in this chapter.

CHAPTER 3

This chapter gives the details of various methods used to collect and analyse data based on mining parameters, meteorological parameters and PM concentration. Data related to 6 case studies have been discussed and processed for development of dust prediction models using ML techniques.

CHAPTER 4

Details on results and analysis of different methods used to predict PM based on the mining and meteorological parameters have been presented in this chapter. This chapter also critically evaluates the selection of ML techniques over traditional mathematical models emphasizing considerations for accuracy in the context of environmental data analysis. A software has been developed to handle large volume of data and to predict the dust concentrations at predetermined locations. Further, QGIS has been used to predict the dust concentrations at non-monitored locations in and around the mines. It also sheds light on determining PM_{2.5}/PM₁₀ ratio in the core and buffer zones of opencast mines.

CHAPTER 5

This chapter culminates by synthesizing the key conclusions drawn from the investigations. It also presents actionable recommendations based on the findings and explores potential areas for further research to advance in this area.

CHAPTER 2

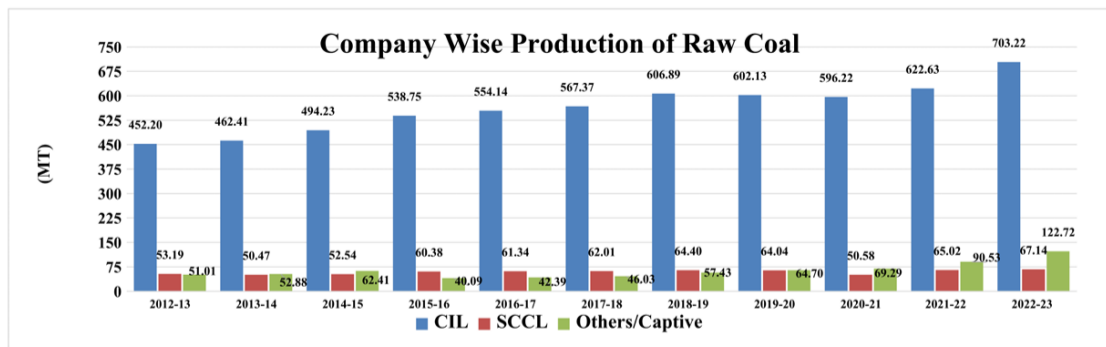
CHAPTER 2

2. LITERATURE REVIEW

This chapter deals with literature review on the status of coal production and particulate matter due to opencast coal mining operations. Dispersion of PM with regard to mining and meteorological parameters, silt and moisture content and ratio of PM_{2.5}/PM₁₀ has also been reviewed in detail.

2.1 General

According to the Ministry of Coal, Government of India, in 2022-23, the domestic coal production increased by 14.77% to reach 893.19 Mt from 778.21 Mt in 2021-22. Further, in the financial year 2023-24, the country has produced 997.25 Mt with a growth of about 11.65%. Further, domestic coal production is expected to grow by 6-7% annually in next few years to reach about 1.5 billion tonnes by 2029-30. Figure 2.1 shows the trend of increase in coal production from Coal India Ltd., Singareni Collieries Company Ltd. and other mines for the last 10 years. It showcases a distinct upward trajectory in coal production, indicating a steady rise in the total amount of coal extracted from mines across the country over this period.



**Figure 2.1 Companywise production of coal in India during last ten years
(in Million Tonnes)**

Source: https://coal.gov.in/sites/default/files/2021-01/productiondata_tenyear.pdf

Notation: CIL- Coal India Ltd.

SCCL- Singareni Collieries Company Ltd.

India's coal production strategy heavily relies on the efficiency and large-scale extraction capabilities of opencast mines. The economic competitiveness of opencast mines has positioned them as a key driver of national coal output. For the past decade, opencast mines have played a critical role in meeting India's growing coal production demands. Figure 2.2 depicts the contribution of opencast coal mines in India's coal production.

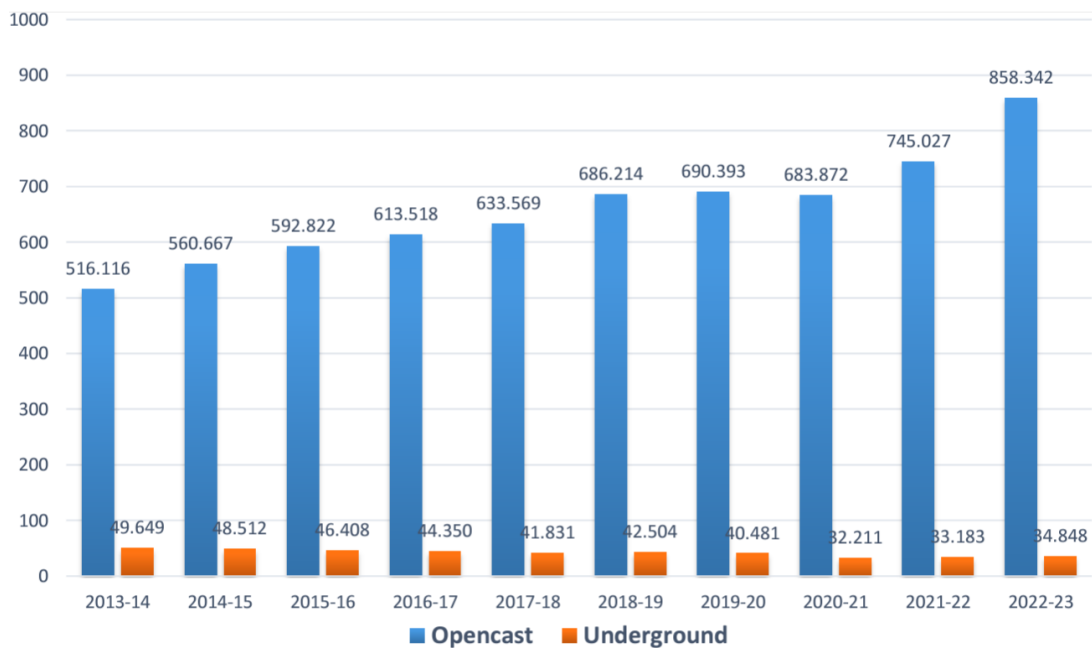


Figure 2.2 Production of coal from underground and opencast mines of India during the last 10 years (in Million Tonnes)

Source: <https://coal.gov.in/sites/default/files/2021-01/Production-Opencast-and-Under-ground-mines-durin-last-ten-years.pdf>

India's economic landscape is undergoing a significant transformation, driven by a burgeoning population, industrial activity and continuous development of infrastructure. This phenomenal growth, while positive, presents a formidable challenge – a rapidly escalating demand for energy. To meet this escalating energy demand and sustain its economic trajectory, India must explore a multifaceted approach which includes high rate of coal production, diversifying energy resources and enhanced energy efficiency in addition to population control.

While opencast coal mines have demonstrably bolstered domestic coal production, their operations are not without significant environmental consequences. One of the associated pollutions due to opencast coal mining is particulate and gaseous emissions. The particulate emissions include PM_{10} & $PM_{2.5}$ and gaseous emissions are CO, CO_2 , SO_2 , NO_x .

Analysis of air quality data at one of the opencast mines in Odisha indicates exceedances of the National Ambient Air Quality Standards (NAAQS) for PM concentrations. Conversely, concentrations of gaseous pollutants including SO_2 , NO_x , CO_2 and CO remained within established NAAQS limits (Chaulya 2003). Particles ranging from 30 to 10 μm may remain airborne for a short duration which are large enough to avoid deep lung penetration and are often trapped in the upper respiratory system, like the nostrils or mouth. Hence, particles less than 10 μm are more likely to be inhaled through the respiratory tract. Respirable particulate matter fractions PM_{10} and $PM_{2.5}$ are significant air quality concerns due to their potential to induce adverse health effects. PM_{10} , with a diameter less than 10 micrometers, can penetrate the thoracic region (Heal et al. 2012; Tsiouri et al. 2015) whereas particles less than 2.5 μm and finer are inhaled deep into the lungs (Dockery et al. 1994). $PM_{2.5}$, even finer at 2.5 micrometers or less has the ability to deposit deep within the alveolar sacs, the gas exchange region of the lungs (Leung and Cheung, 1999). Thus, PM less than 10 μm in diameter, which encompasses even finer $PM_{2.5}$ and PM_1 fractions, significantly contributes to air quality degradation and poses health risks when inhaled.

Dust may be inhaled through either nose or mouth and, in addition with the pharynx and larynx, they form the nasopharyngeal region. Here, particles are equilibrated with body temperature and humidity, and large particles are restricted. Particles, then, enter the tracheobronchial region (airways connecting the larynx to the terminating bronchioles) and finally the alveolar region (bronchioles, alveolar ducts and sacs) (Kastury et al. 2017). A description of respiratory airways and the impact of PM inhalation according to its size is given in Figure 2.3.

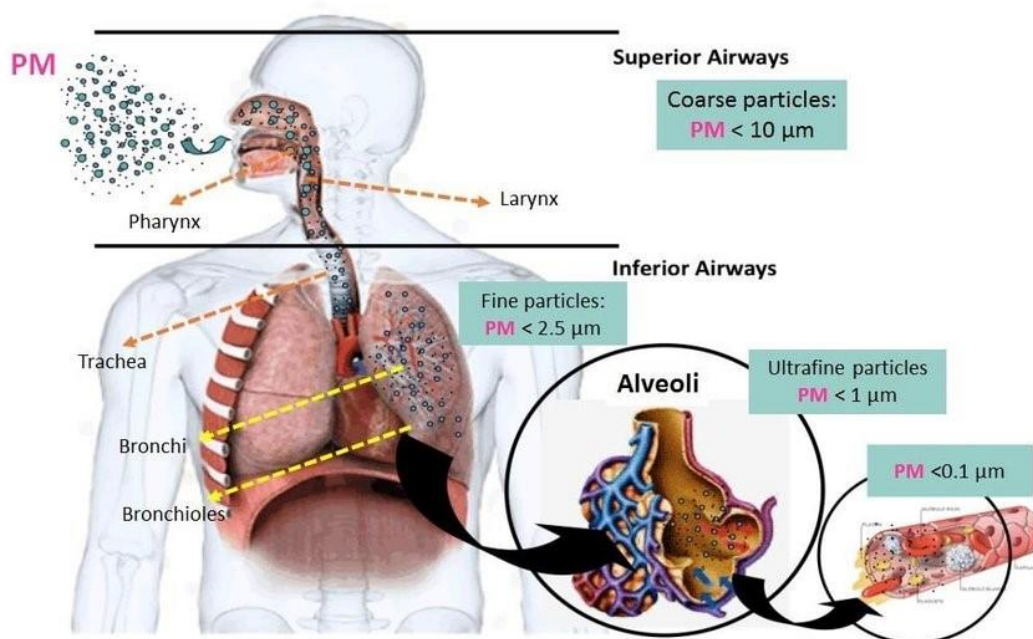


Figure 2.3 Illustration of respiratory tract and PM size classification (Kastury et al. 2017)

Research suggests a connection between PM exposure and asthma (Pless-Mulloli et al. 2000; Banks et al. 1998) as well as black lung disease (Hendryx and Ahern 2008). Some studies point towards a potential association between PM exposure and mesothelioma development (Shah, 1998). Emerging evidence suggests a link between PM exposure and neurodegenerative diseases like Parkinson's and Alzheimer's disease (Buzea et al. 2007).

Thus, inhalation of PM less than 10 μm is associated with enhanced health risks, including respiratory and cardiovascular complications, and even contributes to cancer development. Hence, studies have focused on assessment of PM_{2.5} and PM₁₀ emitted from opencast coal mines (Sinha and Banerjee, 1997; Chakraborty et al. 2002; Gautam and Patra 2015).

Coal miners' health is much more affected because of their exposure to dust not only during working hours but also during non-working hours due to the vicinity of colonies from mines. Research indicates a correlation between elevated PM levels and cardiovascular diseases (Hendryx, et al. 2009). The study revealed that the air pollution originating from Australian coal mining has increased over the years with

corresponding increase in coal production. Figure 2.4 shows the percentage change of particulate matter, metals and NO_x with respect to increased coal production in Australia during the years 2008 to 2018.

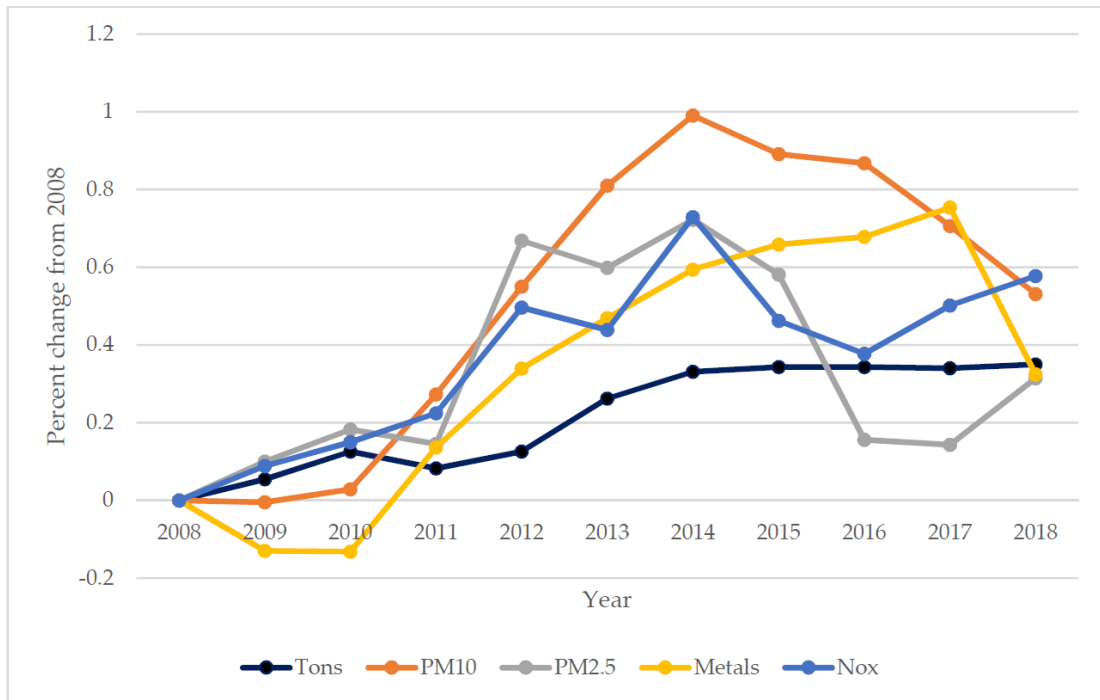


Figure 2.4 Percentage change from 2008 in tons of coal production and in pollution emissions (Hendryx et al. 2020)

The analysis confirmed that PM₁₀ exposure levels were more in mining communities when compared to urban or rural non-mining communities. Vulnerable population like children, pregnant women, aged people are at the most risk from mining related pollutants (Cortes et al. 2018).

2.2 Dust Prediction Models

Historical and real time PM monitored data along with mining parameters and weather forecasts can be useful in developing predictive models. The models can anticipate dust concentration and empowers the mine management and regulatory authorities to implement dust control strategies, evaluate their effectiveness and predict future dust events ultimately leading to cleaner air and a healthier environment.

A number of models have been developed such as Box model, Gaussian model, Eulerian model, Lagrangian model which were reported to be applied for air quality prediction in the mining industry (Reed et al. 2002).

In case of Box models, the site is treated as a box into which the pollutants are emitted. The model requires the meteorological and emission parameters as input. It is the simplest type of model in which it assumes the air shed is box shaped and the air pollution present in the box is homogeneously distributed. But the model suffers the disadvantage of not providing any information on the local concentrations of the pollutants (Holmes et al. 2006). The model generally used (Collett and Oduyemi, 1997; Reed 2005) is given in Eq. (1).

$$\frac{dCV}{dt} = QA + uC_{in}WH - uCWH \quad (2.1)$$

where,

C= concentration of pollutant throughout the box (mg m^{-3})

C_{in} = pollutant concentration entering the box (mg m^{-3})

Q = pollutant emission rate from source per unit area ($\text{mg m}^{-2} \text{s}^{-1}$)

V = volume of the box (m^3)

A = horizontal area (L x W) (m^2)

W = box width (m)

L = box length (m)

H = box height (mixing height) (m)

u = wind speed normal to the box (m s^{-1})

On the other hand, Gaussian models are based on a Gaussian distribution of the plume in the vertical and horizontal directions under steady state conditions.

A significant limitation of plume models for particle dispersion lies in their inherent reliance on steady-state approximations. This assumption disregards the temporal aspect of pollutant transport, failing to account for the time required for the pollutant plume to travel from the source to the receptor location.

Furthermore, the Gaussian models are not designed to model the dispersion under low wind conditions or close to sources less than 100m (Holmes et al. 2006). The equation for the Box model is given in Eq. (2).

$$X = \frac{Q}{2\pi u_s \sigma_x \sigma_z} \left[\exp \left\{ -0.5 \left(\frac{y}{\sigma_y} \right)^2 \right\} \right] \left[\exp \left\{ -0.5 \left(\frac{H}{\sigma_z} \right)^2 \right\} \right] \quad (2.2)$$

where,

X = Concentration ($\mu\text{g}/\text{m}^3$)

Q= Pollutant emission rate (g/s)

H = Source height (m)

σ_y & σ_z = Standard deviation of lateral & vertical concentration distribution

u_s = Mean wind speed (m/s)

y= Crosswind distance from source to receptor (m)

Limitations in Gaussian models become apparent under low wind conditions, leading to over predictions of pollutant concentrations (Benson, 1984).

In case of Eulerian models, chemical species move in a fixed grid. The model uses numerical terms to solve the equation of mass conservant of pollutant. The drawback of this model is that it is difficult to solve the numerical framework in this model. An example of Eulerian model is the Danish Eulerian Model, developed by National Environmental Research Institute of Denmark (Zlatev, 1995) for studying important chemical species like sulphur pollutants, nitrogen pollutants, ammonia-ammonium, ozone and other radicals and hydrocarbons. The advantages of Eulerian are that all physical and chemical processes are considered as all the important physical and chemical processes are solved. It can be used in 3D modeling. However, the model suffers from the disadvantage that the models lead to huge computational tasks which require extra care (Zlatev et al. 2006) and it is not possible to study direct relationships between sources and receptor points.

Lagrangian models are similar to Box models whose approach is based on stochastic ordinary differential equations to estimate the dispersion equation.

These models incorporate changes in concentration due to mean fluid velocity, turbulence of wind components and molecular diffusion. The equation for the model is given in Eq. (3).

$$\frac{dv}{dt} = g - k(V - V_a - V_t) \quad (2.3)$$

where,

g = gravitational acceleration (m/s^2)

V = particle velocity vector (m/s)

V_a = grid scale wind (advection) (m/s)

V_t = sub-grid scale wind fluctuation (turbulence) (m/s)

k = function of the particle size, density and fluid viscosity, usually calculated by Stokes' law

Lagrangian dispersion models are well-suited for scenarios with homogenous conditions, stationary sources and flat terrain (Oetl et al. 2001).

Computational Fluid Dynamics (CFD) models employ numerical methods to analyze complex fluid flow patterns. These models leverage the principles of mass and momentum conservation, achieved by solving the Navier-Stokes equations in three dimensions. Finite difference and finite volume methods are common techniques used within CFD software to achieve these solutions. Trivedi et al. (2009) evaluated the airborne particle concentrations with change in distance from pit boundary up to a distance of 500m in one of the opencast coal projects of Western coalfields Limited, India. Ground-level emission rates were calculated using the Modified Pasquill-Gifford formula and the emissions were predicted using FDM. It was revealed that the predicted values were varying between 68 and 92% of observed values which was due to non-accountability of emissions from other sources. An evaluation of various CFD models revealed consistent agreement in predicting the overall wind flow field. Despite utilizing identical input parameters, the models exhibited significant discrepancies in their estimations of wind velocities and turbulence levels (Gidhagen et al. 2004).

Silvester et al. (2009) studied to assess the dispersion phenomenon of emissions and found that these are determined mainly by the background wind systems associated by the atmospheric boundary layer (ABL). The study was carried out by computational fluid dynamics model to mimic the internal ventilation scenario in an opencast mine due to the presence of ABL. Further, the model was used to study the dispersion and deposition of fugitive dust generated during blasting operations. The paths of the dust particles were modeled using Lagrangian particle tracking. Most of the models have been developed by using Gaussian plume method to predict dust from sources over a flat or undulating terrain. But, complex flow regimes exist inside the quarry due to the action of ABL, thermal buoyancy forces and thermal temperature inversions.

Figure 2.5 depicts a comparison of the actual dust dispersion within a mine with Gaussian plume model and CFD models.

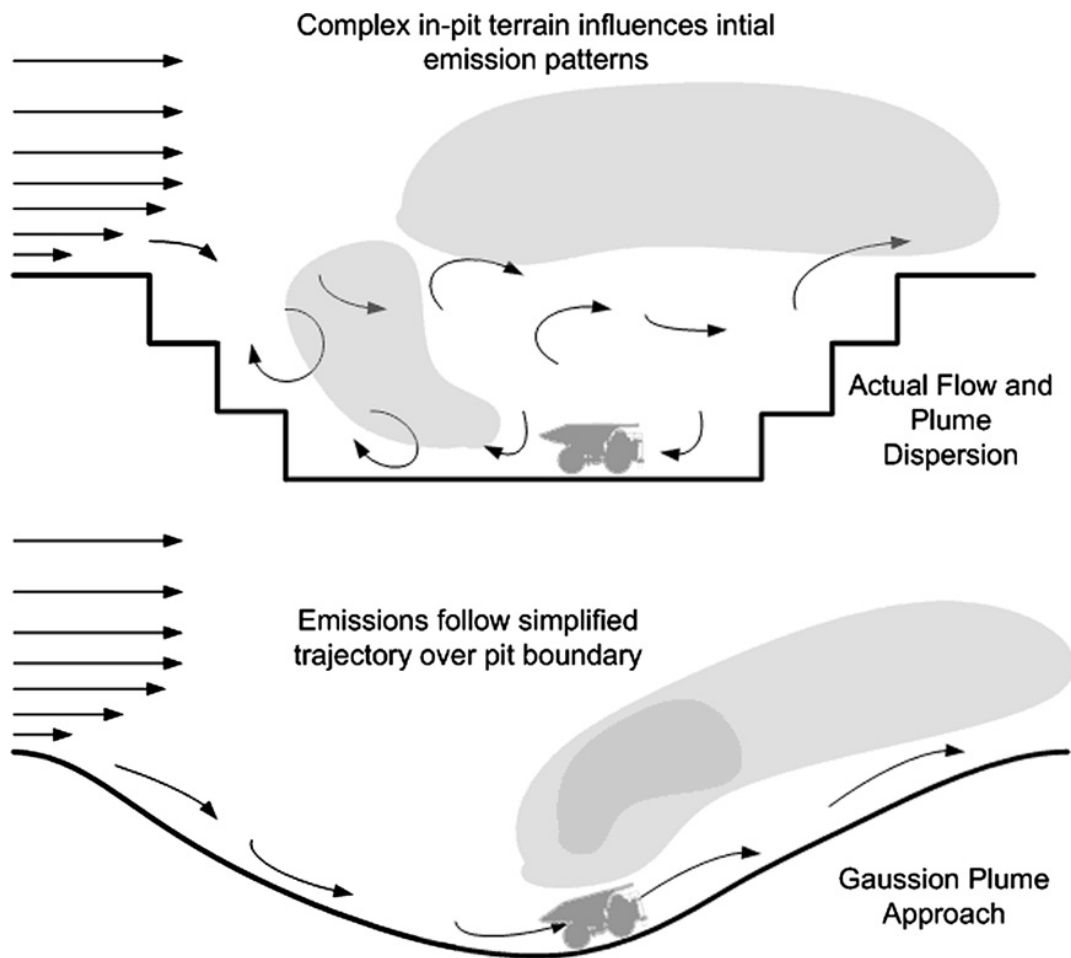


Figure 2.5 A comparison of the actual dust dispersion within a mine with Gaussian plume and CFD models (adapted from Lowndes et al. 2008)

However, these models are not able to predict dust concentration in the atmosphere as close as to the real field values in mining industry (Cole and Zapert, 1995).

In addition, Industrial Source Complex Short Term (ISCST3) model is a versatile steady-state Gaussian plume model designed to evaluate pollutant concentrations emanating from diverse sources within an industrial complex. The input data for model are user source dimensions such as emission rate, wind speed, wind direction, ambient air temperature, mixing height, stability class, and receptor coordinates (Anon, 1995). The dust concentration can be arrived by using Eq. (4).

$$X = \frac{QKVD}{2\pi u_s \sigma_y \sigma_z} \exp \left[-0.5 \left(\frac{y}{\sigma_y} \right)^2 \right] \quad (2.4)$$

where,

X = Concentration ($\mu\text{g}/\text{m}^3$)

Q = Pollutant emission rate (g/s)

K = 10,00,000 default value

D = Decay term (dimensionless)

V = Vertical term (dimensionless)

σ_y & σ_z = Standard deviation of lateral & vertical concentration distribution

u_s = Mean wind speed (m/s)

y = Crosswind distance from source to receptor (m)

Palanivelraja et al. (2008) assessed the performance of the USEPA-ISCST3 model in predicting short-term SO₂ concentrations within the ambient environment surrounding the Neyveli Lignite Corporation (NLC) Complex. The results suggest that the ISCST3 model overestimated the eight-hour average SO₂ concentrations. Similarly, ISCST3 was applied to test three Georgia stone quarries based on data obtained by the U.S. Department of Energy's Hanford, WA, site. It was reported that the model was over predicting the particulate concentrations (Cole and Zapert, 1995).

CALPUFF, another integrated Lagrangian puff modeling system has been adopted by the U.S. Environmental Protection Agency for assessing long range transport of pollutants and their impacts.

CALPUFF is one of the most versatile and most applied Lagrangian puff models used in recent years (Hernández-Garces et al. 2016). It is a multi-layer, multi-species non-steady-state puff dispersion model that simulates the effects of time and space with varying meteorological conditions. However, it lacks the realistic assessment of impacts within short distances within 50 km than that of models such as AERMOD.

AERMOD (American Meteorology Society / Environment Protection Agency Regulatory Model) is a steady state model that assumes a plume of emissions disperses in the horizontal and vertical directions resulting in Gaussian distributions. AERMOD simulates transport and dispersion from multiple points, area or volume sources based on an up-to-date characterization of the atmospheric boundary layer.

The general equation of AERMOD dispersion model is given in Eq. (5).

$$C_T \{X_r, Y_r, Z_r\} = f \cdot C_{c,s}\{X_r, Y_r, Z_r\} + (1-f) C_{c,s} \{X_r, Y_r, Z_p\} \quad (2.5)$$

where,

$C_T \{X_r, Y_r, Z_r\}$ = total concentration ($\mu\text{g}/\text{m}^3$)

f = plume state weighting function ($\mu\text{g}/\text{m}^3$)

$C_{c,s}\{X_r, Y_r, Z_r\}$ = contribution from the horizontal plume state

(subscripts c and s refer to convective and stable conditions respectively) ($\mu\text{g}/\text{m}^3$)

$\{X_r, Y_r, Z_r\}$ = Receptor coordinates (m)

Z_p = Receptor height above local ground (m)

Z_t = Local terrain height (m)

f = Weighting factor

One of the limitations of AERMOD is that users must provide estimates for initial plume dimensions representing mechanical turbulence. Additionally, the model itself doesn't calculate thermal plume rise. AERMOD proved particularly sensitive to changes in surface roughness when values were below 0.5 m and to wind speed when values were below 10 m/sec. Maximum concentrations predicted by AERMOD and ISCST3 correlated well when wind speeds exceeded 5 m/sec but diverged rapidly as wind speed decreased, with AERMOD predicting much higher maximum concentrations than ISCST3 in low wind conditions.

AERMOD has been found to be more reliable than ISCST3 in various studies (Tseng 2015). It has been evaluated on diverse databases and found to perform well in different terrains and land uses. AERMOD's theoretical basis is considered stronger than ISCST3, and its simulation is more reliable (Tseng 2015).

Traditional deterministic models tend to struggle to capture the non-linear relationship between the concentration of air pollutants and their sources of emission and dispersion. To tackle such a limitation, the most promising approach is to use statistical models based on machine learning techniques (Rybarczyk et al. 2018).

A number of studies have explored the use of machine learning techniques in environmental data analysis, specifically in air pollution and particulate matter due to opencast mining. ML algorithms can help to analyze large datasets, identify patterns and make predictions, which are valuable in understanding and mitigating environmental issues like air pollution connected to opencast mines.

Machine learning is a branch of Artificial Intelligence (AI) and computer science which focuses on the use of data and algorithms to imitate the way that humans learn, gradually improving its accuracy by itself. Bellinger (2017) and Kanevski (2004) have highlighted the potential of machine learning in this field. Bellinger specifically noted the application of deep learning and geo-spatial pattern mining. Lal (2012) and Hospedales (2009) provided more specific examples, with Lal using artificial neural networks to predict dust concentration in opencast coal mines and Hospedales introducing a Markov Clustering Topic Model for behavior mining in video data.

These studies collectively underscore the significance of machine learning in addressing environmental challenges, including those related to opencast mining and particulate matter.

2.3 Dispersion of Particulate Matter

Many studies have been conducted on dispersion of particulate matter based on mathematical models but very few have evaluated with testing at mine sites (Bhaskar and Ramani, 1988; Reed et al. 2002; Silvester et al. 2009).

Studies have been conducted on PM emissions due to various mining operations such as drilling, blasting, loading, transportation and unloading (Tripathy et al. 2015). The dust generation from various operations in an opencast coal mine is depicted in Figure 2.6.



Figure 2.6 Different sources of dust from opencast mining operations

The preliminary objective of such studies was to assess the PM from specific mining operation. However, many of the studies have been focusing on a single activity. For example, Silvester et al. (2009) studied the particulate dispersion due to blasting using CFD model. These techniques are used for isolated buildings and wind tunnels (Chavez et al. (2011), Hazra and Stathopoulos, (2012) and hence are suitable for analyzing quarry area or building recirculation. Similarly, Badr and Harion (2007) carried out studies as prediction of particulate matter due to stock piles in an opencast.

The dispersion equations developed within the pit boundary provide a reasonable accurate estimate of PM_{10} dispersion within the near field of the deep OC coal mines (Silvester et al. 2009; Sumanth et al. 2021).

Pit dimensions also play a significant role in PM concentrations. Some studies were conducted to estimate the particulate matter level inside the mine and understanding its dispersion as they travel from source to the surface. An empirical relationship between the PM concentration and depth of the mine was also proposed (Gautam et al. 2015). Studies have shown that PM concentration tends to decrease with increasing distance from the source within the mine. PM concentration exhibits a decreasing trend with increasing elevation ranging from the pit bottom (412 mRL) to the higher level (580 mRL) as shown in Figure 2.7.

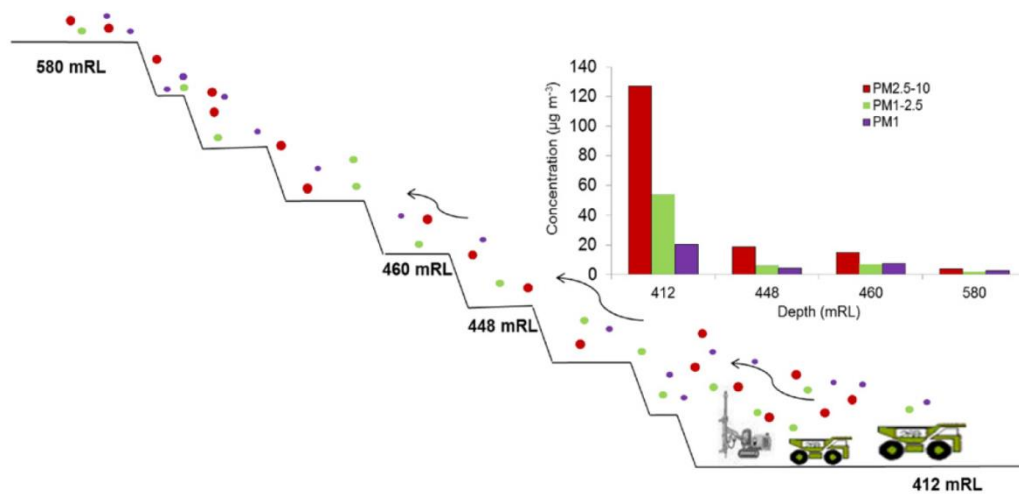


Figure 2.7 Concentration of PM with respect to depth of the mine (Gautam et al. 2015)

The environmental fabric of villages around opencast mines is rapidly deteriorating with increased production of coal (Mishra et al. 2017).

Assessment of air quality monitoring data showed significant spatial and seasonal variations in concentrations of PM depending on pollutant emission or formation and pollutant dispersion mechanisms, which are also influenced by meteorological conditions.

Wind speed, relative humidity, temperature and rainfall were the governing parameters of seasonal variations in air pollutant concentrations in the area (Bhanu et al. 2014).

Site specific factors including topography and meteorological conditions influence PM concentration as evidenced by pollutant dispersion mechanisms (Charron and Harrison 2005).

CALPUFF and AERMOD models have been approved by the US Environmental Protection Agency (USEPA) and can deal with deposition of pollutants. AERMOD is based on a simple Gaussian Algorithm which is able to predict dust concentration up to a distance of 50 km (Tartakovsky et al. 2013). However, it is stated that AERMOD is not suitable for calm conditions (Neshuku 2012). CALPUFF is a non-steady state Lagrangian-Gaussian model but the results tended to over predict the PM₁₀ values when applied to large surface mine (Fishwick et al. 2011). National Pollutant Inventory (NPI) emission estimation methods commonly adopted in Australia have been criticized for inaccuracy and for providing inconsistent data for major sources of emissions (Cooper et al. 2017).

Sastry et al. (2015) developed a regression model to estimate dust dispersion from drilling operations in an opencast mine. The study concluded that the proposed model is more accurate than the one used by the USEPA. Patra et al. (2015) used Levenberg Marquardt learning algorithm and meteorological parameters to predict PM in Malanjkhand copper mine. Nagesha et al. (2016) predicted dust concentrations due to drilling in opencast mines using multiple regression and compared to experimental models. It was indicated that the accuracy of statistical model is higher than the empirical model.

Ratnesh et al. (2008) studied the sources of dust generation and quantified dust emission rates from point, area and line sources at one of the opencast coal mines in Western Coalfields Limited. Studies were carried out for air quality modeling by fugitive dust model which revealed that the dust generated from different activities in the opencast does not contribute to ambient air quality in surrounding areas beyond 500m under normal meteorological conditions. Based on the study, mitigations measures have been suggested including green belt design. Variation between the measured and predicted values using FDM is given in Figure 2.8.

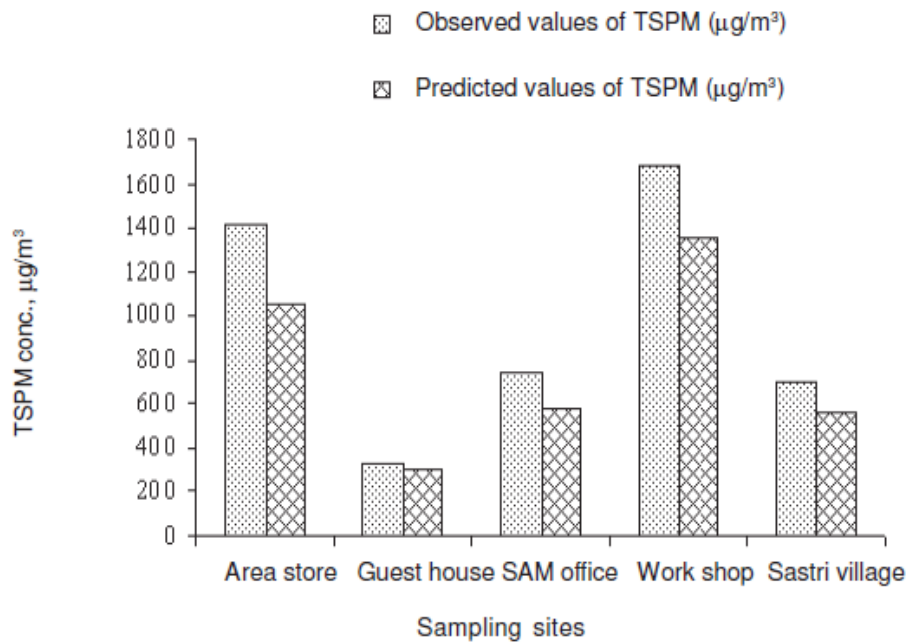


Figure 2.8 Comparison between observed values and values of TSPM (Ratnesh et al. 2008)

Similarly, reduction in TSPM (Total Suspended Particulate Matter) with distance from the source is given in Figure 2.9.

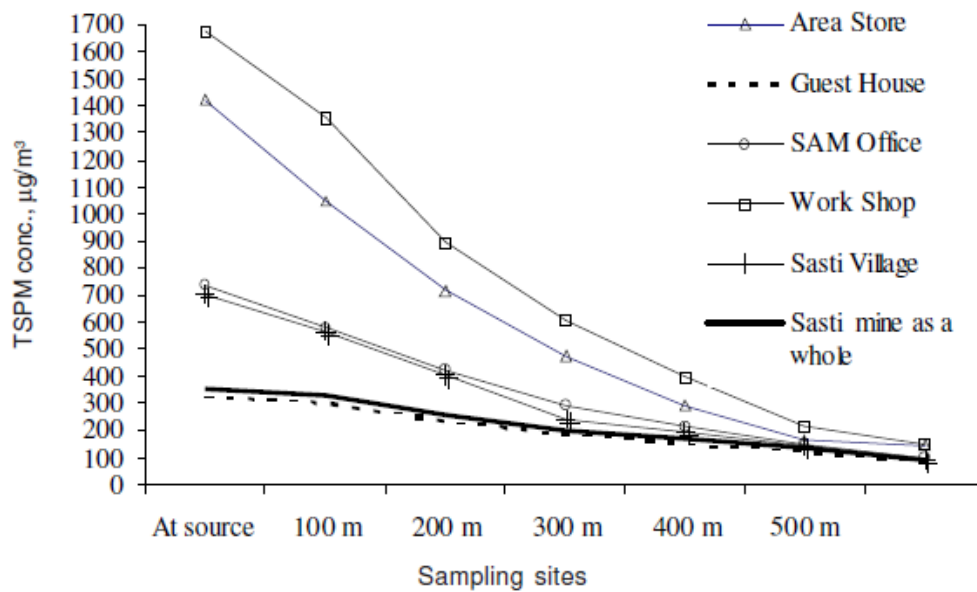


Figure 2.9 Relation of TSPM concentration with distance from sampling sites (Ratnesh et al. 2008)

2.4 Silt and Moisture Content

Air quality management is a complex process due to wide range of factors highly variable in nature in terms of silt and moisture contents. PM₁₀ emissions depend on soil composition like soil texture and PM₁₀ emissions increase with silt and clay contents and decrease with sand contents (USEPA, 1995; Carvacho et al. 2004). The dispersion from the quarry having different rock layers under extraction influences the quality and quantity of PM.

To compute PM emission factors, various input parameters are necessary, including moisture levels, silt content, wind speed, area dimensions, drop height, etc. (Sneha et al. 2016). These formulae provide estimates of emission factors for specific mining scenarios. They are based on empirical data and are suitable when applied to situations with similar mine geometry and meteorological conditions. Therefore, these relationships may not hold true in general for different mining operations. For example, in the case of estimating haul road emissions, while the emission rate showed some correlation with factors like silt content, vehicle speed, and vehicle weight, further analysis revealed that this empirical relationship could result in underestimation or overestimation of emissions by an order of magnitude (Chaulya 2006; Chaulya et al. 2002).

Soils can emit dust within a specific range of moisture, but even a slight increase in soil moisture reduces dust emissions significantly (Funk et al. 2008). Soils of the same textural class may release significantly different amounts of dust (Gill et al. 1999; Alfaro 2008). It was considered that differences in PM₁₀ values are due to differences in organic matter content, aggregates size distribution and stability.

A study was conducted by Aimar et al, (2012) to evaluate the effect of soil texture, organic matter contents and soil moisture on PM₁₀ dispersion from sandy soils. The studies concluded that moisture had a negative effect and silt a positive effect on PM₁₀ concentrations.

2.5 PM_{2.5}/PM₁₀ Ratio

PM is usually divided and nominated by its aerodynamic diameter, and the most widely monitored particles are PM₁₀ and PM_{2.5}, which refer to particles with aerodynamic diameter less than or equal to 10 or 2.5 micrometers, respectively (Nel 2005). Fine particles (PM_{2.5}) and coarse particles (PM_{2.5-10}) are generally produced by different sources, so the PM_{2.5}/PM₁₀ ratio reveals characteristics of particle pollution. A size comparison of PM is given in Figure 2.10.

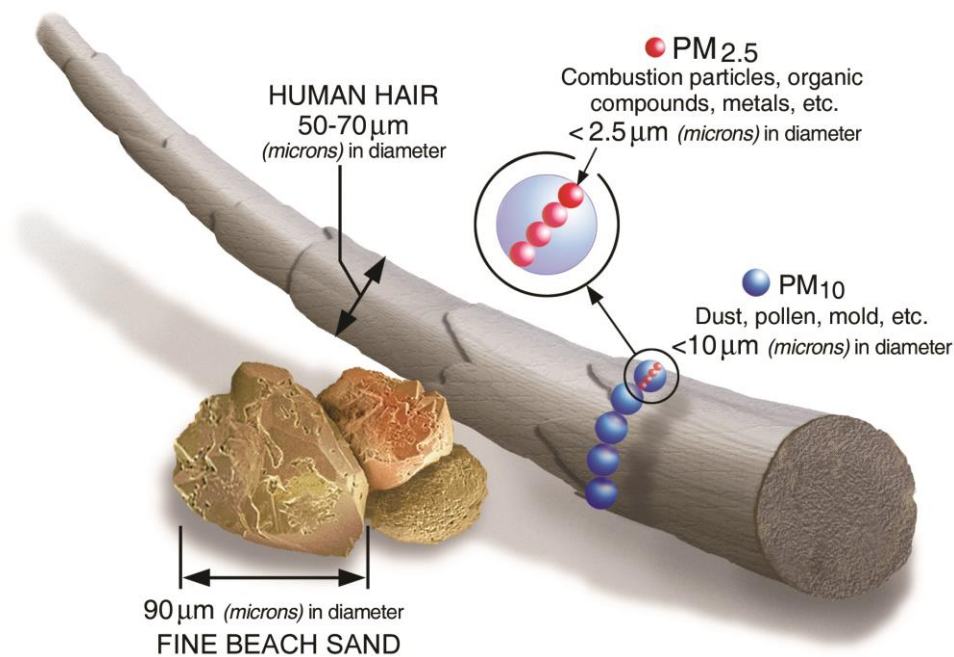


Figure 2.10 PM size comparison (Xayasouk et al. 2020)

The ratio of PM_{2.5} to PM₁₀ is a valuable indicator for understanding source identification, health impact assessment and for air quality monitoring. A high PM_{2.5}/PM₁₀ ratio indicates a dominance of fine particles which typically come from combustion sources like vehicle emissions, industrial process and coal burning. These sources are particularly due to combustion. Conversely, a low ratio indicates coarse particles are more prevalent which originate from mechanical processes like crushing and grinding operations, dust storms and resuspension of road dust.

PM_{2.5} poses a greater health risk due to its smaller size which can penetrate deep in to the lungs, aggravating respiratory problems whereas high ratio suggests a potentially greater risk of adverse health effects. The PM_{2.5}/PM₁₀ ratio is a useful tool for air quality monitoring. By tracking trends in the ratio, one can identify the changes in pollution sources and assess the effectiveness of air quality control measures. For instance, a rise in the ratio might indicate increased traffic congestion or industrial activity. Overall, the PM_{2.5}/PM₁₀ ratio provides a quick and informative way to gauge air quality, pinpoint pollution sources, and estimate potential health risks associated with particulate matter exposure.

Studies on opencast mines have found that they are significant sources of PM_{2.5} and PM₁₀ emissions, with PM_{2.5} levels often exceeding permissible limits (Gautam 2016). These emissions are influenced by the type of substrate, with lignite and lignite-containing substrates emitting higher amounts of PM₁₀ and PM_{2.5} (Funk 2019). The dispersion of particulate matter within opencast mines is also a concern, with deeper mines generating more coarse particles during mining activities (Gautam 2015).

Wang et al. (2008) concluded that the major constituents of PM_{2.5} in Beijing included black carbon, crustal elements, nitrates, ammonium salts, and sulfates, which accounted for 20%-80% of the total PM_{2.5}. Similarly, coal combustion was identified as the largest contributor to PM_{2.5} in Beijing, accounting for 16.6% of the total PM_{2.5} and soil dust was found to be the most significant contributor to PM₁₀ at the Beijing site, with a percentage of 27%.

Since different sizes of PM originate from different sources, the PM_{2.5}/PM₁₀ ratio could be used for identifying their sources (Chan et al. 2008). The ratio can be used to characterize the underlying atmospheric processes and evaluate historical PM_{2.5} pollution in absence of direct measurements. A higher ratio means the overwhelming contribution from PM_{2.5}, which is generally ascribed to primary pollution by anthropogenic activities and secondary particulate formation such as NO₃, SO₄ and NH₄, while a lower ratio is mainly contributed to fugitive dust or sand dust from long-distance transport (Yue et al. 2010).

Figure 2.11 shows the size distribution of various types of airborne dust particles in micrometers. Air borne particles are generally contaminants, particulate matter, gaseous contaminants or dust.

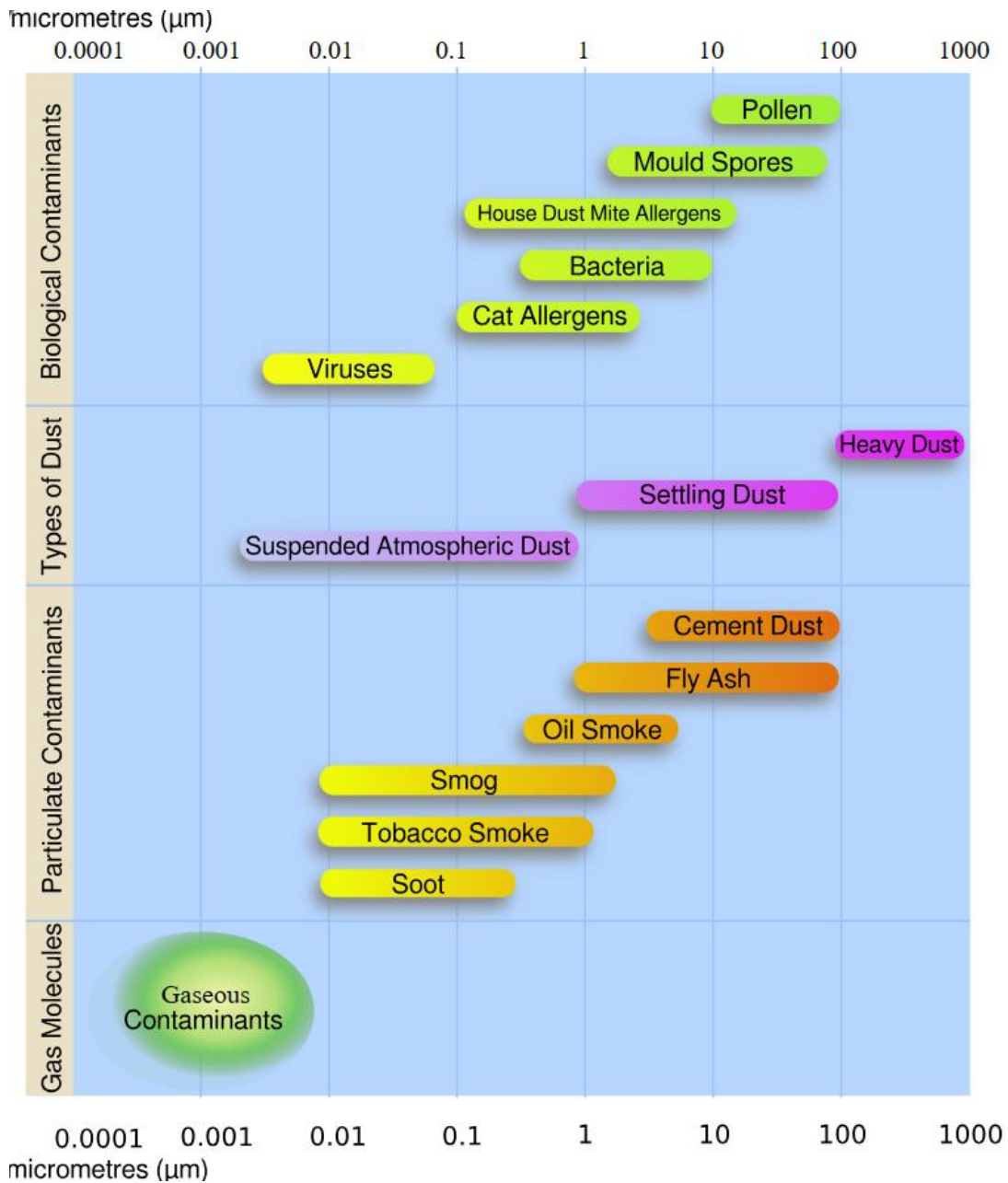


Figure 2.11 Air borne particulate size chart

Source: <https://en.m.wikipedia.org/wiki/File:Airborne-particulate-size-chart.svg>

Furthermore, $PM_{2.5}/PM_{10}$ ratio can help to identify the major pollutants which assist the regulatory bodies to implement separate regulations to reduce emissions instead of focusing on controlling only one parameter. It is important to note that there is significant heterogeneity in the $PM_{2.5}/PM_{10}$ ratio across different regions, as the ratio varies from site to site (Munir et al. 2017).

Gulnur et al. (2018) carried out studies on $PM_{2.5}/PM_{10}$ ratio and its relationship with meteorological parameters in Bahrain. A scatter plot of $PM_{2.5}$ versus PM_{10} was drawn using monthly mean data from the year 2006 to 2012. Figure 2.12 shows the scatter plot in which red color represents high ratios higher than 0.8 indicating dominance of fine particles, green color moderate ratios between 0.2 and 0.8 indicating fair distribution of PM whereas, blue color refers to the ratios lower than 0.2 indicating PM originating from natural sandstorms over deserts and re-suspension of dust.

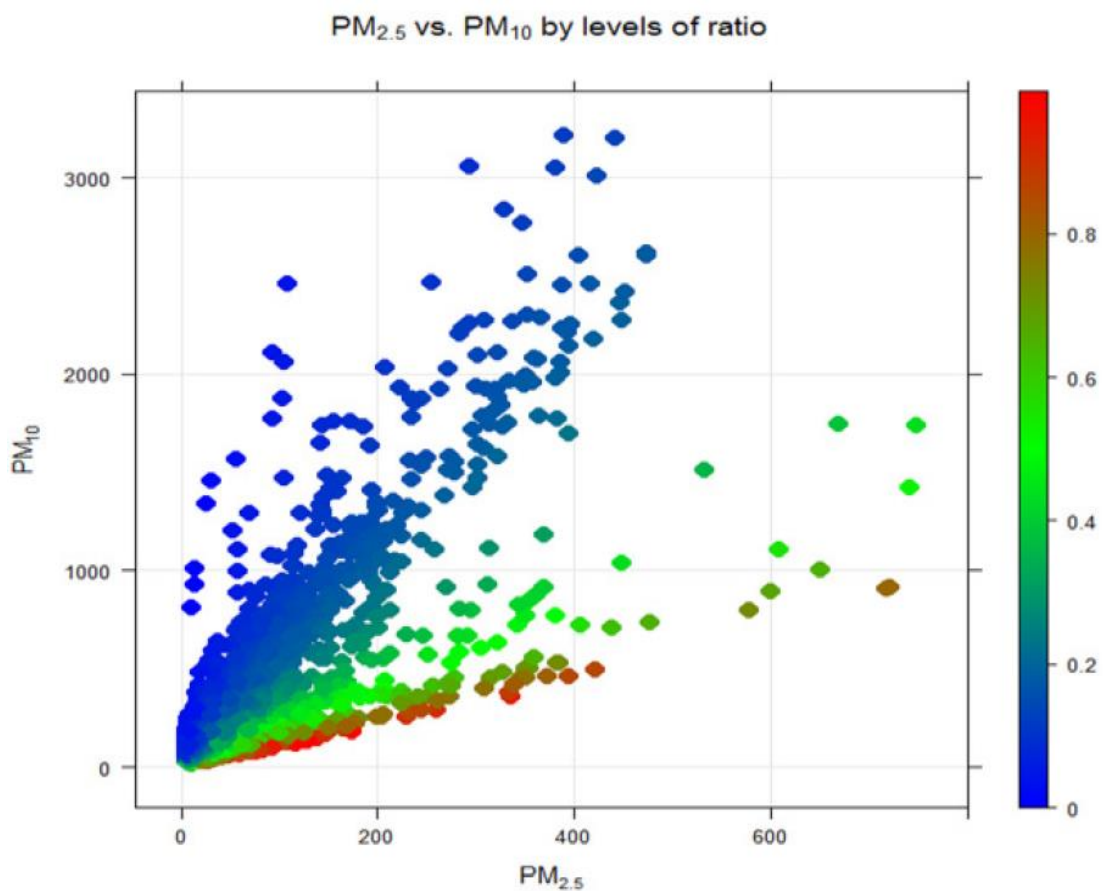


Figure 2.12 Scatter plots of PM₁₀ versus PM_{2.5} using monthly mean data from 2006 to 2012 (Gulnur et al. 2018)

2.6 Machine Learning Techniques

Estimating PM dispersion has been a long-standing challenge for environmental and health researchers as well as for mine management for taking necessary preventive measures. Several contributors like spatial variability, temporal variability, exposure pathways, etc., contribute to this challenge. Addressing these challenges require use of dispersion modeling, machine learning, remote sensing along with improved monitoring networks and data integration efforts.

Machine learning offers several advantages over traditional multivariate regression techniques, particularly in complex datasets. Some of the advantages include flexibility in handling non-linear relationships, relevant feature selection from the dataset thus eliminating the need for manual feature selection, which is often required in multivariate regression. Machine learning algorithms can automate the model building process thus saving time and effort unlike regression.

Different researchers have developed various statistical techniques using multiple regression, artificial neural networks (ANN) and machine learning techniques to analyze the data for better forecasting. ANN show better particle forecasting performance when compared to regression models due to better adaptation ability on fitting data to analyze non-linear physical processes (Paschalidou et al. 2011). ANNs are a subset of machine learning algorithms. ML is a broad field that encompasses a variety of algorithms and techniques used to teach computers to learn the data without explicitly programmed. It includes ANNs as well as other methods like decision trees, support vector machines, and clustering algorithms. ANNs are highly flexible and can model complex relationships in data but they are often considered less interpretable compared to RF where it can provide measures of feature importance that help to understand the contributions of different variables to the predictions. Furthermore, RF is known for its robustness and ability to handle noisy data and outliers. It can also perform well with relatively small datasets and is less prone to overfitting compared to ANNs.

In a study conducted by Doreswamy et al. (2020) on forecasting of PM_{2.5} using machine learning regression models viz., gradient boosting (GBM) regression was examined with models like linear regression, lasso regression, ridge regression, random forest (RF) regression, K-neighbors (KNN) regression, multilayer perceptron (MLP) regression, and decision tree regression. The results showed that RF and GBM values are varying slightly.

Danesh Yazdi et al. (2020) have created a prediction model for PM_{2.5} levels using three different machine learning approaches viz., random forest (RF), gradient boosting machine (GBM), and k-nearest neighbor (KNN) approach. It was concluded that the RF outperformed the GBM and KNN.

The model was adept for predicting daily PM_{2.5} changes with temporal R² of 0.882. But the ability to predict spatial variability was weaker due to smaller spatial variation in pollutant levels in the area.

Jirat et al. (2019) carried out studies to estimate a likelihood of PM_{2.5} exceeding a predefined safety threshold. Different machine learning models like Naïve Bays, Logistic Regression, Random Forest and Neural Networks have been used to predict the likelihood of PM_{2.5} exceeding the healthy threshold.

To evaluate the performance of the models, traditional metrics such as a confusion matrix and F1-score are utilized. A higher F1 score indicates better performance, with a maximum value of 1 indicating perfect precision and recall, and a minimum value of 0 indicating poor performance. It was concluded that the Random forest model provided the best performance with 0.82 F1 score.

Random Forest (RF) is a widely used supervised learning algorithm excelling in both classification and regression tasks. RF leverages the power of ensemble learning, where numerous decision trees (models) are constructed and combined. The block diagram of data process is given in Figure 2.13.

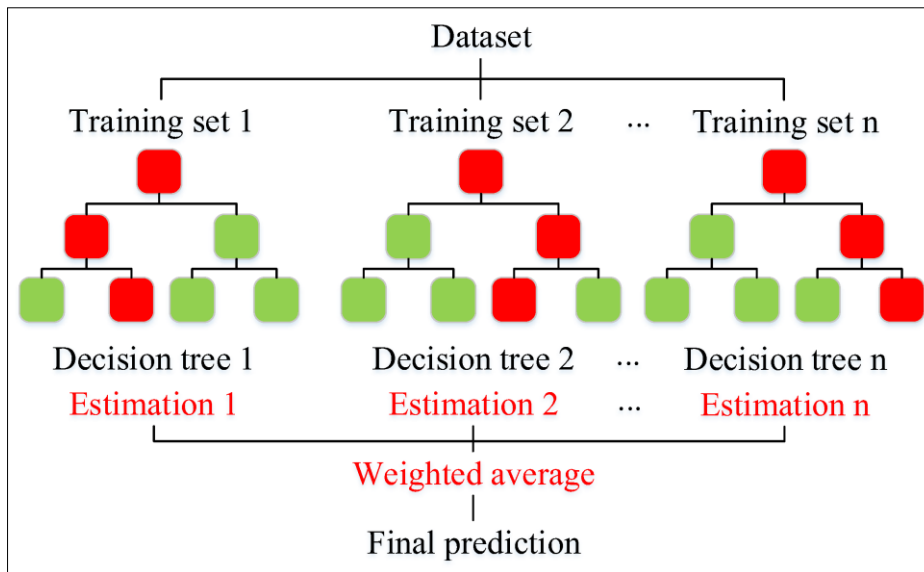


Figure 2.13 Schematic diagram of Random forest

Each tree forecasts a separate outcome, and the final prediction is derived by aggregating these individual forecasts (e.g., majority vote for classification, average for regression).

Random Forest is a powerful and versatile algorithm that is widely used in practice due to its simplicity and effectiveness in handling a variety of machine learning tasks.

2.7 Summary

Literature has been thoroughly reviewed based on the previous researchers work on development of dust prediction models. The researchers have primarily focused on a single source of pollution viz., drilling, transportation within the mine boundary using different mathematical models. Traditional models tend to struggle to capture the non-linear relationship between the concentration of air pollutants and their sources of emission and dispersion. Even where the estimation methods are applied in mines in the country for which they were developed, the uncertainties can be large. The same empirical formulae cannot be considered for all Indian mines. Statistical data analysis combined with machine learning techniques yields a better prediction model. Hence, historical data collected from the mines has been analyzed and processed using different machine learning techniques in order to develop the best dust prediction model.

CHAPTER 3

CHAPTER 3

3. FIELD INVESTIGATIONS

This chapter gives the details of field investigations involving collection and monitoring of diverse historical datasets from 6 opencast mines related to mine parameters, meteorological data and particulate matter measurements. These 6 mines belonging to M/s Singareni Collieries Company Limited (SCCL), the largest coal producing company in South India, are spread over 350 km along the Godavari Valley Coal Field (GVCF). The data pertaining to mining parameters like production, area, height of over burden dump, quarry depth and lead distance have been compiled from the working plans. Similarly, data pertaining to PM₁₀ and PM_{2.5} has been collected from the equipment installed in and around the mines and also monitored over a period. Furthermore, the meteorological data has been collected from the micro-meteorological stations installed near the mines. The collected and monitored data has been processed for development of dust prediction models using machine learning techniques.

3.1 Opencast Mine Parameters

The data pertaining to the following mine parameters has been collected from six opencast mines for a period of 10 years from 2012 to 2022:

a. Quantity of coal produced and overburden extracted

The quantity of coal extracted and overburden removed in tonnes has been collected on the dates of PM monitoring.

b. Effective area contributing to pollution

The total project area of an opencast coal mine may not be the source of pollution. Some of the areas may be highly contributing to pollution, some areas may be medium and some may not contribute at all or may not be significant. Accordingly, the total area of the project is classified in to different areas like quarry area, dumping area, infrastructure area consisting of office buildings, CHP, workshop, roads, etc., other area like undisturbed area, reclaimed area, etc.

Quarry area, dump area and infrastructure area are the sources of air pollution due to mining activities whereas undisturbed and reclaimed areas are not considered as sources of pollution. The undisturbed areas are those where mining operations are yet to start which is virgin. The reclaimed areas are those areas where technical and biological reclamation of overburden dumps have been done. Technical reclamation involves leveling, sloping, stabilizing and compaction of dumps, spreading of top soil and biological reclamation involves planting of saplings on the spread top soil. As such, the net effective area contributing to pollution is arrived by summing up the quarry area, dump area and infrastructure area and then subtracting the undisturbed and reclaimed areas.

c. Quarry depth

Coal extraction in an opencast mine typically begins near the surface at the outcrop. As mining operations progress, the depth of quarry increases due to the natural inclination (dip) of the coal seam, leading to deeper excavation.

To determine the evolving depth of the quarry over time, a comprehensive review of year-wise mining plans has been conducted. Contour plans have been studied and the difference between the surface reduced level (RL) to the bottom most RL has been calculated to arrive at the quarry depth in each year.

Instead of considering the width and length of the quarry, the **area** of quarry has been considered as a factor contributing to pollution and the change in temporal areas of quarry has been obtained from the year-wise working plans.

By analyzing these historical data, a detailed understanding of the quarry's development and current depth has been achieved.

d. Overburden dump height

As the mine progresses, the quantity of overburden removal increases thereby increasing the height of dump in order to optimize the land requirement for dumping. The yearly dump heights have been obtained from the year-wise working plans of the mines by calculating the difference in RLs between the ground level and top of overburden dump. However, the quantity of overburden handled annually is covered under production.

e. Lead distance

The distance of transportation of overburden material from the loading point to the dumping point is the lead distance. The lead distance includes both the transport in the quarry and on the overburden dump. This distance varies over time because initially, the dumping will be carried over external dump and the depth of quarry is shallow. This distance gradually increases as the depth of the quarry and dump height increases. However, as coal extraction continues and the quarry deepens, internal filling or backfilling within the depleted quarry area begins, which reduces the lead distance.

The haul roads are constructed using the overburden material and stabilized. Additionally, any undulations caused by machinery movement are levelled using dozers and graders. Regular water sprinkling is being done using water sprinklers of 10 KL to 28 KL capacity.

The dumpers of 60 t capacity travels at a speed of 40 kmph and as there will be no much variation, it is not included in the model.

3.2 Meteorological Data

Meteorological data pertaining to six projects for 10 years from 2012 to 2022 has been collected for the following parameters:

- a. Predominant wind direction
- b. Average temperature
- c. Average humidity
- d. Average rainfall
- e. Average wind speed

The meteorological data has been collected using micro-meteorological station. Data pertaining to meteorological conditions existing in the surrounding area is collected once in a fortnight from a standard WM271 system as shown in Figure 3.1 which is supported with sensors for Wind Speed, Wind Direction, Temperature, Relative Humidity and Rainfall.

Specifications of Meteorological Monitoring Station (WM271):

Wind Speed : Range 0 to 100 km/hour

Wind Direction: Range 0 to 360⁰ with 1⁰ resolution

Temperature : Range 0 to 50⁰C with resolution of 0.1⁰C

RH : 0 to 100% RH with 1% resolution

Rainfall: Range 0 to 50 mm/hour with 0.5mm resolution

Data Access: Built-in firmware supports land-line and GSM

Modems for remote data access. The WM271 can also be interfaced directly to a standard RS232 port (COM port) of a computer for data transfer.

Software: Windows XP compatible, Envirotech Met-Log software is

provided with the WM 271 for data download to a computer.

Power requirement: The WM 271 is powered by a Rechargeable Ni-MH battery

pack that can keep the system operating for about 20 hours. The standard system is supplied with a main power-based Charger.

An optional Solar Panel based charger is available as an accessory.

The meteorological data has been monitored on hourly basis continuously throughout the study period. However, the daily average values corresponding to the dates of ambient air quality monitoring have been taken into consideration for analysis.



Figure 3.1 Micro-meteorological station

3.3 Particulate Matter

PM₁₀ and PM_{2.5} have been collected in the core and buffer zones of the Project area. Ministry of Environment, Forest & Climate Change, Government of India released Environment Impact Assessment (EIA) Guidance Manual 2010 with respect to mining of minerals in accordance with EIA Notification 2006, wherein the core and buffer zones have been defined. According to this, core zone is the mine lease area and the buffer zone is the 10 km radius from the boundary limits of the mine lease area. Two monitoring stations are selected in the core zone (within the mine boundary) i.e., one at the Coal Handling Plant (CHP) and the other at the Base Workshop (BWS). Similarly, 4 stations in the buffer zone (within 10 km from the mine boundary) near the villages are selected covering all the four directions so that the dust dispersed in all the directions from the mine can be monitored. The PM₁₀ and PM_{2.5} monitoring was done using Respirable and Fine dust samplers respectively.

The PM monitoring has been carried out at a standard frequency of once in a fortnight as per Central Pollution Control Board (CPCB) guidelines. The Coal Mines Standards and National Ambient Air Quality Standards prescribed by CPCB are given in Appendix I. The equipment has been calibrated once in 6 months in order to ensure accurate measurements.

PM₁₀ samplers work based on the principle of size-selective sampling, where particles with diameters equal to or smaller than 10 micrometers (PM₁₀) are collected onto a filter or other collection media while excluding larger particles. The most commonly used Respirable dust sampler operates according to the following principles:

Inlet system: The sampler is equipped with an inlet system designed to separate and collect particles of specific sizes. The inlet typically includes a size-selective inlet head, such as an impactor or cyclone, which separate the particles larger than 10 micrometers while allowing smaller particles to pass through.

Airflow control: The sampler maintains a constant and controlled airflow rate of 1.1 l/min and is critical for achieving accurate and representative sampling results. The sampler is equipped with a flow measurement device to monitor and adjust the airflow rate. This ensures that the desired flow rate is maintained throughout the sampling period, allowing for accurate quantification of particle concentrations.

Collection media: The collected particles are deposited onto a glass fiber filter paper which serves as the sampling substrate and captures the airborne particles as the air passes through it.

Sampling duration: PM₁₀ samplers are operated for 24 hours during which air is continuously drawn through the inlet and onto the collection media.

Post-sampling analysis: Once the sampling period is complete, the filters are removed from the sampler and transported to laboratory for analysis. The collected particles are typically analyzed using gravimetric techniques, where the mass of particulate matter deposited on the filter is determined by weighing the filter before and after sampling.



Figure 3.2 Respirable dust sampler

The Respirable Dust Sampler shown in Figure 3.2, uses proven orifice plate-based flow metering system. The pressure drop across the orifice is measured by a manometer in which the scale is calibrated in units of flow rate (m³/min). Dust concentration is measured within acceptable range of $\pm 10\%$. The respirable dust standard set by the Central Pollution Control Board recommends a 10-micron cut-off size for respirable dust measurements.

PM_{2.5} samplers work on a similar principle to PM₁₀ samplers, but they are designed to selectively collect fine particulate matter with a diameter of 2.5 micrometers or smaller. The working principle of PM_{2.5} sampler is as follows:

Inlet system: PM_{2.5} samplers are equipped with an inlet system which typically includes a size-selective inlet head i.e., WINS impactor designed to remove particles larger than 2.5 micrometers and allow smaller particles to enter the sampling system.

Airflow control: The sampler maintains a controlled airflow rate of 16.67 lpm ensuring representative sampling of PM_{2.5} particles from the ambient air. PM_{2.5}

samplers use rotameter for flow measurement to monitor and adjust the airflow rate during sampling.

Collection media: The collected $PM_{2.5}$ particles are deposited onto a Polytetrafluoroethylene filter paper which serves as sampling substrate and captures the fine particles as the air passes through it.

Sampling duration: $PM_{2.5}$ samplers operated for 24 hours during which air is continuously drawn through the inlet and onto the collection media.

The collected $PM_{2.5}$ particles are analyzed using gravimetric techniques, where the mass of particulate matter deposited on the filter is determined by weighing the filter before and after sampling. The mass concentration of $PM_{2.5}$ particles in ambient air is computed by dividing the total mass of collected particles by the total volume of sampled air and is expressed in $\mu g/m^3$.

Thus, $PM_{2.5}$ samplers operate on the principle of size-selective sampling combined with controlled airflow rates and appropriate collection media to accurately measure fine particulate matter concentrations in ambient air. The ambient Fine Dust Sampler is shown in Figure 3.3.



Figure 3.3 Fine dust sampler

3.4 Laboratory Analysis of Silt and Moisture

Silt and moisture content was analyzed in the laboratory for the samples collected along the haul road at different depths of quarry and heights of overburden. All the samples have been carefully packed in zip lock covers and transported to the laboratory for analysis. Collected samples and laboratory analysis are shown in Figure 3.4 & 3.5 respectively. IS 2386-1963 (Part II) procedure is used in determining the silt content in the aggregate by sedimentation method. IS 2386-1963 (Part III) procedure is used in determining the moisture content in the sample.

The sedimentation method for estimating silt content involves suspending an aggregate sample in water, allowing it to settle, and then measuring the depth of settled silt relative to the total depth of the suspension. The silt content is calculated based on the ratio of settled silt depth to the total suspension depth.

For estimating moisture content in the overburden, the samples are crushed to uniform size and the pre-weighed samples are placed in the oven maintained at a temperature of 110⁰C for 2 hours and then the sample is weighed for calculating the moisture.



Figure 3.4 Collection of overburden samples



Figure 3.5 Analysis of samples in the laboratory

3.5 Case Studies

The following mines six opencast coal mining projects of the Singareni Collieries Company Limited located in Godavari Valley Coal Field have been considered as case studies for carrying out field investigations based on data availability, period of operation, expansion in terms of production, closed and operating mines.

- 1) Jalagam Vengal Rao Open Cast (JVR OC)
- 2) Gautham Khani Open Cast (GK OC)
- 3) Ramagundam Open Cast-I (RG OC-I)
- 4) Srirampur Open Cast (SRP OC)
- 5) Bellampalli Open Cast (BPA OC)
- 6) Khairagura Open Cast (KHG OC)

The relative positions of these opencast coal mines considered for the study are given in Figure 3.6.



Figure 3.6 Image showing the relative locations of 6 OC mines considered for the study

3.5.1 Case study I

Jalagam Vengal Rao Open Cast (JVR OC) coal mine has been considered as case study I. The mine is located in Khammam District of Telangana State, operating since 2005. The production capacity of the mine is increased from 2.5 Mt per annum to 5.0 Mt per annum in the project area of 544.81 Ha. The block is located between North Latitude of $17^{\circ}11'28.4''$ and $17^{\circ}12'42.87''$ and East longitude $80^{\circ}46'44.99''$ and $80^{\circ}49'26.53''$ in the Survey of India Topo sheet No. 65-C/16. The mine is being operated with drilling and blasting technology for extraction of coal & overburden and transportation by shovel dumper combination. A view of JVR OC is shown in Figure 3.7.



Figure 3.7 A view of JVR OC coal mine

3.5.1.1 Quantity of coal and overburden removal

The method of extraction of coal and overburden is by drilling and blasting whereas transportation is by shovel dumper combination. The total coal production and overburden removed ranged from 1,236 t per day to 2,04,121 t per day. The quantity of coal extracted and overburden removed on the dates of monitoring are given in Appendix II/Table 1.

3.5.1.2 Effective area in the project contributing to pollution

Plan showing the boundary of the project and other areas like dumping, quarry, and infrastructure is shown in Figure 3.8.

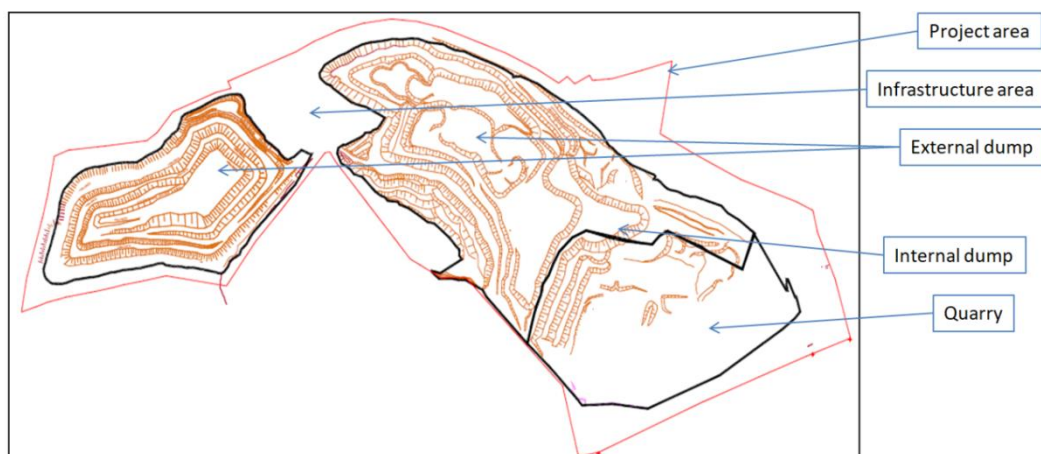


Figure 3.8 Plan of JVR OC

These areas have been derived by processing the year-wise working plans of the opencast mine. The year-wise net effective areas contributing to pollution are furnished in Table 3.1 and the areas on the dates of PM monitoring are given in Appendix II/Table 1.

Table 3.1 Effective area contributing to pollution

Year	Quarry area	Dump area	Infra-structure area	Un disturbed area	Total area	Reclaimed area	Effective area contributing to pollution
	(Ha)	(Ha)	(Ha)	(Ha)	(Ha)	(Ha)	(Ha)
2012-13	89.00	138.00	33.40	274.41	534.81	132.5	127.90
2013-14	105.60	151.00	33.40	244.81	534.81	141.0	149.00
2014-15	120.00	151.00	33.40	230.41	534.81	153.0	151.40
2015-16	127.50	204.77	33.40	169.14	534.81	164.0	201.67
2016-17	160.30	204.77	33.40	136.34	534.81	169.0	229.47
2017-18	101.40	251.25	33.40	148.76	534.81	173.0	213.05
2018-19	104.36	251.25	33.40	145.80	534.81	176.5	212.51
2019-20	104.36	251.25	33.40	145.80	534.81	180.5	208.51
2020-21	104.36	251.25	33.40	145.80	534.81	190.9	198.11
2021-22	104.36	251.25	33.40	145.80	534.81	250.0	139.01

It is evident from the above table that the quarry area and dump area have increased while the other area like vacant area has decreased.

3.5.1.3 Quarry depth

The depth of the quarry increased from 103m to 130m during the years 2012 to 2022. The year-wise maximum depth of the quarry is provided in Appendix II/Table 1.

3.5.1.4 Overburden dump height

The overburden dump height remained 90m from 2012 to 2022. However, the dump area has increased. The year-wise maximum height of the dump is provided in Appendix II/Table 1.

3.5.1.5 Lead Distance

The lead distance has reduced from 4.4km to 2.5km over a period of 10 years from 2012 to 2022, due to back filling. The lead distances of transportation considered for the study are provided in Appendix II/Table 1.

3.5.1.6 Meteorological data

Meteorological data pertaining to temperature, humidity, rainfall, predominant wind direction and wind speed has been collected from the year 2012 to 2022. The daily average temperature varied from 19.3⁰ to 42.6⁰ C, predominant wind direction from 5 to 360 degrees, humidity varied from 25.4% to 100%, rainfall varied from 0 to 74.2mm per day and average wind speed varied from 0 to 18.7m/s. The data has been provided in Appendix II/Table 2.

3.5.1.7 Particulate matter data

Dust monitoring has been carried out as per the Central Pollution Control Board and Ministry of Environment, Forest & Climate Change guidelines. Once in a fortnight data for duration of 24 hours sampling of PM₁₀ and PM_{2.5} has been collected over a period of 10 years from the year 2012 to 2022 and the data has been provided in Appendix II/Table 3. Figure 3.9 shows the mine boundary along with air quality monitoring locations in the core and buffer zones.



Figure 3.9 Image showing the core and buffer locations of JVR OC

The distance from source to the dust monitoring points in buffer zone (villages) of the mine is given in Table 3.2.

Table 3.2 Directions and distances of villages from the mine boundary

Village name	Direction	Distance from meteorological station (m)
Kistaram	NW	750
Pallewada	SW	4500
Venkatapuram	NE	1300
Sathupally	E	1500

The daily average PM_{10} at the CHP varied from 84 to 282 $\mu\text{g}/\text{m}^3$, at BWS from 95 to 260 $\mu\text{g}/\text{m}^3$, at Kistaram varied from 52 to 146 $\mu\text{g}/\text{m}^3$, at Pallewada varied from 40 to 108 $\mu\text{g}/\text{m}^3$, Sathupally varied from 44 to 103 $\mu\text{g}/\text{m}^3$ and Venkatapuram varied from 40 to 119 $\mu\text{g}/\text{m}^3$.

Similarly, the daily average $PM_{2.5}$ in the CHP varied from 30.2 to 93.2 $\mu\text{g}/\text{m}^3$, BWS varied from 29.8 to 71.1 $\mu\text{g}/\text{m}^3$, Kistaram varied from 21.3 to 64.3 $\mu\text{g}/\text{m}^3$, Pallewada varied from 16.5 to 81.8 $\mu\text{g}/\text{m}^3$, Sathupally varied from 18.2 to 80.9 $\mu\text{g}/\text{m}^3$ and Venkatapuram varied from 16.1 to 88.0 $\mu\text{g}/\text{m}^3$.

3.5.1.8 Laboratory analysis of silt and moisture content

Silt and moisture content was analyzed in the laboratory for the samples collected along the haul road at different depths of quarry and heights of overburden. Average silt content of JVR OC is 11.39% and the average moisture content is 4.51%. The details of silt and moisture contents at different locations are given in Appendix-VIII.

3.5.2 Case study-II

Gautham Khani Open Cast (GK OC) coal mine has been considered as case study II. The mine is located in Bhadradi Kothagudem District of Telangana State, operating since 1993. The production capacity of the mine increased from 2.0 Mt per annum to 4.0 Mt per annum in the project area of 902.00 Ha. The block is located between North Latitude of 17°26'18.09" and 17°28'11" and East longitude 80°37'32" and 80°40'2" in the Survey of India Topo sheet No. 65 C/11. The mine is being operated with drilling and blasting technology for extraction of coal & overburden and transportation by shovel dumper combination. A view of GK OC is shown in Figure 3.10.



Figure 3.10 A view of GK OC coal mine

3.5.2.1 Quantity of coal and overburden removal

The total coal production and overburden removed ranged from 8,390 t per day to 1,48,682 t per day. The quantity of coal extracted and overburden removed on the dates of monitoring are provided in Appendix III/Table 1.

3.5.2.2 Effective area in the project contributing to pollution

Plan showing the project area and other areas like dumping, quarry, and infrastructure is shown in Figure 3.11.

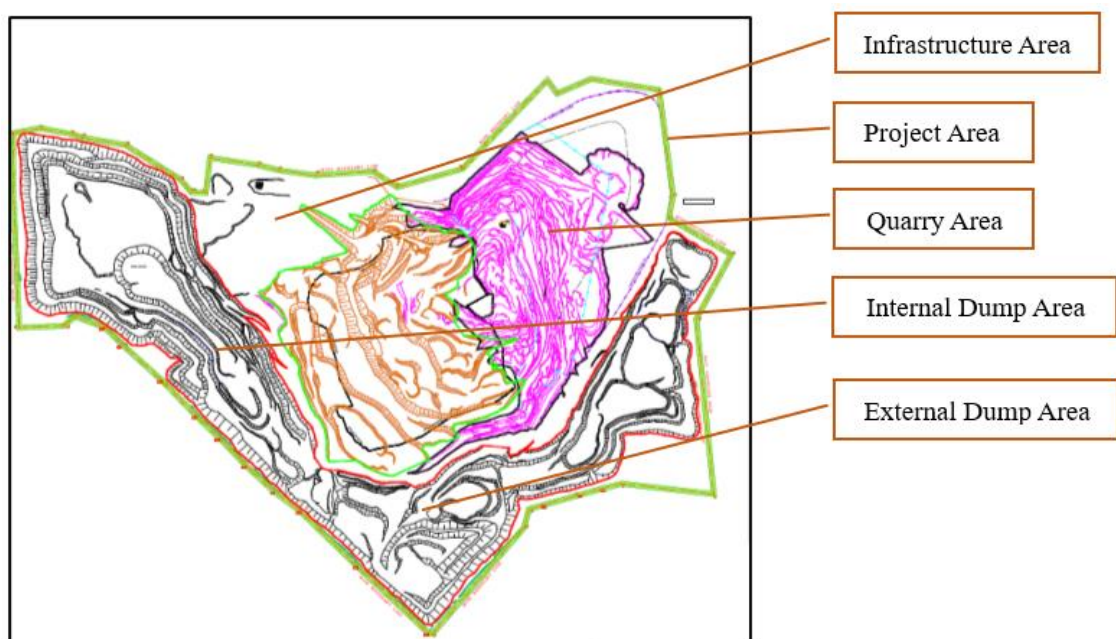


Figure 3.11 Plan of GK OC

These areas have been derived by processing the year-wise working plans of the opencast mine. The year-wise net effective areas contributing to pollution is furnished in Table 3.3 and the areas on the dates of PM monitoring are given in Appendix III/Table 1.

Table 3.3 Effective area contributing to pollution

Year	Quarry area	Dump area	Infra-structure area	Undisturbed area	Total area	Reclaimed area	Effective area contributing to pollution
	(Ha)	(Ha)	(Ha)	(Ha)	(Ha)	(Ha)	(Ha)
2012-13	308.54	355.85	71.14	166.47	902.00	395.50	340.03
2013-14	255.32	384.96	71.14	162.18	902.00	428.00	311.82
2014-15	233.09	413.36	71.14	169.80	902.00	440.00	292.20
2015-16	245.83	427.97	71.14	157.06	902.00	452.00	292.94
2016-17	243.68	447.85	71.14	139.33	902.00	476.00	286.67
2017-18	222.29	476.80	71.14	131.77	902.00	488.00	282.23
2018-19	199.17	488.30	71.14	143.39	902.00	538.00	220.61
2019-20	146.02	488.30	71.14	196.54	902.00	538.00	167.46
2020-21	115.34	488.30	71.14	227.22	902.00	538.00	136.78
2021-22	100.39	488.30	71.14	242.17	902.00	538.00	121.83

3.5.2.3 Quarry depth

The depth of the quarry ranged from 182m to 235m during the years 2012 to 2022. The year-wise maximum depth of the quarry is provided in Appendix III/Table 1.

3.5.2.4 Overburden dump height

The overburden dump height ranged from 70m to 80m. The year-wise maximum height of the dump is provided in Appendix III/Table 1.

3.5.2.5 Lead distance

The lead distance has reduced from 5.0km to 0.2km over a period of 10 years from 2012 to 2022, due to back filling. The lead distances of transportation considered for the study are provided in Appendix III/Table 1.

3.5.2.6 Meteorological data

Meteorological data pertaining to temperature, humidity, rainfall, predominant wind direction and wind speed has been collected from the year 2012 to 2022.

The daily average temperature varied from 17.2⁰ to 45.8⁰ C, predominant wind direction from 1 to 360 degrees, humidity from 25.4% to 99%, rainfall from 0 to 74.2mm and average wind speed from 0 to 31.8m/s. The data has been provided in Appendix III/Table 2.

3.5.2.7 Particulate matter data

Dust monitoring has been carried out as per the Central Pollution Control Board and Ministry of Environment, Forest & Climate Change guidelines. Once in a fortnight data for duration of 24 hours sampling of PM₁₀ and PM_{2.5} has been collected over a period of 10 years from the year 2012 to 2022 and the data is provided in Appendix III/Table 3. Figure 3.12 shows the mine boundary along with air quality monitoring locations in the core and buffer zones.



Figure 3.12 Image showing the core and buffer locations of GK OC

The distance from source to the dust monitoring points in buffer zone (villages) of the mine is given in Table 3.4.

Table 3.4 Directions and distances of villages from the mine boundary

Village name	Direction	Distance from meteorological station (m)
Penagadapa	E	1000
Rudrampur	N	1500
Sitampeta	W	2000
Tippanapalli	S	2500

The daily average PM₁₀ in the CHP varied from 95 to 275 µg/m³, BWS from 57 to 266 µg/m³, Penagadapa from 43 to 108 µg/m³, Rudrampur from 40 to 128 µg/m³, Sitampeta from 40 to 98 µg/m³ and Tippanapalli from 40 to 97 µg/m³.

Similarly, the daily average PM_{2.5} in the CHP varied from 29.4 to 85.6 µg/m³, BWS from 37.1 to 75.5 µg/m³, Penagadapa from 18.9 to 76.9 µg/m³, Rudrampur from 17.3 to 58.3 µg/m³, Sitampeta from 16.1 to 71.4 µg/m³ and Tippanapalli from 16.1 to 60 µg/m³.

3.5.2.8 Laboratory analysis of silt and moisture content

Overburden samples have been collected from the opencast mine for analyzing Silt and Moisture content in the laboratory. Average silt content is 19.6% and average moisture content is 8.1%. The details of silt and moisture contents at different locations are given in Appendix-VIII.

3.5.3 Case study III:

Ramagundam Open Cast-I (RGOC-I) coal mine has been considered as case study III. The mine is located in Peddapally District of Telangana State, operating since 2008. The production capacity of the mine increased from 3.3 Mt per annum to 5.3Mt per annum in the project area of 923.88 Ha. The block is located between North Latitude of 18°39'07" and 18°41'05" and East longitude 79°32'37" and 79°33'53" in the Survey of India Topo sheet No. 65-N/10. The mine is being operated with drilling and blasting technology for extraction of coal & overburden and transportation by shovel dumper combination. A view of RG OC-I is shown in Figure 3.13.



Figure 3.13 A view of RG OC-I Coal Mine

3.5.3.1 Quantity of coal and overburden removal

The method of extraction of coal and overburden is by drilling & blasting whereas transportation is by shovel dumper combination. The total coal production and overburden removed ranged from 49,785 t per day to 2,00,885 t per day. The quantity of coal extracted and overburden removed on the dates of monitoring are provided in Appendix IV/Table 1.

3.5.3.2 Effective area in the project contributing to pollution

Plan showing the boundary of the project and other areas like dumping, quarry, and infrastructure is shown in Figure 3.14.

These areas have been derived by processing the year-wise working plans of the opencast mine. The year-wise net effective areas contributing to pollution is furnished in Table 3.5 and the areas on the dates of PM monitoring are given in Appendix IV/Table 1.



Figure 3.14 Plan of RG OC-I Coal Mine

Table 3.5 Effective area contributing to pollution

Year	Quarry area	Dump area	Infra-structure area	Undisturbed area	Total area	Reclaimed area	Effective area contributing to pollution
	(Ha)	(Ha)	(Ha)	(Ha)	(Ha)	(Ha)	(Ha)
2012-13	256.00	180.00	35.77	452.11	923.88	50.00	421.77
2013-14	286.67	302.45	35.77	298.99	923.88	89.30	535.59
2014-15	295.50	302.45	35.77	290.16	923.88	100.80	532.92
2015-16	310.00	302.45	35.77	275.66	923.88	108.80	539.42
2016-17	320.50	350.00	35.77	217.61	923.88	120.00	586.27
2017-18	336.45	388.97	35.77	162.69	923.88	130.80	630.39
2018-19	348.21	388.97	35.77	150.93	923.88	192.80	580.15
2019-20	348.21	388.97	35.77	150.93	923.88	192.80	580.15
2020-21	360.10	388.97	35.77	139.04	923.88	204.20	580.64
2021-22	363.14	388.97	35.77	136.00	923.88	222.80	565.08

From the above table, it is clear that the quarry area and dump area have increased while the other area like vacant area has decreased. The reclaimed area has been increased whereas undisturbed area has been decreased.

3.5.3.3 Quarry depth

The depth of the quarry increased from 105m to 180m during the years 2012 to 2022. The year-wise maximum depth of the quarry is provided in Appendix IV/Table 1.

3.5.3.4 Overburden dump height

The overburden dump height increased from 60m to 120m from 2012 to 2022. The year-wise maximum height of the dump is provided in Appendix IV/Table 1.

3.5.3.5 Lead distance

The lead distance has ranged from 3.0km to 5.0km over a period of 10 years from 2012 to 2022. The lead distances of transportation considered for the study are provided in Appendix IV/Table 1.

3.5.3.6 Meteorological data

Meteorological data pertaining to temperature, humidity, rainfall, predominant wind direction and wind speed has been collected from the year 2012 to 2022. The daily average temperature varied from 19.1⁰ to 39.2⁰ C, predominant wind direction varied from 12 to 351 degrees, humidity varied from 15.4% to 91.9%, rainfall varied from 0 to 60.0mm per day and average wind speed varied from 0 to 15.3m/s. The data has been provided in Appendix IV/Table 2.

3.5.3.7 Particulate matter data

Dust monitoring has been carried out as discussed in previous case studies and the data is provided in Appendix IV/Table 3. Figure 3.15 shows the mine boundary along with air quality monitoring locations in the core and buffer zones.



Figure 3.15 Image showing the core and buffer locations of RG OC-I

The distance from source to the dust monitoring points in buffer zone (villages) of the mine is given in Table 3.6.

Table 3.6 Directions and distances of villages from the mine boundary

Village name	Direction	Distance from meteorological station (m)
Gunjapadugu	NE	2800
Sector-III	N	1000
Julapally	W	750
Mulakalpally	S	850

The daily average PM_{10} at the CHP varied from 92 to 290 $\mu\text{g}/\text{m}^3$, at BWS varied from 93 to 252 $\mu\text{g}/\text{m}^3$, at Gunjapadugu varied from 41 to 97 $\mu\text{g}/\text{m}^3$, at Sector-III varied from 49 to 128 $\mu\text{g}/\text{m}^3$, Julapally varied from 51 to 109 $\mu\text{g}/\text{m}^3$ and Mulakalpally varied from 48 to 101 $\mu\text{g}/\text{m}^3$.

Similarly, the daily average $PM_{2.5}$ in the CHP varied from 36.8 to 97.1 $\mu\text{g}/\text{m}^3$, BWS varied from 31.6 to 96.6 $\mu\text{g}/\text{m}^3$, Gunjapadugu varied from 12.8 to 58.1 $\mu\text{g}/\text{m}^3$, Sector-

III varied from 23.9 to 67.1 $\mu\text{g}/\text{m}^3$, Julapally varied from 24.3 to 61.5 $\mu\text{g}/\text{m}^3$ and Mulakalpally varied from 24.1 to 57.4 $\mu\text{g}/\text{m}^3$.

3.5.3.8 Laboratory analysis of silt and moisture content

Silt and moisture content was analyzed in the laboratory for the samples collected along the haul road at different depths of quarry and heights of overburden. Average silt content of RG OC-I is 18.18% and the average moisture content is 5.38%. The details of silt and moisture contents at different locations are given in Appendix-VIII.

3.5.4 Case study IV:

Srirampur Open Cast (SRP OC) coal mine has been considered as case study IV. The mine is located in Mancherial District of Telangana State, operating since 2008. The production capacity of the mine is 2.5 Mt per annum in the project area of 707.63 Ha. The block is located between North Latitude of 18°49'04" and 18°51'12" and East longitude 79°28'50" and 79°31'18" in the Survey of India Topo sheet No. 56-N/5. The mine is being operated with drilling and blasting technology for extraction of coal & overburden and transportation by shovel dumper combination. A view of SRP OC is shown in Figure 3.16.



Figure 3.16 A view of SRP OC Coal Mine

3.5.4.1 Quantity of coal and overburden removal

The method of extraction of coal and overburden is by drilling & blasting whereas transportation of coal is by in-pit crushing and conveying, and overburden is by shovel dumper combination. The total coal production and overburden removed ranged from 9,524 t per day to 4,40,712 t per day. The quantity of coal extracted and overburden removed on the dates of monitoring are provided in Appendix V/Table 1.

3.5.4.2 Effective area in the project contributing to pollution

Plan showing the boundary of the project and other areas like dumping, quarry, and infrastructure is shown in Figure 3.17.

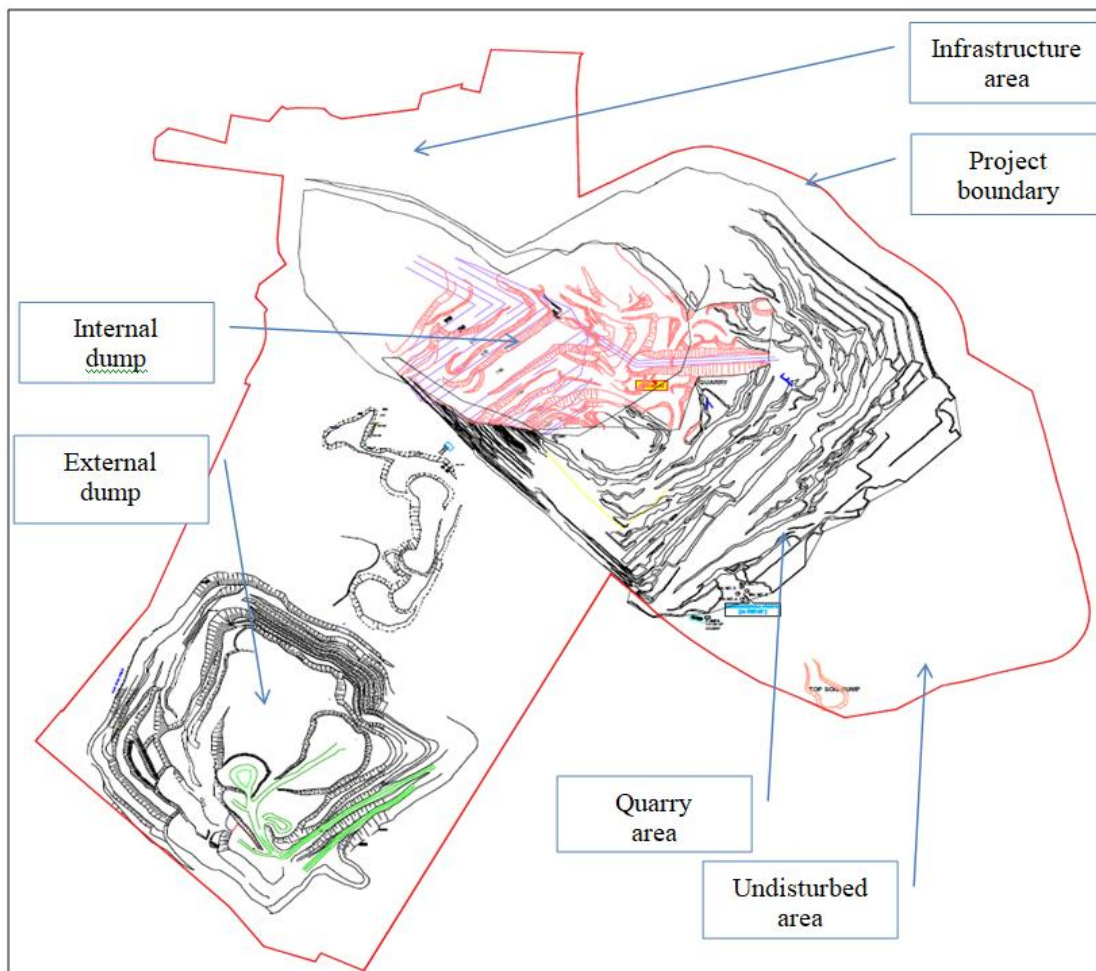


Figure 3.17 Plan of SRP OC Coal Mine

The year-wise net effective areas contributing to pollution is furnished in Table 3.7 and the areas on the dates of PM monitoring are given in Appendix V/Table 1.

Table 3.7 Effective area contributing to pollution

Year	Quarry area	Dump area	Infra-structure area	Un-disturbed area	Total area	Reclaimed area	Effective area contributing to pollution
	(Ha)	(Ha)	(Ha)	(Ha)	(Ha)	(Ha)	(Ha)
2012-13	126.00	127.00	23.94	430.69	707.63	18.04	258.90
2013-14	134.00	174.00	23.94	375.69	707.63	18.04	313.90
2014-15	156.30	184.00	23.94	343.39	707.63	95.50	268.74
2015-16	156.30	184.00	23.94	343.39	707.63	61.98	302.26
2016-17	159.30	256.00	23.94	268.39	707.63	103.88	335.36
2017-18	193.00	186.40	23.94	304.29	707.63	129.30	274.04
2018-19	227.00	225.60	23.94	231.09	707.63	135.30	341.24
2019-20	259.90	232.90	23.94	190.89	707.63	181.00	335.74
2020-21	275.80	243.80	23.94	164.09	707.63	192.65	350.89
2021-22	289.90	265.10	23.94	128.69	707.63	244.91	334.03

It is evident from the above table that the quarry area and dump area have increased while the other area like vacant area has decreased. Similarly, reclaimed area has increased.

3.5.4.3 Quarry depth

The depth of the quarry increased from 80m to 180m during the years 2012 to 2022. The year-wise maximum depth of the quarry is provided in Appendix V/Table 1.

3.5.4.4 Overburden dump height

The overburden dump height increased from 30m to 90m from 2012 to 2022. The year-wise maximum height of the dump is provided in Appendix V/Table 1.

3.5.4.5 Lead distance

The Lead distance has ranged from 3.0km to 7.0km over a period of 10 years from 2012 to 2022. The lead distances of transportation considered for the study are provided in Appendix V/Table 1.

3.5.4.6 Meteorological data

Meteorological data pertaining to temperature, humidity, rainfall, predominant wind direction and wind speed has been collected from the year 2012 to 2022. The daily average temperature varied from 18.2⁰ to 39.7⁰ C, predominant wind direction varied from 7 to 355 degrees, humidity varied from 12.2% to 99.1%, rainfall varied from 0 to 38.8mm per day and average wind speed varied from 0 to 12.7m/s. The data has been provided in Appendix V/Table 2.

3.5.4.7 Particulate matter data

Dust monitoring has been carried out as discussed in the earlier case studies and the data is provided in Appendix V/Table 3. Figure 3.18 shows the mine boundary along with air quality monitoring locations in the core and buffer zones.



Figure 3.18 Image showing the core and buffer locations of SRP OC

The distance from source to the dust monitoring points in buffer zone (villages) of the mine is given in Table 3.8.

Table 3.8 Directions and distances of villages from the mine boundary

Village name	Direction	Distance from meteorological station (m)
SRP Colony	N	800
Ramaraopet	SE	1000
Singapuram	E	300
Sitarampalli	W	800

The daily average PM_{10} at the CHP varied from 43 to 278 $\mu\text{g}/\text{m}^3$, at BWS varied from 61 to 281 $\mu\text{g}/\text{m}^3$, at Srirampur varied from 46 to 103 $\mu\text{g}/\text{m}^3$, at Ramaraopet varied from 35 to 98 $\mu\text{g}/\text{m}^3$, Indaram varied from 41 to 125 $\mu\text{g}/\text{m}^3$ and Sitarampally varied from 41 to 98 $\mu\text{g}/\text{m}^3$.

Similarly, the daily average $PM_{2.5}$ in the CHP varied from 21.1 to 87.5 $\mu\text{g}/\text{m}^3$, BWS varied from 22.6 to 86.7 $\mu\text{g}/\text{m}^3$, Srirampur varied from 21.2 to 65.8 $\mu\text{g}/\text{m}^3$, Ramaraopet varied from 18.4 to 62.8 $\mu\text{g}/\text{m}^3$, Indaram varied from 20.2 to 90.2 $\mu\text{g}/\text{m}^3$ and Sitarampally varied from 20.1 to 65.7 $\mu\text{g}/\text{m}^3$.

3.5.4.8 Laboratory analysis of silt and moisture content

Silt and moisture content was analyzed in the laboratory for the samples collected along the haul road at different depths of quarry and height of overburden. Average silt content of SRP OC is 15.99% and the average moisture content is 6.03%. The details of silt and moisture contents at different locations are given in Appendix-VIII.

3.5.5 Case study V:

Bellampalli Open Cast (BPA OC) coal mine has been considered as case study V. The mine is located in Kumram Bheem Asifabad District of Telangana State, operating since 2006. The production capacity of the mine is 0.40 Mt per annum in the project area of 191.98 Ha. The block is located between North Latitude of $19^{\circ}12'34''$ and $19^{\circ}12'56''$ and East longitude $79^{\circ}20'53''$ and $79^{\circ}21'41''$ in the Survey of India Topo sheet No. 56-M/8.

The mine is being operated with drilling and blasting technology for extraction of coal & overburden and transportation by shovel dumper combination. A view of BPA OC is shown in Figure 3.19.



Figure 3.19 A view of BPA OC Coal Mine

3.5.5.1 Quantity of coal and overburden removal

The method of extraction of coal and overburden is by drilling & blasting whereas transportation of coal and overburden is by shovel dumper combination. The total coal production and overburden removed ranged from 0 t per day to 81,309 t per day. The quantity of coal extracted and overburden burden removed on the dates of monitoring are provided in Appendix VI/Table 1.

3.5.5.2 Effective area in the project contributing to pollution

Plan showing the boundary of the project and other areas like dumping, quarry, and infrastructure is shown in Figure 3.20.

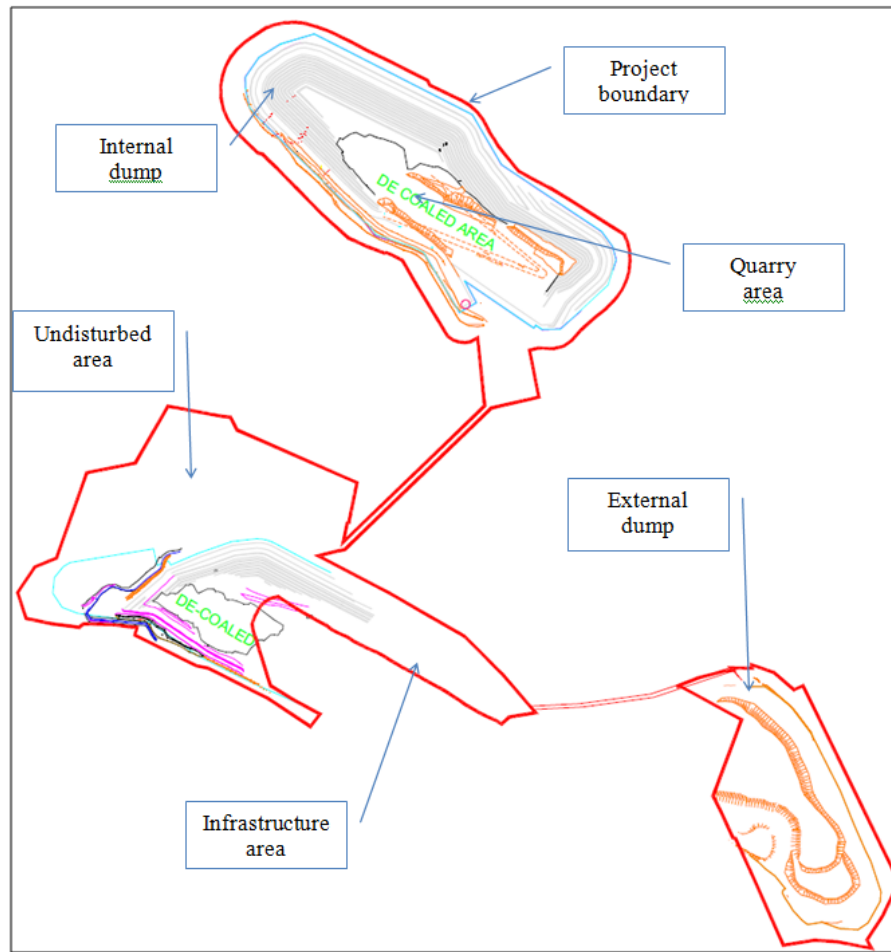


Figure 3.20 Plan of BPA OC Coal Mine

These areas have been derived by processing the year-wise working plans of the opencast mine. The year-wise net effective areas contributing to pollution is furnished in Table 3.9 and the areas on the dates of PM monitoring are given in Appendix VI/Table 1.

It is evident from Table 3.9 that the quarry area and dump area have increased while the other area like vacant area has decreased. Similarly, reclaimed area has increased. However, the effective area contributing to pollution has changed due to reclamation activities.

Table 3.9 Effective area contributing to pollution

Year	Quarry area	Dump area	Infra-structure area	Un-disturbed area	Total area	Reclaimed area	Effective area contributing to pollution
	(Ha)	(Ha)	(Ha)	(Ha)	(Ha)	(Ha)	(Ha)
2012-13	28.7	10.20	3.10	149.98	191.98	4.79	37.21
2013-14	28.7	10.20	3.10	149.98	191.98	4.79	37.21
2014-15	28.7	10.20	3.10	149.98	191.98	4.79	37.21
2015-16	29.7	10.20	3.10	148.98	191.98	6.00	37.00
2016-17	24.4	10.20	3.10	154.28	191.98	6.00	31.70
2017-18	50.5	18.00	3.10	120.38	191.98	8.00	63.60
2018-19	79.7	18.00	3.10	91.18	191.98	10.50	90.30
2019-20	85.2	22.00	3.10	81.68	191.98	12.61	97.69
2020-21	85.2	22.00	3.10	81.68	191.98	12.61	97.69
2021-22	85.2	23.81	3.10	79.87	191.98	55.65	56.46

3.5.5.3 Quarry depth

The depth of the quarry increased from 60m to 100m during the years 2012 to 2022. The year-wise maximum depth of the quarry is provided in Appendix VI/Table 1.

3.5.5.4 Overburden dump height

The overburden dump height remained constant at 30m from 2012 to 2022. The year-wise maximum height of the dump is provided in Appendix VI/Table 1.

3.5.5.5 Lead distance

The Lead distance has ranged from almost nil to 1.5km over a period of 10 years from 2012 to 2022. The lead distances of transportation considered for the study are provided in Appendix VI/Table 1.

3.5.5.6 Meteorological data

Meteorological data pertaining to temperature, humidity, rainfall, predominant wind direction and wind speed has been collected from the year 2012 to 2022. The daily average temperature varied from 17.4⁰to 42.2⁰ C, predominant wind direction varied

from 1 to 355 degrees, humidity varied from 16.3% to 98.1%, rainfall varied from 0 to 60.4mm per day and average wind speed varied from 0 to 23.9m/s. The data has been provided in Appendix VI/Table 2.

3.5.5.7 Particulate matter data

Dust monitoring has been carried out as discussed in the earlier case studies and the data has been provided in Appendix VI/Table 3. Figure 3.21 shows the mine boundary along with air quality monitoring locations in the core and buffer zones.



Figure 3.21 Image showing the core and buffer locations of BPA OC

The distance from source to the dust monitoring points in buffer zone (villages) of the mine is given in Table 3.10.

Table 3.10 Directions and distances of villages from the mine boundary

Village name	Direction	Distance from meteorological station (m)
Khairagura	NE	2000
Sonapur	N	250
Bijal	SW	500
Gampalapalli	S	600

The daily average PM₁₀ at the CHP varied from 83 to 235 µg/m³, at BWS varied from 70 to 216 µg/m³, at Khairagura varied from 33 to 97 µg/m³, at Sonapur varied from 40 to 99 µg/m³, Bijal varied from 46 to 95 µg/m³ and Gampalapalli varied from 44 to 98 µg/m³.

Similarly, the daily average PM_{2.5} in the CHP varied from 40.5 to 117.4 µg/m³, BWS varied from 37.6 to 106.6 µg/m³, Khairagura varied from 16.4 to 93.2 µg/m³, Sonapur varied from 21.8 to 69.3 µg/m³, Bijal varied from 21.9 to 59.5 µg/m³ and Gampalapalli varied from 23.1 to 62.1 µg/m³.

3.5.5.8 Laboratory analysis of silt and moisture content

Silt and moisture content was analyzed in the laboratory for the samples collected along the haul road at different depths of quarry and heights of overburden. Average silt content of KHG OC is 11.44% and the average moisture content is 7.19%. The details of silt and moisture contents at different locations are given in Appendix-VIII.

3.5.6 Case study VI:

Khairagura Open Cast (KHG OC) coal mine has been considered as case study VI. The mine is located in Kumram Bheem Asifabad District of Telangana State, operating since 2015. The production capacity of the mine is 3.75 Mt per annum in the project area of 1217.50 Ha. The block is located between North Latitude of 19°14'10" and 19°15'20" and East longitude 79°16'00" and 79°18'15" in the Survey of India Topo sheet No. 56-M/7. The mine is being operated with drilling and blasting technology for extraction of coal & overburden and transportation by shovel dumper combination. A view of KHG OC is shown in Figure 3.22.



Figure 3.22 A view of KHG OC Coal Mine

3.5.6.1 Quantity of coal and overburden removal

The method of extraction of coal and overburden is by drilling & blasting whereas transportation of coal and overburden is by shovel dumper combination. The total coal production and overburden removed ranged from 6,159 t per day to 2,89,376 t per day. The quantity of coal extracted and overburden burden removed on the dates of monitoring are provided in Appendix VII/Table 1.

3.5.6.2 Effective area in the project contributing to pollution

Plan showing the boundary of the project and other areas like dumping, quarry, and infrastructure is shown in Figure 3.23.

These areas have been derived by processing the year-wise working plans of the opencast mine. The year-wise net effective areas contributing to pollution is furnished in Table 3.11 and the areas on the dates of PM monitoring are given in Appendix VII/Table 1.

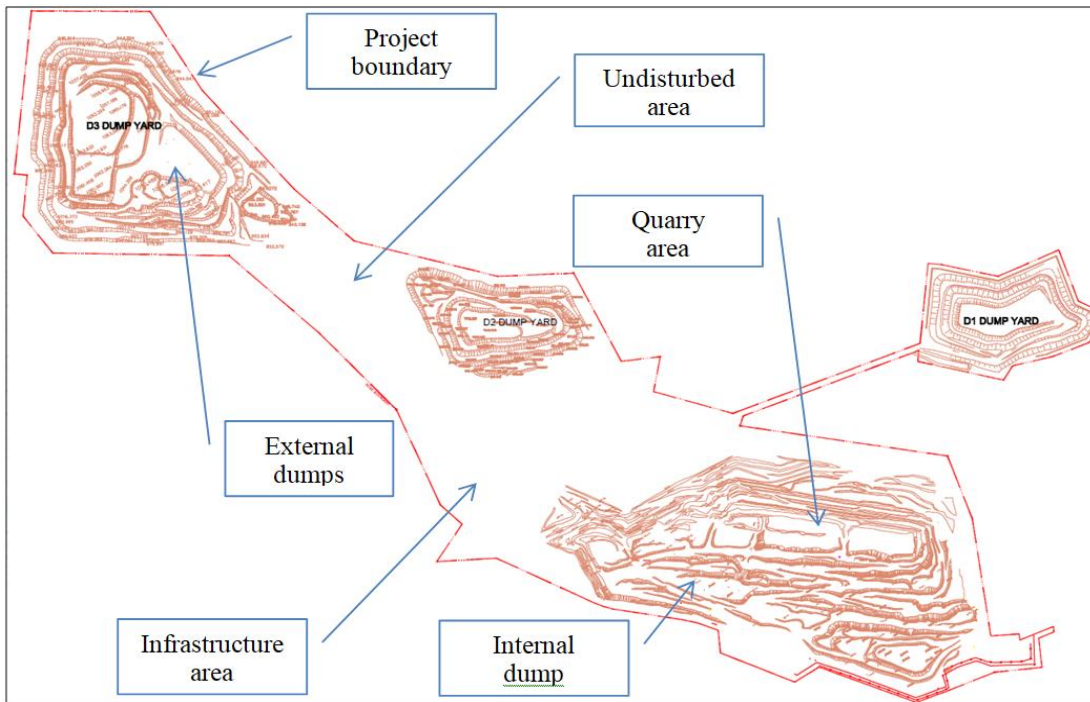


Figure 3.23 Plan of KHG OC Coal Mine

Table 3.12 Effective area contributing to pollution

Year	Quarry area	Dump area	Infra-structure area	Undisturbed area	Total area	Reclaime d area	Effective area contributing to pollution
	(Ha)	(Ha)	(Ha)	(Ha)			
2012-13	165.00	151.30	52.47	848.73	1217.50	68.0	300.77
2013-14	170.00	168.30	52.47	826.73	1217.50	88.0	302.77
2014-15	210.00	190.70	52.47	764.33	1217.50	126.0	327.17
2015-16	252.00	210.20	52.47	702.83	1217.50	167.0	347.67
2016-17	269.00	308.70	52.47	587.33	1217.50	183.0	447.17
2017-18	269.00	323.00	52.47	573.03	1217.50	204.0	440.47
2018-19	310.00	338.43	52.47	516.60	1217.50	246.0	454.90
2019-20	318.29	346.60	52.47	500.14	1217.50	256.0	461.36
2020-21	325.65	347.92	52.47	491.46	1217.50	277.0	449.09
2021-22	355.27	347.92	52.47	461.84	1217.50	372.5	383.21

It is evident from the above table that the quarry area and dump area have increased while the other area like vacant area has decreased. Similarly, reclaimed area has increased. However, the effective area contributing to pollution has changed due to reclamation activities.

3.5.6.3 Quarry depth

The depth of the quarry increased from 55m to 148m during the years 2012 to 2022. The year-wise maximum depth of the quarry is provided in Appendix VII/Table 1.

3.5.6.4 Overburden dump height

The overburden dump height increased from 55m to 120m from 2012 to 2022. The year-wise maximum height of the dump is provided in Appendix VII/Table 1.

3.5.6.5 Lead distance

The Lead distance has ranged from 1.7km to 6.9km over a period of 10 years from 2012 to 2022. The lead distances of transportation considered for the study are provided in Appendix VII/Table 1.

3.5.6.6 Meteorological data

Meteorological data pertaining to temperature, humidity, rainfall, predominant wind direction and wind speed has been collected from the year 2012 to 2022. The daily average temperature varied from 17.4⁰ to 42.2⁰ C, predominant wind direction varied from 1 to 355 degrees, humidity varied from 16.3% to 98.1%, rainfall varied from 0 to 60.4mm per day and average wind speed varied from 0 to 23.9m/s. The data has been provided in Appendix VII/Table 2.

3.5.6.7 Particulate matter data

Dust monitoring has been carried out as discussed in the earlier case studies and the data is provided in Appendix VII/Table 3. Figure 3.24 shows the mine boundary along with air quality monitoring locations in the core and buffer zones.



Figure 3.24 Image showing the core and buffer locations of SRP OC

The distance from source to the dust monitoring points in buffer zone (villages) of the mine is given in Table 3.12.

Table 3.13 Directions and distances of villages from the mine boundary

Village name	Direction	Distance from meteorological station (m)
Ontimamidi	W	4300
Ullipitta	N	500
Chopidi	E	500
Goverguda	S	600

The daily average PM_{10} at the CHP varied from 91 to 248 $\mu\text{g}/\text{m}^3$, at BWS varied from 70 to 216 $\mu\text{g}/\text{m}^3$, at Goverguda varied from 33 to 125 $\mu\text{g}/\text{m}^3$, at Ullipitta varied from 37 to 98 $\mu\text{g}/\text{m}^3$, Chopidi varied from 40 to 113 $\mu\text{g}/\text{m}^3$ and Ontimamidi varied from 32 to 131 $\mu\text{g}/\text{m}^3$.

Similarly, the daily average $PM_{2.5}$ in the CHP varied from 40.9 to 120.9 $\mu\text{g}/\text{m}^3$, BWS varied from 37.6 to 106.6 $\mu\text{g}/\text{m}^3$, Goverguda varied from 16.5 to 66.8 $\mu\text{g}/\text{m}^3$, Ullipitta varied from 17.2 to 68.3 $\mu\text{g}/\text{m}^3$, Chopidi varied from 21.8 to 68.6 $\mu\text{g}/\text{m}^3$ and Ontimamidi varied from 15.2 to 72.4 $\mu\text{g}/\text{m}^3$.

3.5.6.8 Laboratory analysis of silt and moisture content

Average silt content of KHG OC is 10.91% and the average moisture content is 6.77%. The details of silt and moisture contents at different locations are given in Appendix-VIII.

CHAPTER 4

CHAPTER 4

4. RESULTS AND ANALYSIS

This chapter gives the details of results and analysis of data. Multivariate Regression (MVR) and Machine Learning (ML) methods and selection of the best method based on the accuracy to develop dust prediction models for PM₁₀ and PM_{2.5} of all the 6 opencast coal mines. Software has been developed to handle large volume of complex data and create a user-friendly environment for data entry and display the predicted result. Contour plots have also been developed using geospatial application to predict the concentrations at non-monitored locations in and around the six opencast coal mines.

The datasets containing historical air quality data along with other variables like meteorological conditions and mining parameters have been collected for analysis. The data has been cleaned by handling missing values, removal of outliers and normalising the features to ensure uniformity and accuracy. The data has been further processed with statistical summaries for better visualisation and interpretation. Considering the difficulty in understanding the trend analysis of air quality parameters and due to complexity of interrelationship between number of variables contributing to pollution, ML tools have been used to address these issues and make accurate air quality impact predictions.

The concept of R^2 is used in evaluating machine learning algorithms for air quality prediction. It measures the proportion of variance in the observed data that is explained by the model. It typically ranges from 0 to 1 and can be expressed in terms of percentages, with higher values indicating a better fit of the model to the data. Thus, R^2 values have been computed with the above techniques for making a comparison of MVR and ML methods. By comparing R^2 scores across different ML algorithms, the most accurate predictions for air quality parameters have been determined in all the 6 opencast mines. This analysis aids in selecting the optimal algorithm for precise and reliable air quality forecasting, ensuring the effectiveness of the methodology.

4.1 Development of Prediction Models using MVR Analysis

MVR is a technique used to measure the degree to which the various independent and dependent variables are linearly related to each other. The relation is said to be linear due to the correlation between the variables. Once the multivariate regression is applied to the dataset, this method is then used to predict the behaviour of the response variable based on its corresponding predictor variables.

Multivariate regression is commonly used as a supervised algorithm in machine learning, a model to predict the behaviour of dependent variables and multiple independent variables.

A statistical analysis using Minitab 17 has been performed to establish regression equations for PM₁₀ and PM_{2.5} at core and buffer locations of all the 6 mines to determine the R² values. However, the regression equations developed for one of the opencast mines i.e., JVR OC mine along with the R² values are given hereunder.

Regression equations have been developed for 2 locations in core zone i.e., CHP, BWS and 4 locations in buffer zone i.e., Kistaram, Pallewada, Sathupally, Venkatapuram in respect of JVR OC.

4.1.1 Regression equations at CHP

$$\text{For PM}_{10}: \text{CHP_PM}_{10} = 315.9 + 0.000187 P + 0.772 A - 2.977 \text{ QD} + 27.14 \text{ LD} - 0.0017 \text{ WD} + 0.083 T - 0.157 H - 0.530 \text{ RF} + 2.938 \text{ WS} \quad (4.1)$$

$$\text{For PM}_{2.5}: \text{CHP_PM}_{2.5} = 75.1 + 0.000031 P + 0.2573 A - 0.693 \text{ QD} + 5.64 \text{ LD} - 0.00937 \text{ WD} - 0.081 T + 0.0887 H - 0.165 \text{ RF} + 0.461 \text{ WS} \quad (4.2)$$

where,

P= Production of coal and overburden (Mt)

A= Area contributing to pollution (Ha)

QD= Quarry depth (m)

LD= Lead distance (m)

WD= Predominant wind direction (degrees)

T= Temperature (°c)

H= Humidity (%)

RF= Rainfall (mm)

WS= Wind speed (m/s)

The R^2 values for PM_{10} and $PM_{2.5}$ are 0.67 (Eq. 4.1) and 0.50 (Eq. 4.2), with corresponding standard deviations of 28.11 and 10.93 respectively.

4.1.2 Regression equations at BWS

$$\text{For } PM_{10}: WS_{PM_{10}} = 315.9 + 0.000209 P - 0.0823 A - 1.100 QD + 5.85 LD + 0.0398 WD - 0.181 T - 0.758 H + 0.272 RF + 3.310 WS \quad (4.3)$$

$$\text{For } PM_{2.5}: WS_{PM_{2.5}} = 99.9 + 0.000030 P - 0.0316 A - 0.2844 QD - 1.01 LD + 0.00732 WD - 0.151 T - 0.0997 H - 0.0511 RF + 0.203 WS \quad (4.4)$$

The R^2 value for PM_{10} and $PM_{2.5}$ are 0.47 (Eq. 4.3) and 0.25 (Eq. 4.4), with corresponding standard deviations of 25.97 and 7.17 respectively.

4.1.3 Regression equations at Kistaram located in buffer zone

$$\text{For } PM_{10}: KSTRM_{PM_{10}} = 187.7 + 0.000087 P - 0.0710 A - 0.774 QD + 4.40 LD - 0.00096 WD - 0.492 T - 0.1627 H - 0.2994 RF + 0.718 WS \quad (4.5)$$

$$\text{For } PM_{2.5}: KSTRM_{PM_{2.5}} = 111.93 + 0.000059 P - 0.0433 A - 0.5442 QD + 1.709 LD + 0.00811 WD - 0.294 T - 0.1032 H - 0.0487 RF + 0.852 WS \quad (4.6)$$

The R^2 value for PM_{10} and $PM_{2.5}$ are 0.52 (Eq. 4.5) and 0.64 (Eq. 4.6), with corresponding standard deviations of 5.38 and 8.10 respectively.

4.1.4 Regression equations at Pallewada located in buffer zone

$$\text{For } PM_{10}: PLWD_{PM_{10}} = 237.8 + 0.000074 P - 0.1615 A - 1.2367 QD + 8.74 LD + 0.00701 WD - 0.700 T - 0.2022 H - 0.1232 RF + 0.869 WS \quad (4.7)$$

$$\text{For } PM_{2.5}: PLWD_{PM_{2.5}} = 140.6 + 0.000065 P - 0.1068 A - 0.7927 QD + 4.018 LD + 0.00113 WD - 0.271 T - 0.1032 H - 0.0006 RF + 0.626 WS \quad (4.8)$$

The R^2 value for PM_{10} and $PM_{2.5}$ are 0.70 (Eq. 4.7) and 0.68 (Eq. 4.8), with corresponding standard deviations of 7.71 and 5.79 respectively.

4.1.5 Regression equations at Sathupally located in buffer zone

$$\text{For PM}_{10}: \text{STPL_PM}_{10} = 236.3 + 0.000083 \text{ P} - 0.1667 \text{ A} - 1.2895 \text{ QD} + 9.79 \text{ LD} - 0.00030 \text{ WD} - 0.425 \text{ T} - 0.1401 \text{ H} - 0.0687 \text{ RF} + 0.972 \text{ WS} \quad (4.9)$$

$$\text{For PM}_{2.5}: \text{STPL_PM}_{2.5} = 130.8 + 0.000092 \text{ P} - 0.1308 \text{ A} - 0.7317 \text{ QD} + 4.401 \text{ LD} - 0.00528 \text{ WD} - 0.113 \text{ T} - 0.0633 \text{ H} - 0.0289 \text{ RF} + 1.023 \text{ WS} \quad (4.10)$$

The R^2 values for PM_{10} and $\text{PM}_{2.5}$ are 0.77 (Eq. 4.9) and 0.73 (Eq. 4.10), with corresponding standard deviations of 6.77 and 5.85 respectively.

4.1.6 Regression equations at Venkatapuram located in buffer zone

$$\text{For PM}_{10}: \text{VKTPRM_PM}_{10} = 226.8 + 0.000086 \text{ P} - 0.1682 \text{ A} - 1.160 \text{ QD} + 7.80 \text{ LD} + 0.01251 \text{ WD} - 0.601 \text{ T} - 0.1369 \text{ H} - 0.0642 \text{ RF} + 1.393 \text{ WS} \quad (4.11)$$

$$\text{For PM}_{2.5}: \text{VKTPRM_PM}_{2.5} = 137.9 + 0.000097 \text{ P} - 0.1379 \text{ A} - 0.7747 \text{ QD} + 4.76 \text{ LD} - 0.00459 \text{ WD} - 0.174 \text{ T} - 0.0847 \text{ H} - 0.0661 \text{ RF} + 1.111 \text{ WS} \quad (4.12)$$

The R^2 value for PM_{10} and $\text{PM}_{2.5}$ are 0.70 (Eq. 4.11) and 0.73 (Eq. 4.12), with corresponding standard deviations of 8.44 and 6.21 respectively.

R^2 values unveil a clear differentiation in the strength of the relationships observed within the core and buffer zones. In the core zone, R^2 values ranging from 0.25 to 0.67 suggest a weak association between the variables. Conversely, the buffer zone exhibits R^2 values between 0.52 and 0.77, indicative of a moderately weak relationship.

4.2 Development and Validation of Prediction Models using ML

Prediction models have been developed using different machine learning tools in order to arrive at R^2 values for all the 6 opencast coal mines. In each case study, CHP, BWS and 4 villages are the response variables and remaining parameters are independent variables. As the data is related to time and the response variables are continuous, methods which take less time like Random Forest, Decision Tree and Bagging algorithms are used for determining the R^2 values. Of the total data analyzed, 80% of the data is used for training and the rest 20% is used for testing at different locations. For 80-20 ratio, out of total 31,680 observations, 25,344 observations came under training data with 6,336 cases as test data.

Decision Tree involves dividing the dataset based on relationships between explanatory and outcome/response variable i.e., the tree building starts by finding the variable / feature for the best split. Finding such variable is done by criteria like Entropy, Information Gain, Gini Index, Chi square test etc.,

Random Forest generates the result which is the average value/result/prediction of several decision trees and these decision trees are formed by taking different training and test data samples each time randomly. In this method, only few independent variables, most probably important variables, are considered for analysis.

Bagging works same as Random Forest but the major difference is that it considers all the independent variables for finding the ultimate solution.

The concept of R^2 is used in evaluating machine learning algorithms for air quality prediction. It measures the proportion of variance in the observed data that is explained by the model. It typically ranges from 0 to 1 and can be expressed in terms of percentages, with higher values indicating a better fit of the model to the data. Thus, R^2 values have been computed with the above techniques for making a comparison of MVR and ML methods. By comparing R^2 scores across different ML algorithms, the most accurate predictions for air quality parameters have been determined for all the 6 opencast mines. A comparison of R^2 values using MVR, DT, Bagging and RF for 6 case studies is given below.

4.2.1 Comparison of R^2 values for JVR OC

A comparison of R^2 values using MVR and ML methods carried out at 6 locations of the mine are given in Table 4.1.

The high values of R^2 across all locations indicate better performance of RF models for both PM_{10} and $PM_{2.5}$. Hence, plots have been generated using RF to illustrate the predicted values versus actual at core and buffer locations of the project.

Table 4.1 Comparison of R² values of MVR, DT, Bagging and RF for JVR OC

Location	R ² for PM ₁₀				R ² for PM _{2.5}			
	MVR	DT	Bagging	RF	MVR	DT	Bagging	RF
CHP	0.67	0.84	0.95	0.96	0.50	0.88	0.94	0.96
BWS	0.47	0.82	0.79	0.92	0.25	0.51	0.75	0.92
Kistaram	0.53	0.57	0.62	0.65	0.65	0.61	0.97	0.97
Pallewada	0.68	0.75	0.89	0.90	0.71	0.66	0.79	0.79
Sathupally	0.73	0.81	0.97	0.97	0.78	0.92	0.95	0.95
Venkatapuram	0.73	0.79	0.84	0.86	0.71	0.75	0.90	0.90

4.2.2 Comparison of R² values for GK OC

A comparison of R² values using MVR, Decision Tree (DT), Bagging and Random Forest (RF) at different locations of GK OC mine is given in Table 4.2.

Table 4.2 Comparison of R² values of MVR, DT, Bagging and RF for GK OC

Location	R ² for PM ₁₀				R ² for PM _{2.5}			
	MVR	DT	Bagging	RF	MVR	DT	Bagging	RF
CHP	0.26	0.16	0.51	0.70	0.17	0.23	0.49	0.67
BWS	0.44	0.45	0.63	0.65	0.12	0.15	0.20	0.32
Penagadapa	0.65	0.58	0.74	0.80	0.68	0.62	0.75	0.83
Rudrampur	0.56	0.24	0.84	0.86	0.72	0.61	0.82	0.89
Sitampeta	0.72	0.80	0.93	0.94	0.70	0.65	0.84	0.86
Tippanapalli	0.58	0.66	0.84	0.87	0.70	0.75	0.83	0.88

4.2.3 Comparison of R² values for RG OC-I

A comparison of R² values using MVR, DT, Bagging and RF at different locations of RG OC-I mine is given in Table 4.3.

Table 4.3 Comparison of R² values of MVR, DT, Bagging and RF for RG OC-I

Location	R ² for PM ₁₀				R ² for PM _{2.5}			
	MVR	DT	Bagging	RF	MVR	DT	Bagging	RF
CHP	0.48	0.40	0.74	0.80	0.55	0.53	0.69	0.76
BWS	0.42	0.21	0.73	0.77	0.46	0.52	0.77	0.78
Gunjapadugu	0.24	0.71	0.73	0.75	0.21	0.68	0.70	0.76
Sector-III	0.27	0.31	0.75	0.77	0.30	0.42	0.74	0.76
Julapally	0.22	0.22	0.75	0.78	0.22	0.37	0.70	0.79
Mulakalpally	0.18	0.55	0.72	0.82	0.19	0.35	0.79	0.83

4.2.4 Comparison of R² values for SRP OC

A comparison of R² values using MVR, DT, Bagging and RF at different locations of SRP OC mine is given in Table 4.4.

Table 4.4 Comparison of R² values of MVR, DT, Bagging and RF for SRP OC

Location	R ² for PM ₁₀				R ² for PM _{2.5}			
	MVR	DT	Bagging	RF	MVR	DT	Bagging	RF
CHP	0.37	0.27	0.75	0.83	0.31	0.39	0.79	0.83
BWS	0.59	0.48	0.74	0.79	0.13	0.75	0.70	0.75
Srirampur	0.17	0.65	0.70	0.82	0.12	0.70	0.74	0.77
Ramaraopet	0.18	0.37	0.73	0.78	0.12	0.50	0.71	0.75
Indaram	0.33	0.41	0.77	0.79	0.25	0.35	0.70	0.78
Sitarampalli	0.21	0.61	0.73	0.75	0.09	0.30	0.74	0.78

4.2.5 Comparison of R² values for BPA OC

A comparison of R² values using MVR, DT, Bagging and RF at different locations of BPA OC mine is given in Table 4.5.

Table 4.5 Comparison of R² values of MVR, DT, Bagging and RF for BPA OC

Location	R ² for PM ₁₀				R ² for PM _{2.5}			
	MVR	DT	Bagging	RF	MVR	DT	Bagging	RF
CHP	0.46	0.45	0.79	0.80	0.41	0.61	0.71	0.76
BWS	0.59	0.46	0.73	0.74	0.46	0.19	0.66	0.79
Khairagura	0.71	0.71	0.71	0.75	0.65	0.27	0.78	0.81
Sonapur	0.63	0.57	0.74	0.76	0.55	0.39	0.74	0.84
Bijal	0.43	0.63	0.72	0.80	0.45	0.17	0.73	0.80
Gampalapalli	0.64	0.53	0.74	0.75	0.53	0.56	0.72	0.77

4.2.6 Comparison of R² values for KHG OC

A comparison of R² values using MVR, DT, Bagging and RF at different locations of KHG OC mine is given in Table 4.6.

Table 4.6 Comparison of R² values of MVR, DT, Bagging and RF for KHG OC

Location	R ² for PM ₁₀				R ² for PM _{2.5}			
	MVR	DT	Bagging	RF	MVR	DT	Bagging	RF
CHP	0.31	0.39	0.81	0.87	0.35	0.52	0.62	0.79
BWS	0.58	0.70	0.57	0.83	0.46	0.46	0.52	0.67
Goverguda	0.66	0.61	0.81	0.85	0.69	0.51	0.78	0.83
Ullipitta	0.72	0.82	0.77	0.84	0.59	0.52	0.68	0.83
Chopdi	0.74	0.76	0.88	0.93	0.75	0.67	0.87	0.88
Ontimamidi	0.67	0.81	0.80	0.86	0.60	0.75	0.82	0.82

From the analysis of the above 6 case studies, it is evident that RF technique has yielded the highest accuracy, for both PM₁₀ as well as PM_{2.5}.

Hence, the predictions are made using RF technique and plots depicting the predicted values with actual at core and buffer locations of 6 mines are shown in Figure nos. 4.1 to 4.6.

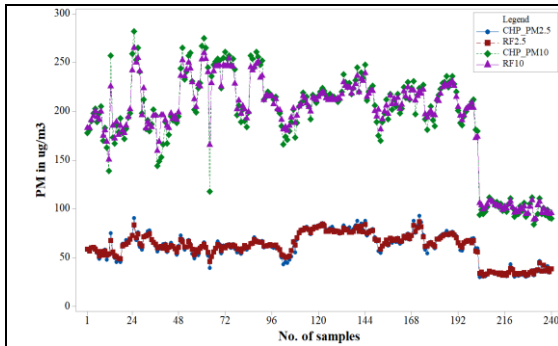


Figure 4.1(a) PM₁₀ and PM_{2.5} at CHP – Predicted Vs Actual

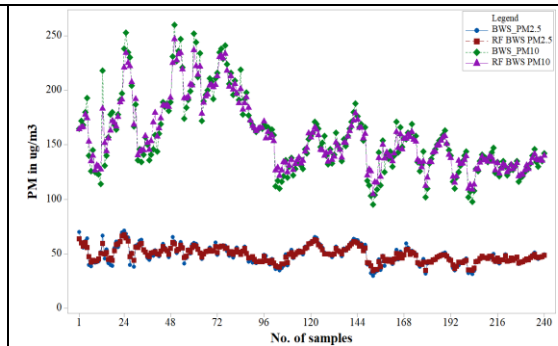


Figure 4.1(b) PM₁₀ and PM_{2.5} at BWS – Predicted Vs Actual

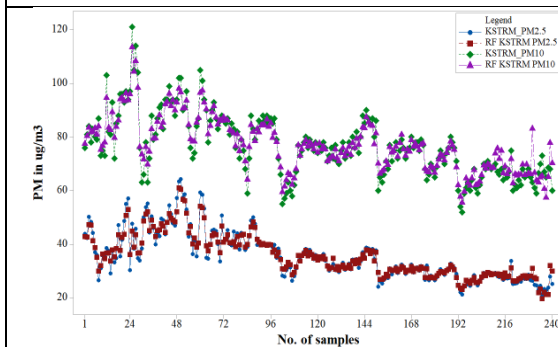


Figure 4.1(c) PM₁₀ and PM_{2.5} at Kistaram – Predicted Vs Actual

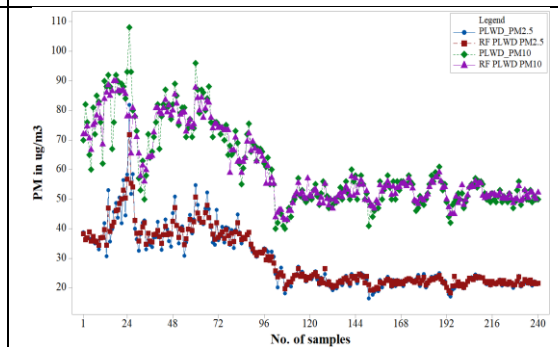


Figure 4.1(d) PM₁₀ and PM_{2.5} at Pallewada – Predicted Vs Actual

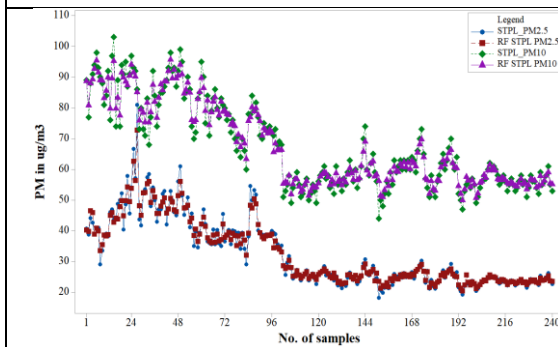


Figure 4.1(e) PM₁₀ and PM_{2.5} at Sathupally – Predicted Vs Actual

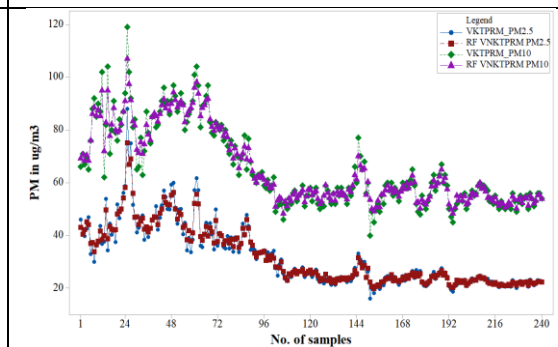


Figure 4.1(f) PM₁₀ and PM_{2.5} at Venkatapuram – Predicted Vs Actual

Figure 4.1 PM₁₀ and PM_{2.5} values at core and buffer areas of JVR OC – Predicted Vs Actual

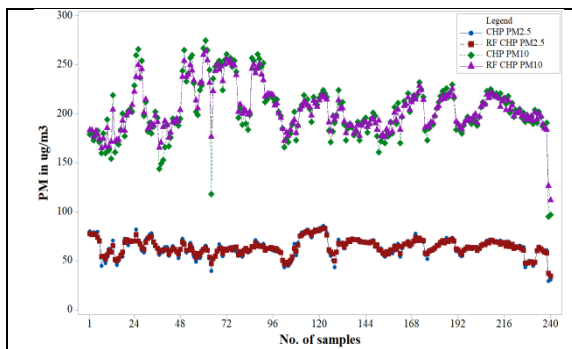


Figure 4.2(a) PM₁₀ and PM_{2.5} at CHP – Predicted Vs Actual

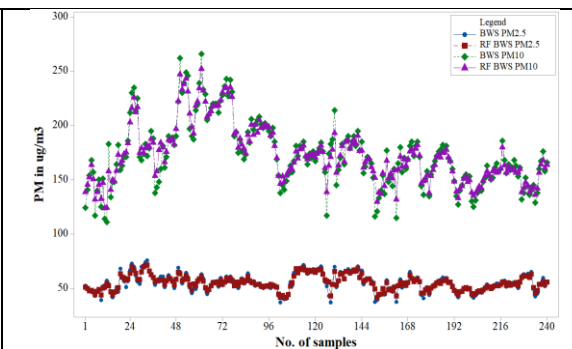


Figure 4.2(b) PM₁₀ and PM_{2.5} at BWS – Predicted Vs Actual

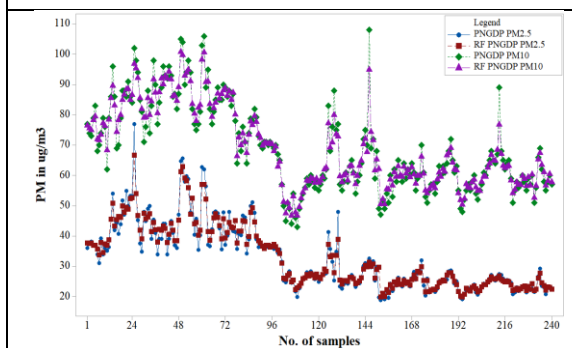


Figure 4.2(c) PM₁₀ and PM_{2.5} at Penagadapa – Predicted Vs Actual

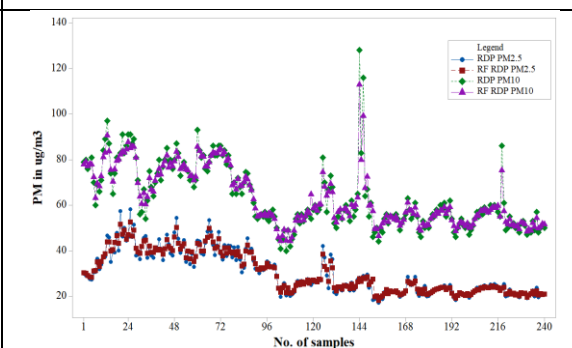


Figure 4.2(d) PM₁₀ and PM_{2.5} at Rudrampur – Predicted Vs Actual

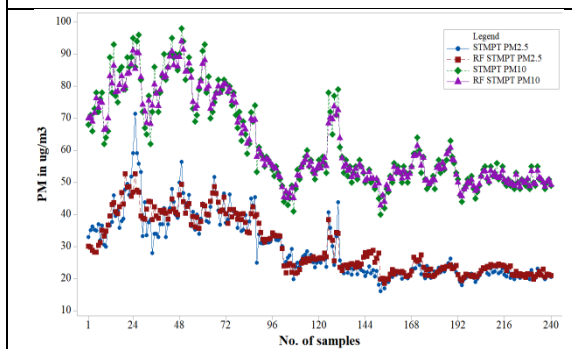


Figure 4.2(e) PM₁₀ and PM_{2.5} at Sitampet – Predicted Vs Actual

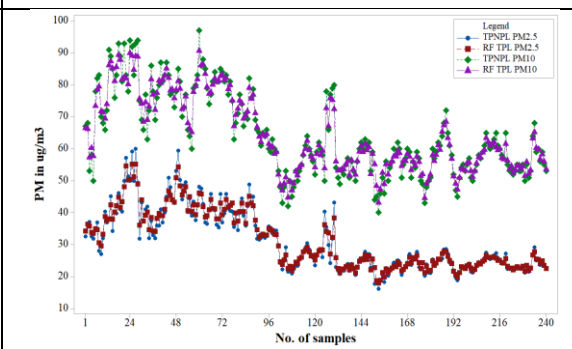


Figure 4.2(f) PM₁₀ and PM_{2.5} at Tippanapalli – Predicted Vs Actual

Figure 4.2 PM₁₀ and PM_{2.5} values at core and buffer areas of GK OC – Predicted Vs Actual

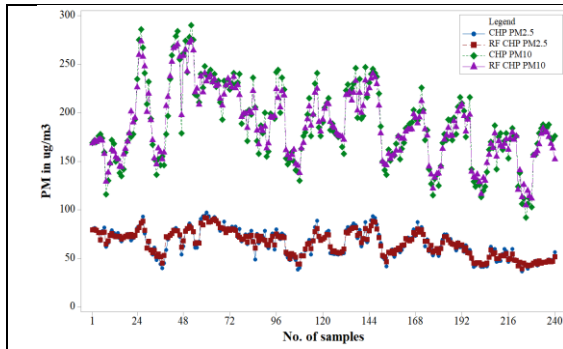


Figure 4.3(a) PM₁₀ and PM_{2.5} at CHP – Predicted Vs Actual

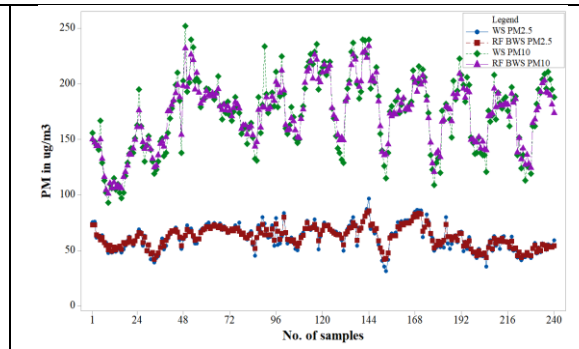


Figure 4.3(b) PM₁₀ and PM_{2.5} at BWS – Predicted Vs Actual

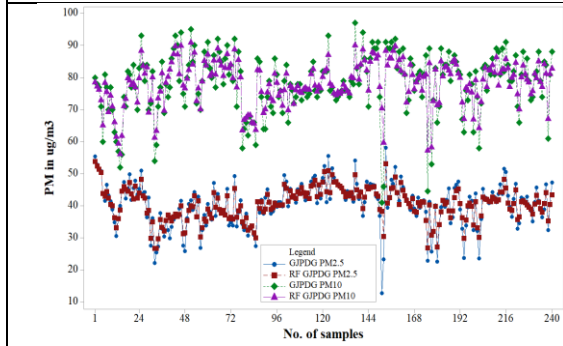


Figure 4.3(c) PM₁₀ and PM_{2.5} at Gunjapadugu – Predicted Vs Actual

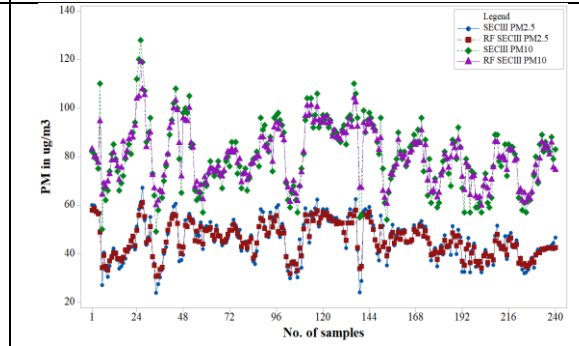


Figure 4.3(d) PM₁₀ and PM_{2.5} at Sector-III – Predicted Vs Actual

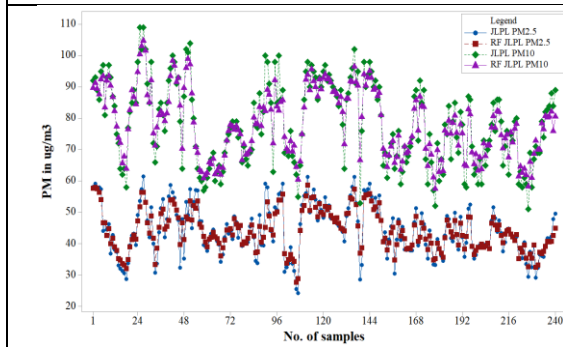


Figure 4.3(e) PM₁₀ and PM_{2.5} at Julapalli – Predicted Vs Actual

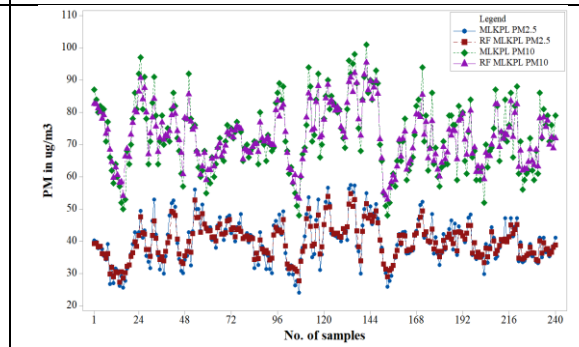


Figure 4.3(f) PM₁₀ and PM_{2.5} at Mulakalpalli – Predicted Vs Actual

Figure 4.3 PM₁₀ and PM_{2.5} values at core and buffer areas of RG OC-I – Predicted Vs Actual

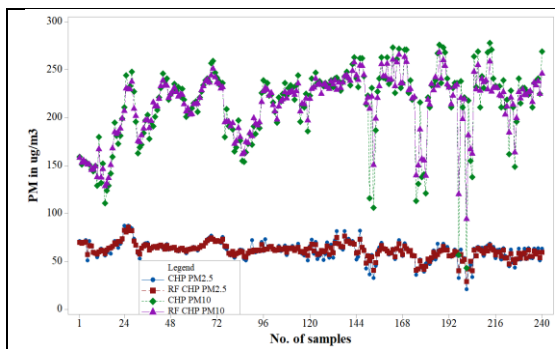


Figure 4.4(a) PM₁₀ and PM_{2.5} at CHP – Predicted Vs Actual

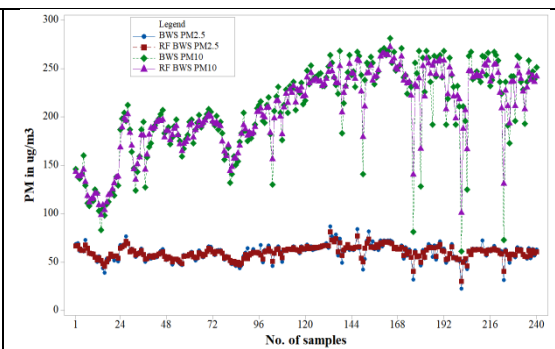


Figure 4.4(b) PM₁₀ and PM_{2.5} at BWS – Predicted Vs Actual

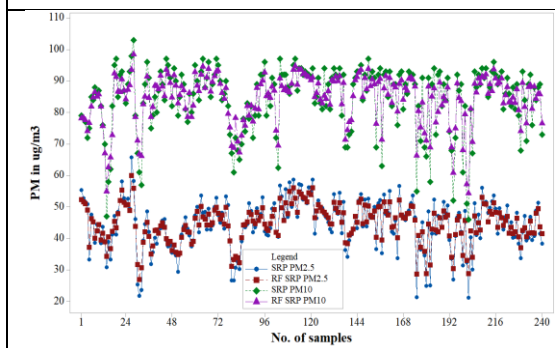


Figure 4.4(c) PM₁₀ and PM_{2.5} at Srirampur – Predicted Vs Actual

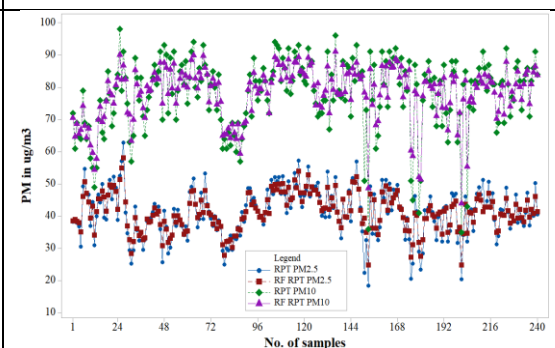


Figure 4.4(d) PM₁₀ and PM_{2.5} at Ramaraopet – Predicted Vs Actual

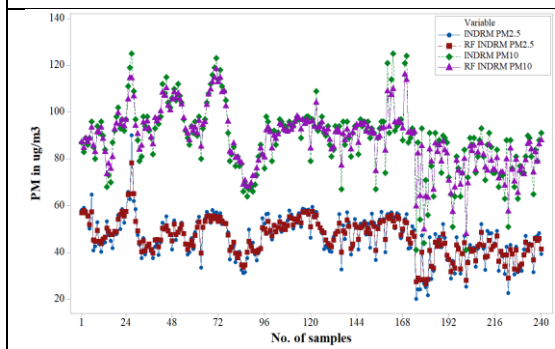


Figure 4.4(e) PM₁₀ and PM_{2.5} at Indaram – Predicted Vs Actual

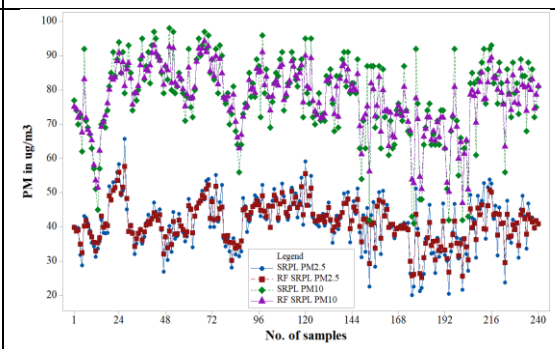


Figure 4.4(f) PM₁₀ and PM_{2.5} at Sitarampally – Predicted Vs Actual

Figure 4.4 PM₁₀ and PM_{2.5} values at core and buffer areas of SRP OC – Predicted Vs Actual

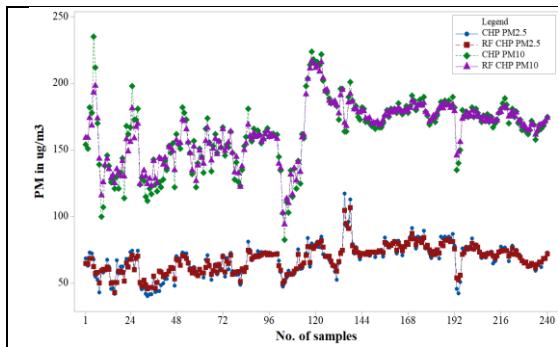


Figure 4.5(a) PM₁₀ and PM_{2.5} at CHP – Predicted Vs Actual

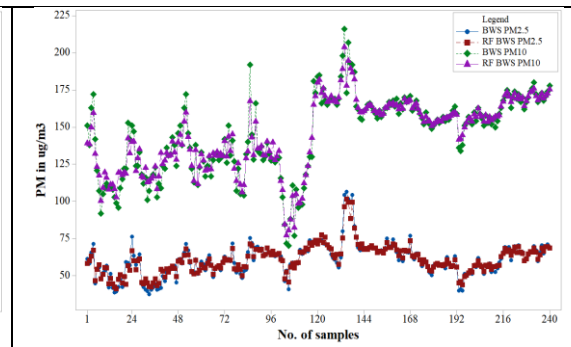


Figure 4.5(b) PM₁₀ and PM_{2.5} at BWS – Predicted Vs Actual

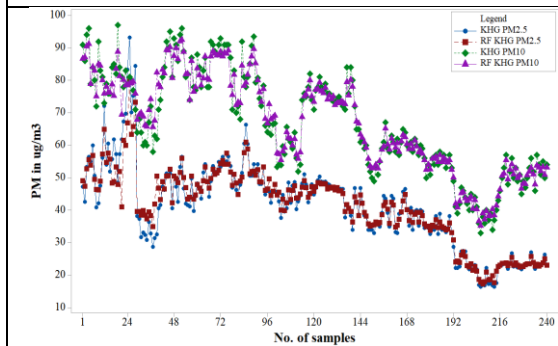


Figure 4.5(c) PM₁₀ and PM_{2.5} at Khairagura – Predicted Vs Actual

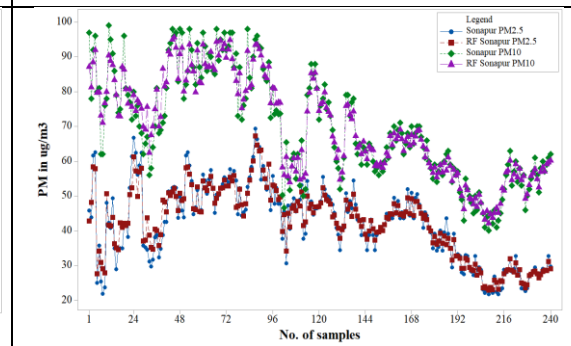


Figure 4.5(d) PM₁₀ and PM_{2.5} at Sonapur – Predicted Vs Actual

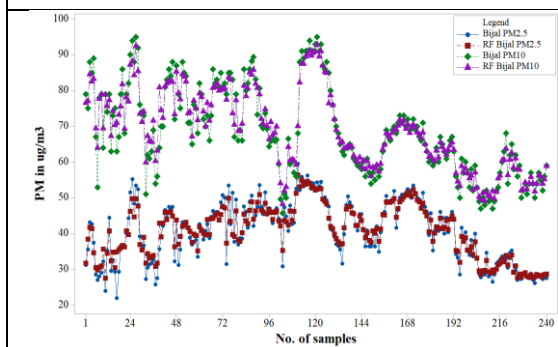


Figure 4.5(e) PM₁₀ and PM_{2.5} at Bijal – Predicted Vs Actual

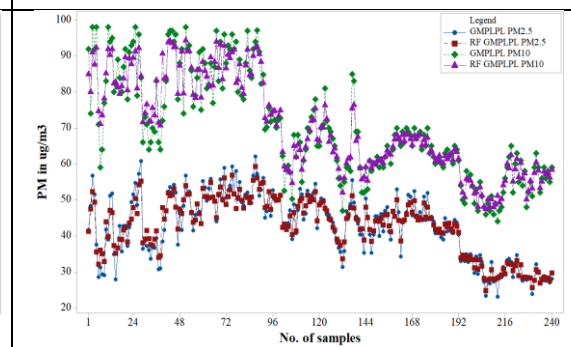


Figure 4.5(f) PM₁₀ and PM_{2.5} at Gampalpally – Predicted Vs Actual

Figure 4.5 PM₁₀ and PM_{2.5} values at core and buffer areas of BPA OC – Predicted Vs Actual

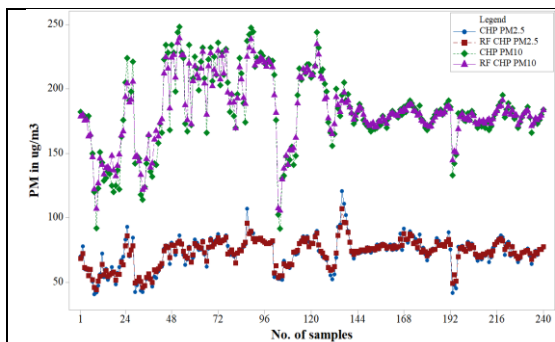


Figure 4.6(a) PM₁₀ and PM_{2.5} at CHP – Predicted Vs Actual

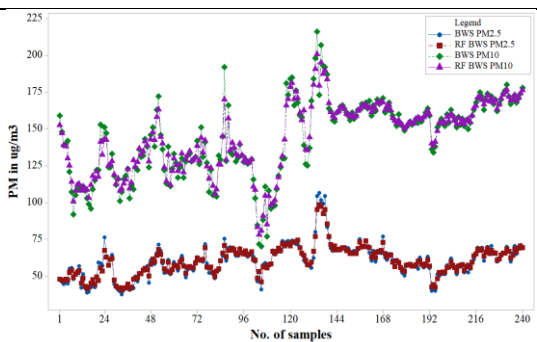


Figure 4.6(b) PM₁₀ and PM_{2.5} at BWS – Predicted Vs Actual

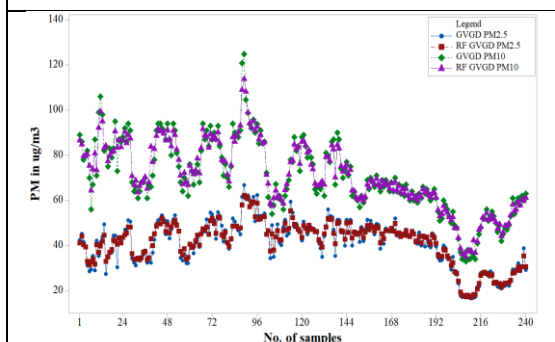


Figure 4.6(c) PM₁₀ and PM_{2.5} at Goverguda – Predicted Vs Actual

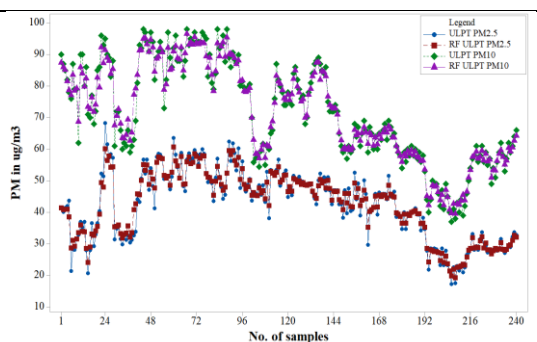


Figure 4.6(d) PM₁₀ and PM_{2.5} at Ullipitta – Predicted Vs Actual

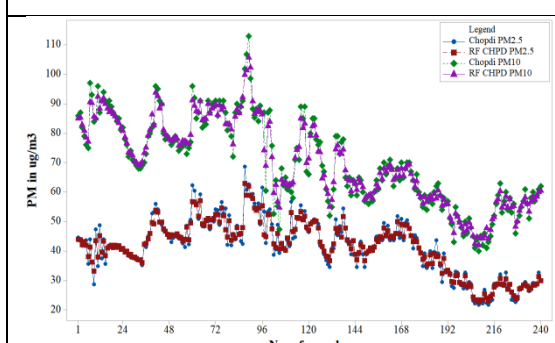


Figure 4.6(e) PM₁₀ and PM_{2.5} at Chopdi – Predicted Vs Actual

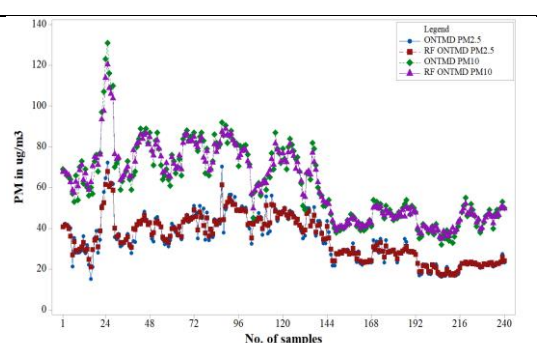


Figure 4.6(f) PM₁₀ and PM_{2.5} at Ontimamidi – Predicted Vs Actual

Figure 4.6 PM₁₀ and PM_{2.5} values at core and buffer areas of Khairagura OC – Predicted Vs Actual

Visual inspection of the plots reveals a high degree of concordance between predicted and actual air quality values. The scatter plot reveals a minimal spread between the predicted and actual values, indicating a good fit for the model.

This suggests that the Random Forest algorithm is well-suited for air quality prediction in opencast mine environments. Software has been developed using Python to facilitate prediction of PM₁₀ and PM_{2.5} values at different locations in each mine based on the mining and meteorological parameters.

4.3 Development of a Software to Predict PM by using Random Forest Algorithm

A software program named PMPOM (Particulate Matter Prediction in Opencast Mines), has been developed for prediction of PM₁₀ and PM_{2.5} in core and buffer zones of these 6 opencast projects. It is a Python based software working on RF algorithm. Python serves as the development platform due to its extensive libraries and frameworks, particularly well-suited for machine learning tasks. Scikit-learn provide a pre-built 'RandomForestClassifier' class that encapsulates the core functionalities of the Random Forest algorithm. Developers can define the model parameters, such as the number of trees and the maximum depth of each tree, within a few lines of code. Scikit-learn also handles tasks like data splitting for training and testing, model fitting, and prediction generation. This streamlines the development process, allowing developers to focus on the core aspects of their application, such as data preparation and feature engineering, which are crucial for achieving optimal model performance.

The developed software has provision to select a particular opencast mine from the dropdown list and opt for predicting either PM_{2.5} or PM₁₀. The predictions can be made on the season-wise basis. The mining parameters like daily production, area contributing to pollution, maximum quarry depth, maximum dump height and lead distance of transportation of material can be fed to the model. Furthermore, meteorological data like average wind direction, temperature, humidity, rainfall and wind speed also to be provided. After entering these input parameters, the predicted values of PM₁₀ or PM_{2.5} can be obtained for all the 6 identified locations of the selected mine.

Screenshots showing the sequence of operations involved in prediction of PM₁₀ or PM_{2.5} values using the software are given in Figure 4.7 to 4.10.

Figure 4.7 Screen for entering input parameters

Figure 4.8 Screen showing for selection of mine from the dropdown list

Figure 4.9 Screen showing the entered sample parameters

CHP	71.29
WS	51.74
Kistaram	35.0
Pallewada	27.54
Sathupally	28.15
Venkatapuram	29.5

Figure 4.10 Screen showing the predicted PM_{2.5} values at core and buffer locations of JVR OC along with entered sample parameters

4.4 Influence of Production and Pit Dimensions on Particulate Matter

PM predictions have been made with different input mining parameters including increase in production, area contributing to pollution, quarry depth, dump height and lead distance at the core and buffer areas for all the 6 case studies.

4.4.1 Influence of production on PM

Production has been increased from 25,000 tpd to 1,25,000 tpd with an interval of 25,000 tpd and the corresponding PM values are predicted. Figure 4.11 and 4.12 shows the trend of PM_{2.5} and PM₁₀ at different core and buffer locations of each mine.

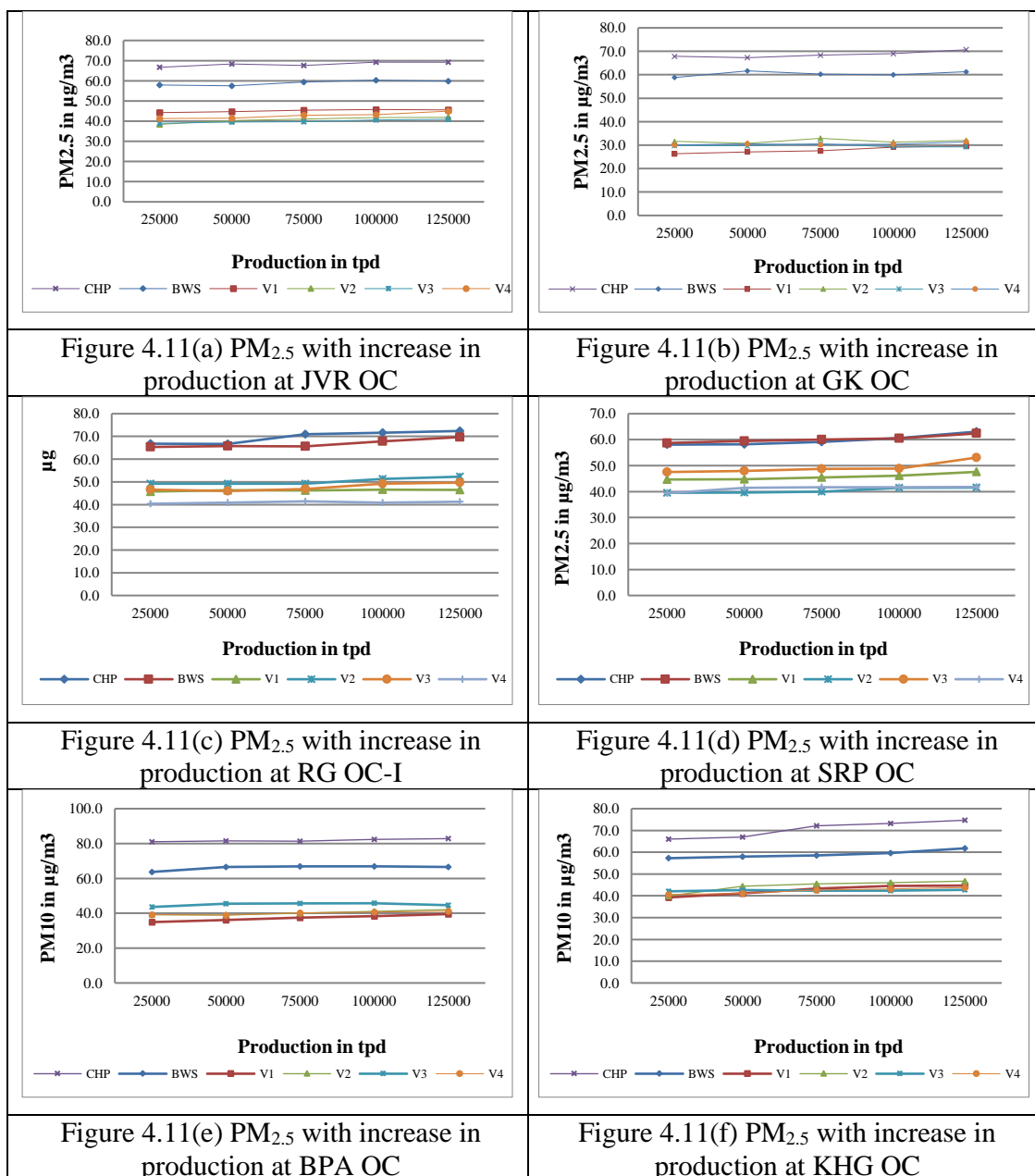


Figure 4.11 Predicted PM_{2.5} values at 6 OC mines with increase in production

From the above Figures, it is evident that the PM_{2.5} values have increased marginally with increase in production at all the locations in and around 6 OC mines. The increase in PM is due to the amplified activities associated with the increased production.

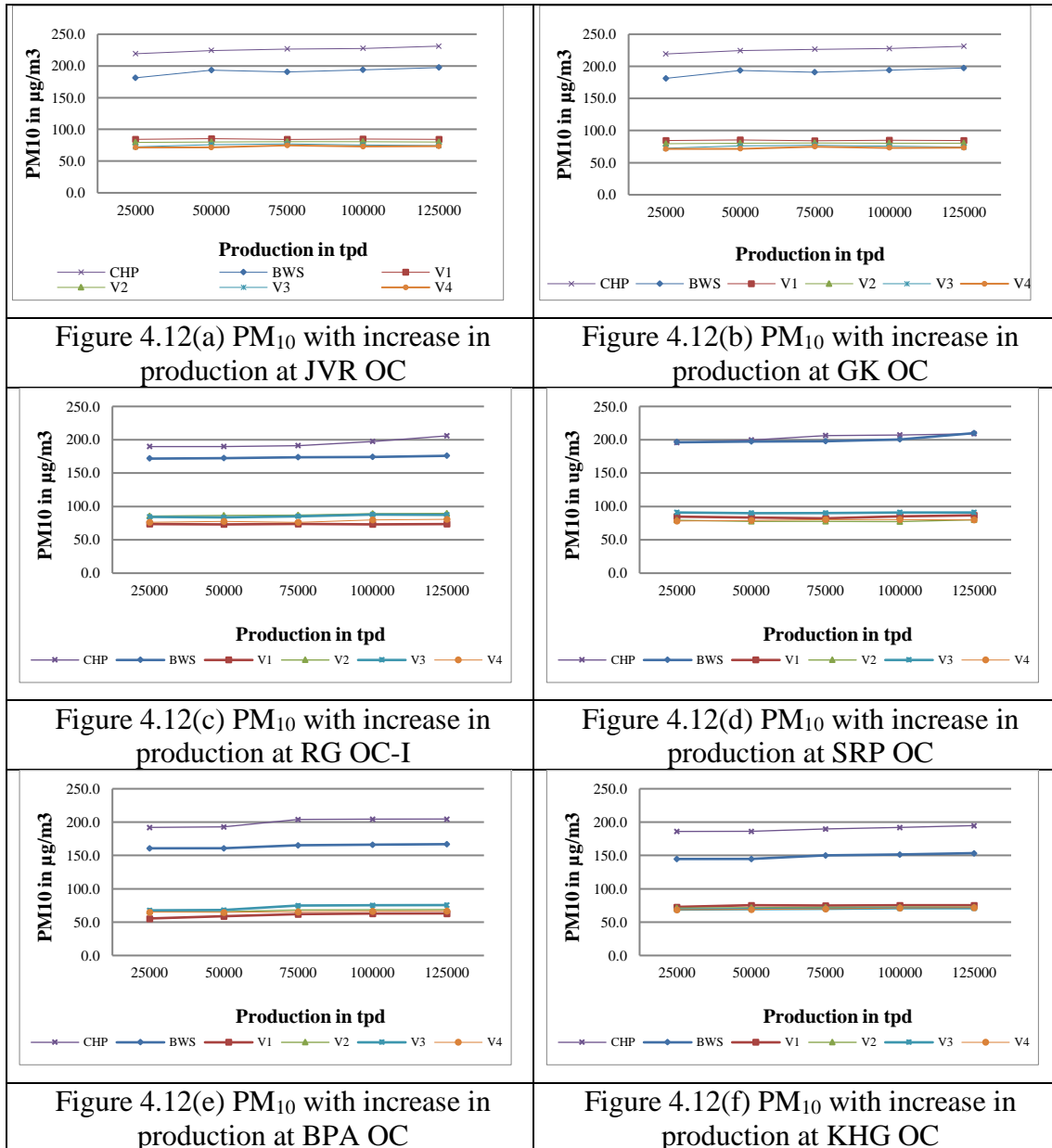


Figure 4.12 Predicted PM₁₀ values at 6 OC mines with increase in production

It can be noted from the above Figures, that PM₁₀ values are increasing with increase in production at all the locations in and around 6 opencast mines due to the increased mining activities. The increase in PM is distinct at CHP and BWS whereas there is a meagre increase from V1 to V4 locations. This can be attributed to the size of the dust particles which are not able to be carried away to longer distances.

4.4.2 Influence of area contributing to pollution

As the mine progresses, the area contributing to pollution also gets changed due to change in quarry area, dump area and other areas including reclaimed and infrastructure areas. Hence, PM values have been predicted by increasing the area contributing to pollution from 100 Ha to 300 Ha with an interval of 50 Ha.

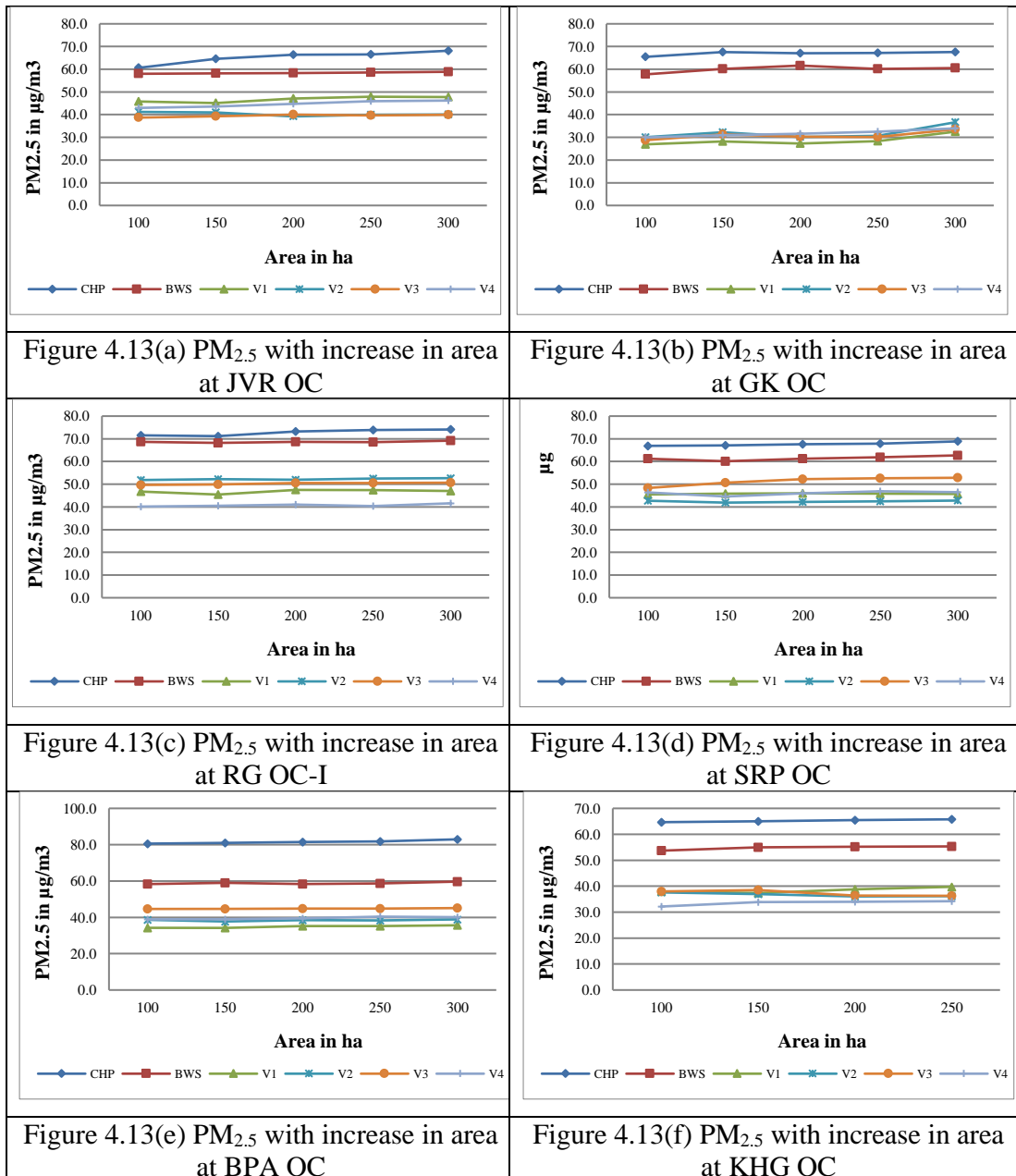


Figure 4.13 Predicted PM_{2.5} values at 6 OC mines with increase in area

It can be noted from the above plots that PM_{2.5} is increasing proportionately with respect to production in the core zone i.e., at CHP and BWS. However, at locations

like V3 in Figure 4.13(a), V4 in Figure 4.13(c), V1 and V2 in Figure 4.13(d) and V3 in Figure 4.13(f) shows a very less increase in $PM_{2.5}$ values as the mining activities moved away from them and due to the predominant wind direction.

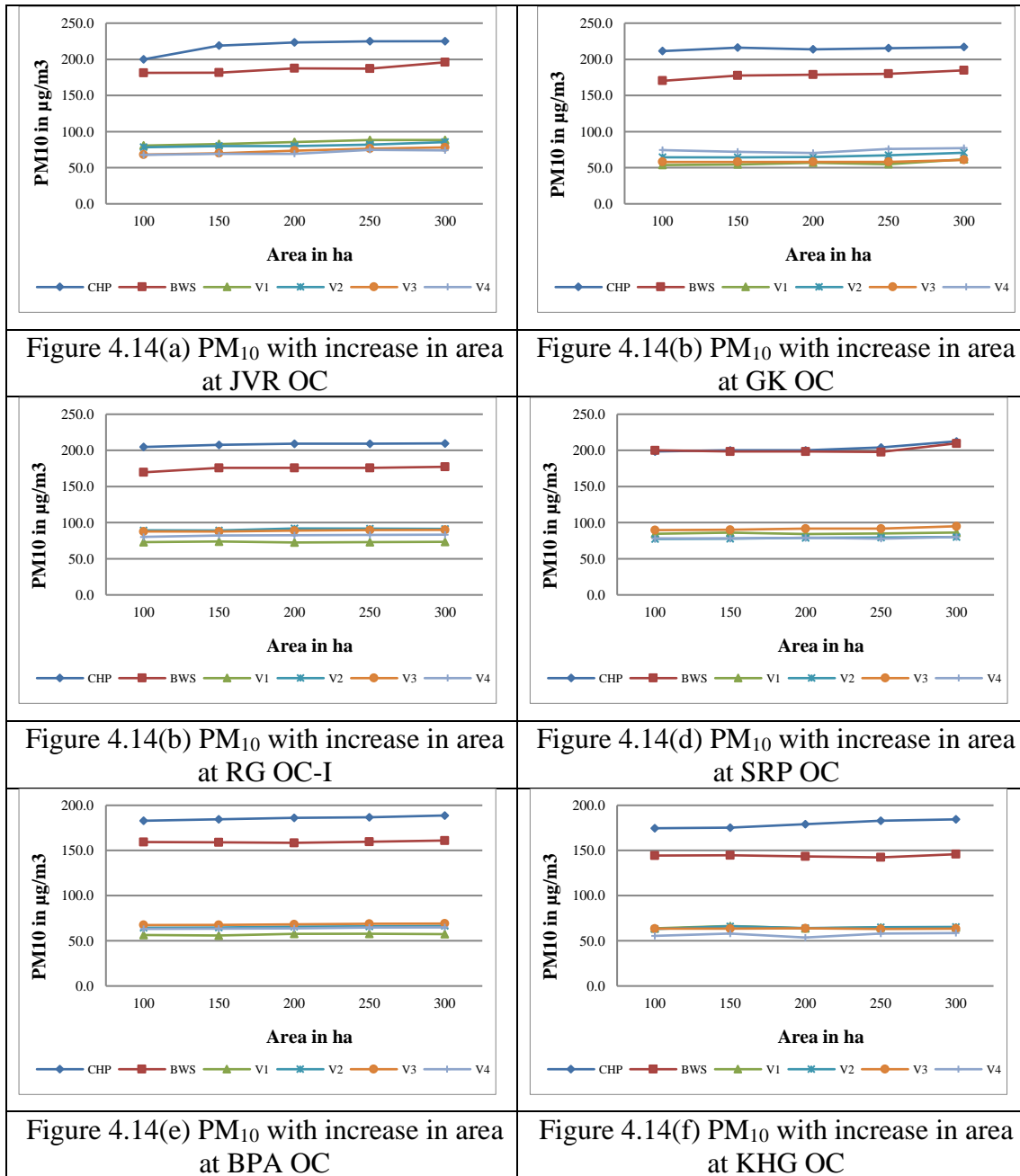


Figure 4.14 Predicted PM_{10} values at 6 OC mines with increase in area

It can be inferred from the above Figure 4.14 that the PM_{10} values have increased with the increase in the area contributing to pollution. However, the PM_{10} values in the buffer zone has shown a slight increase due to the size of the PM and as the locations are farther from the source when compared to the core locations.

4.4.3 Influence of quarry depth on PM

Quarry gets deepened as the mine develops and the changes in PM have been predicted at all the six locations of 6 opencast mines with increasing depth from 40m to 200m.

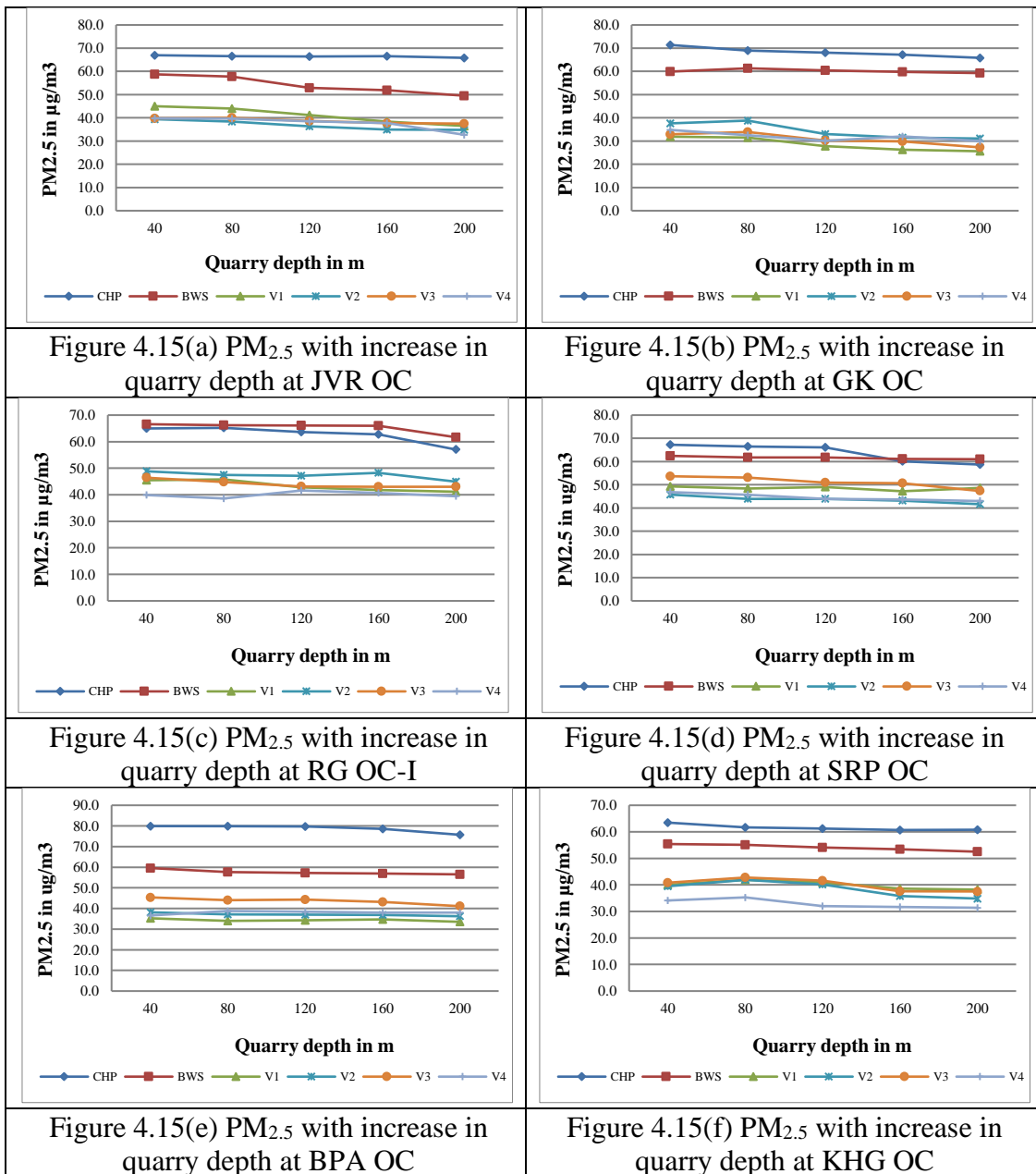


Figure 4.15 Predicted PM_{2.5} values at 6 OC mines with increase in quarry depth

Figure 4.15 clearly indicate that the PM_{2.5} values are decreasing with the increasing quarry depth due to the confinement of the particles within the quarry area under poor air circulation. The minute changes in the buffer area can be attributed to the dust concentrations due to local activities.

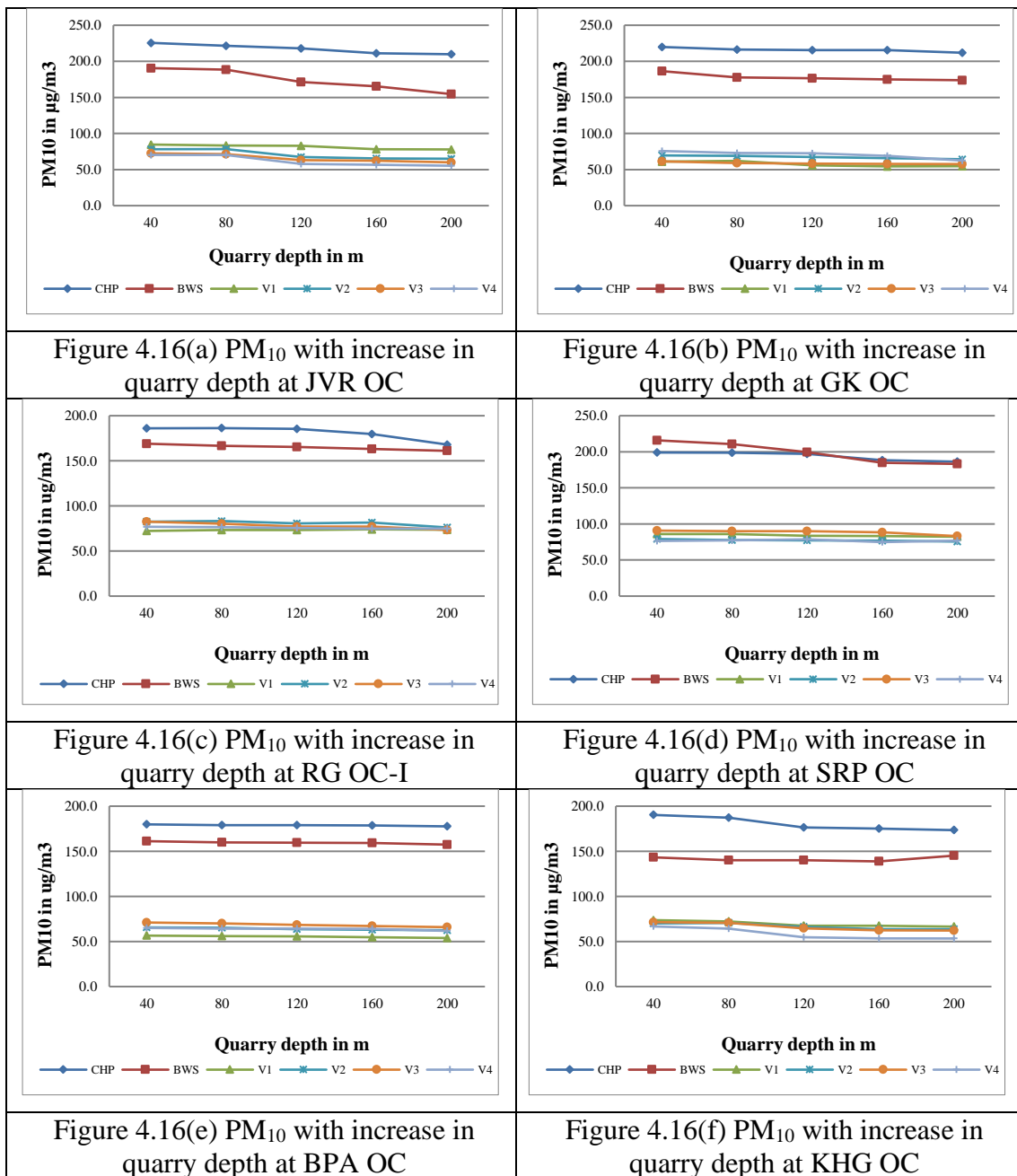


Figure 4.16 Predicted PM₁₀ values at 6 OC mines with increase in quarry depth

It can be inferred from the Figure 4.16 that PM₁₀ values are decreasing with increasing quarry depth due to the size of the particles and their retention in the quarry itself under poor wind speeds.

4.4.4 Influence of dump height on PM

The height of the dump increases to accommodate the overburden within the demarcated area as the mine progresses. Height of the dump reaches up to 90m and in some cases up to 120m. PM predictions have been made with respect to increasing dump height from 20m to 100m for all the six location and for all the mines.

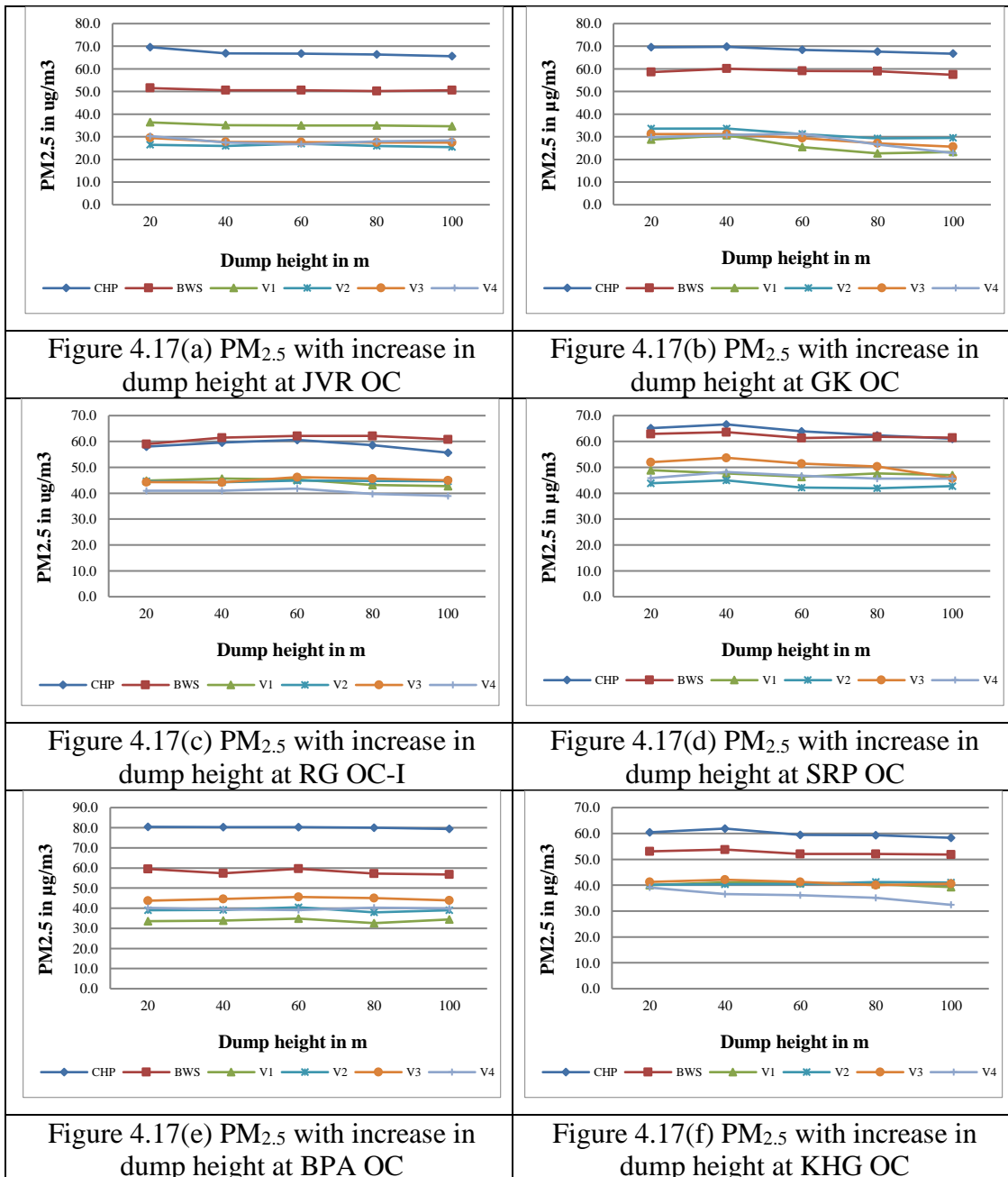


Figure 4.17 Predicted PM_{2.5} values at 6 OC mines with increase in dump height

It can be concluded from the above Figure 4.17 that the PM is increasing up to a dump height of 40 to 60m and thereon reducing. This can be attributed to the increasing wind speeds at higher altitudes and hence the better dispersion of dust.

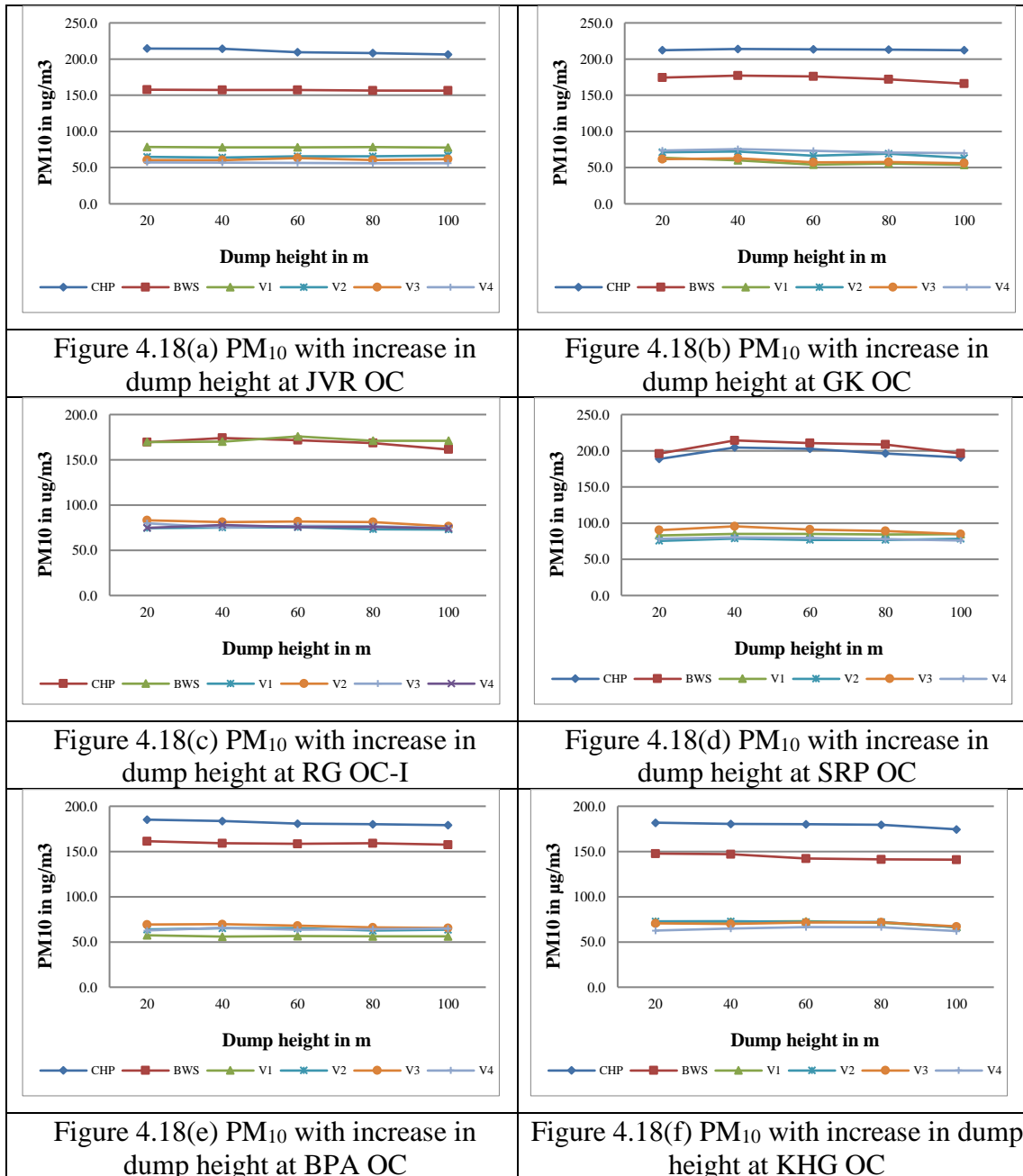


Figure 4.18 Predicted PM₁₀ values at 6 OC mines with increase in dump height

The observable fact is same in the above scenarios with PM₁₀ also, where there is a reduced value with the increase of dump height due to greater dispersion of PM at higher altitudes.

4.4.5 Influence of lead distance on PM

Lead distance is the length of transportation route for unloading the material. PM predictions have been made with increasing distances from 1 to 5km. Figure 4.19 and 4.20 shows the trend of PM_{2.5} and PM₁₀ with increasing lead distances.

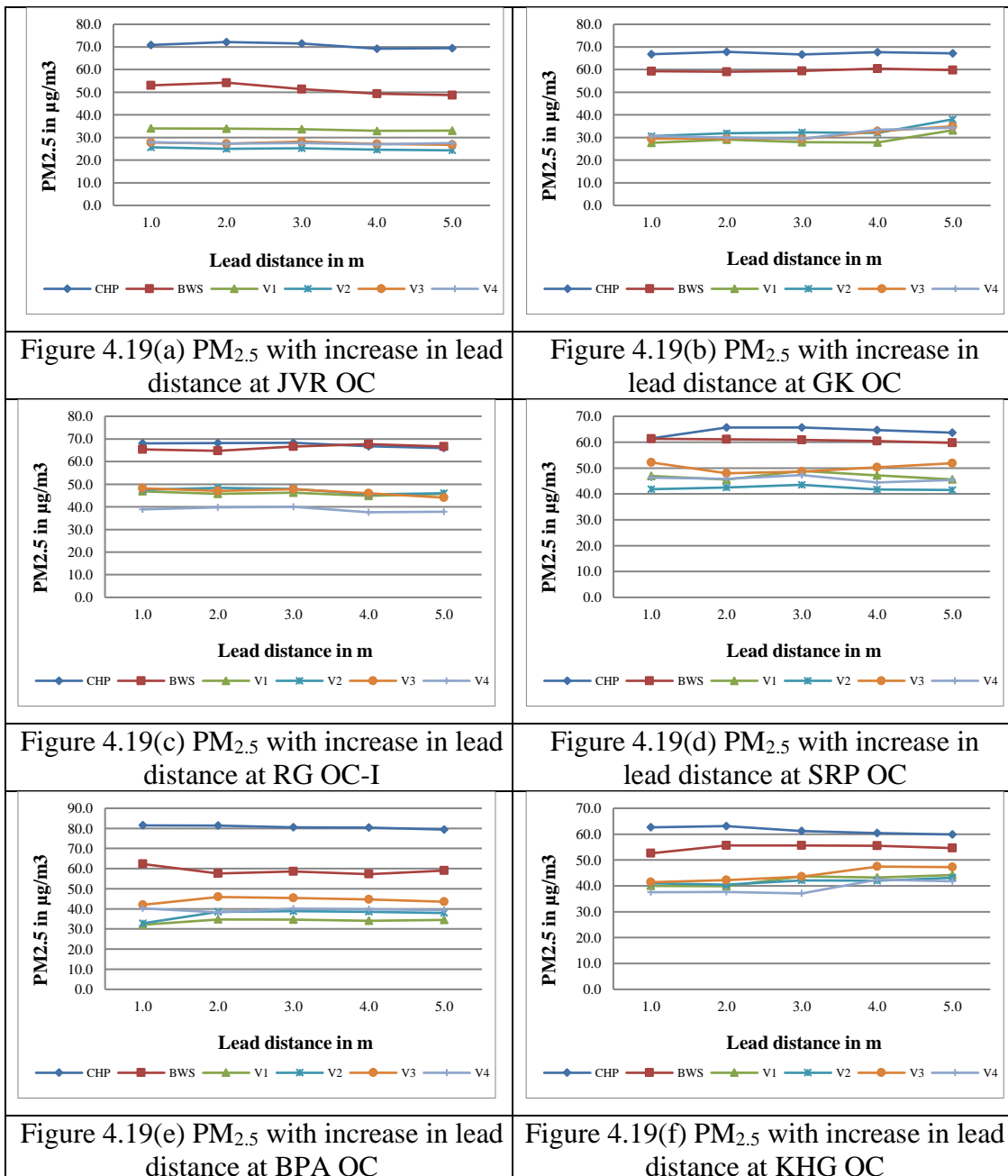


Figure 4.19 Predicted PM_{2.5} values at 6 OC mines with increase in lead distance

From the above Figures, it can be noted that there is a variation in the PM values at different locations due to increase in lead distance. This can be attributed to the proximity of the transportation route with respect to the locations and wind direction.

The PM has increased in the core zone i.e., at CHP and BWS when the distance is up to 2km and later on decreased due to farther point of dumping. Similarly, the PM values show a slight increase in some of the villages as shown in Figure 4.19(b) and 4.19(f) due to the proximity of dumping towards the villages.

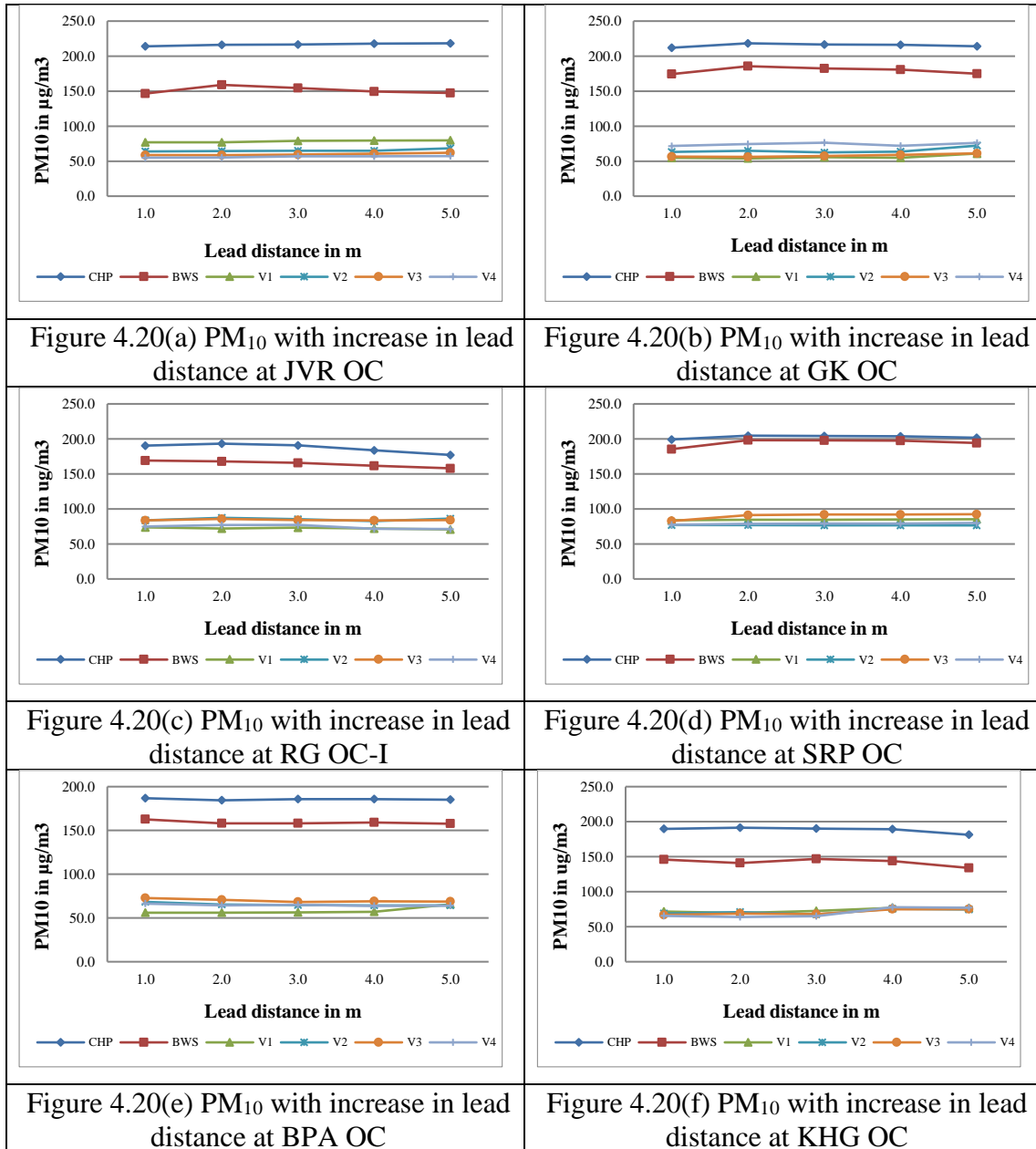


Figure 4.20 Predicted PM₁₀ values at 6 OC mines with increase in lead distance

Similar phenomenon can be attributed to PM₁₀ values also in line with PM_{2.5} wherein the PM₁₀ values have slightly decreased after 2 km lead distance in core zone whereas slightly increased in some villages in the buffer zone due to proximity of active dumping area.

The analysis reveals that a positive correlation between production rate and area contributing to pollution suggesting that these factors contribute proportionally to increased particulate matter (PM) concentrations. Conversely, a weak inverse correlation exists with quarry depth and dump height, indicating that PM concentrations tend to decrease slightly at greater depths and heights potentially due to pit retention and enhanced dispersion respectively.

4.5 Developing Dust Contour Plots using QGIS Software

Self-developed software tool can only predict PM values at selected locations. In order to assess the PM values at unmonitored locations, Quantum Geographic Information System (QGIS), a geospatial modelling application has been used to develop predictive models for air quality. The predicted PM concentrations are subsequently visualized using isopleths. These lines connect points with the same predicted PM value, creating a visual map of the spatial distribution across the entire region. This geospatial technique estimates PM concentrations at unsampled locations based on a weighted average of surrounding monitoring stations. This approach allows for efficient identification of areas with high or low PM concentrations, providing valuable insights into air quality variations that help in understanding the dispersion of PM in and around the opencast coal mines.

Accordingly, QGIS 3.34, has been used for developing contour plots using the predicted values obtained from RF algorithm to estimate PM values at any given location. Steps involved in processing the data in QGIS are given in Figure 4.21.

Data Acquisition and Exploration

- Collecting field data and ensure compatibility with QGIS by collecting data in formats like shape files for vector data, or GeoTIFF or JPEG for raster imagery.
- Locating the core and buffer points with latitudes and longitudes along with corresponding PM values.
- Building CSV file using predicted PM values obtained by programming season-wise

Data Projection Considerations

- Converting location points to coordinate reference system (CRS) to have accurate spatial relationships between features.

Data Loading and Layer Management

- Import geospatial data into the project using the Layers panel.
- Attributing the labels and PM values to each location.

Symbology Application and Thematic Exploration

- Applying thematic symbology for effective visualization of the data layers.
- This entails customizing the data represented on the map (color, size, transparency, patterns) to reveal patterns and trends.

Data Labeling and Annotation

- Enhance map clarity and information presentation by adding labels to data features. By selecting the appropriate attribute from the data table to be displayed as labels, and customize their size, font, and placement aids in avoiding overlapping features.

Layout Creation and Professional Map Design

- Designing map layout by utilizing the Print Layout manager. This allows to precisely arrange map elements such as title, legend, scale bar, north arrow, and other informative components.
- Additional elements like text boxes or inset maps can be incorporated to provide context and enhance the overall presentation.

Exportation and Sharing

- Exporting final map as a high-resolution image (JPEG, PNG) or a portable document format (PDF) for sharing or inclusion in reports.

Figure 4.21 Steps involved in QGIS

Plots have been developed using QGIS software for PM₁₀ and PM_{2.5} predictions in all the 3 seasons covering all the 6 opencast mines. Also, these plots have been exported to Google earth so as to have better visualisation and analysis. This helped in leveraging the capabilities of both the platforms to work with the spatial data more effectively.

The figures 4.22, 4.24, 4.26, 4.28, 4.30 and 4.32 depict the dust contours of PM₁₀ and PM_{2.5} along with the predicted values of all the 6 mines at select locations whereas the figures 4.23, 4.25, 4.27, 4.29, 4.31 and 4.33 shows the images of contours exported to Google earth covering 3 seasons.

Summer months often experience low precipitation and increased atmospheric stability, leading to reduced dispersion of pollutants. This phenomenon allows PM to accumulate in the atmosphere, resulting in higher concentrations. Winter seasons may also witness elevated PM levels due to lower boundary layer heights which can trap pollutants near the surface. Conversely, rainy seasons are characterized by enhanced precipitation, which effectively scavenges PM from the atmosphere, leading to lower PM values.

The resumption of production processes that has been curtailed during the monsoon months, coupled with an upsurge in construction activities witnessed towards financial year-end, contributed to the increased PM burden during the summer months. The analysis reveals that a high level of homogeneity exists in the patterns across all the 6 case studies.

Contour plots are generated for 2 locations in core zone and 4 locations in the buffer zone of JVR OC for three seasons and are given in Figure 4.22.

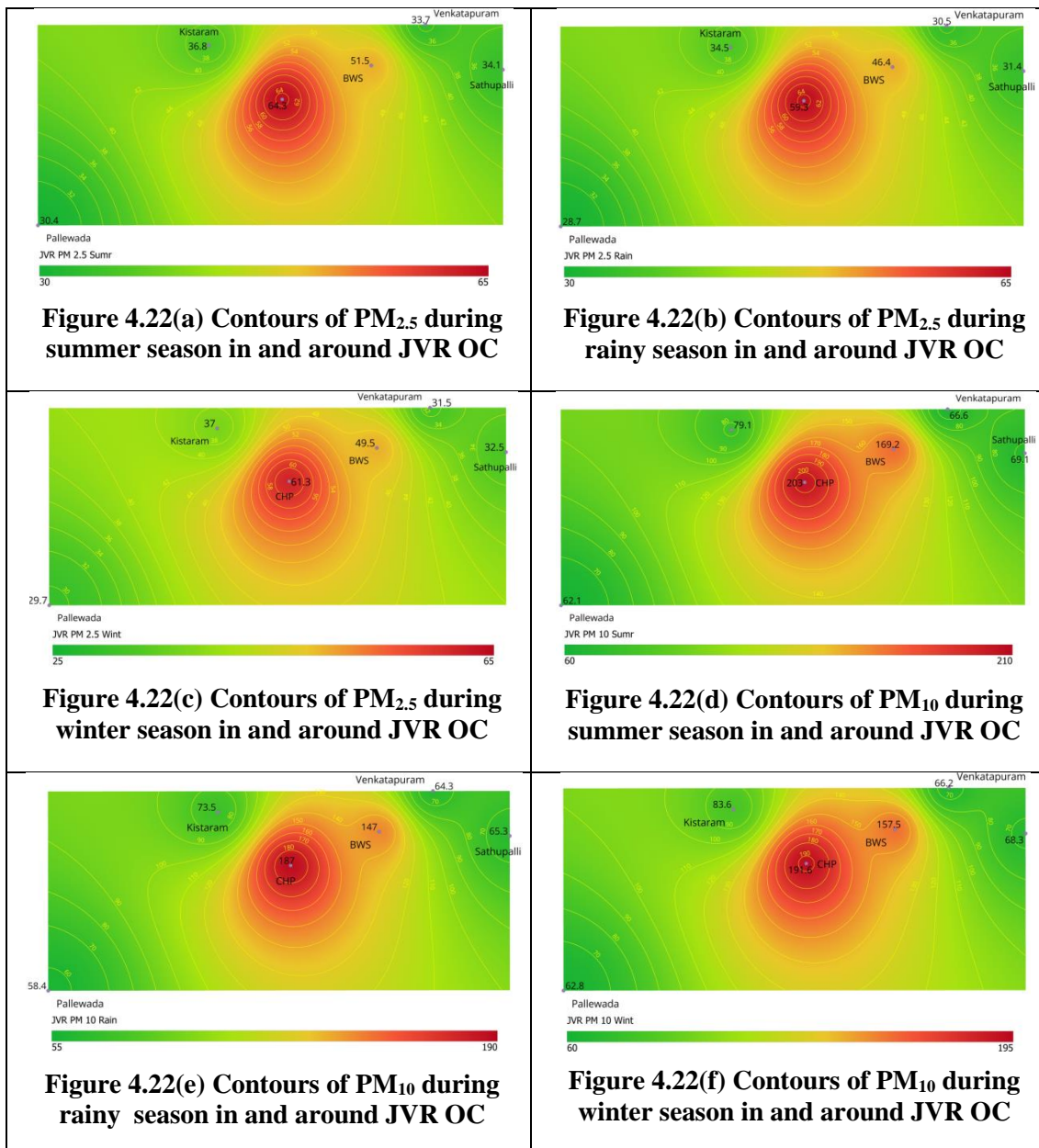


Figure 4.22 Contours of PM_{2.5} and PM₁₀ during 3 seasons in and around JVR OC

The highest value for PM_{2.5} is 64.3 in summer and the lowest value is 31.4 $\mu\text{g}/\text{m}^3$ in rainy season. Similarly, highest value for PM₁₀ is 203 $\mu\text{g}/\text{m}^3$ in summer and the lowest value is 187 $\mu\text{g}/\text{m}^3$ in rainy season. The observed seasonal trend in PM concentrations, with peaks in summer and winter and a minimum during the rainy season, can be attributed to meteorological factors and mining parameters.

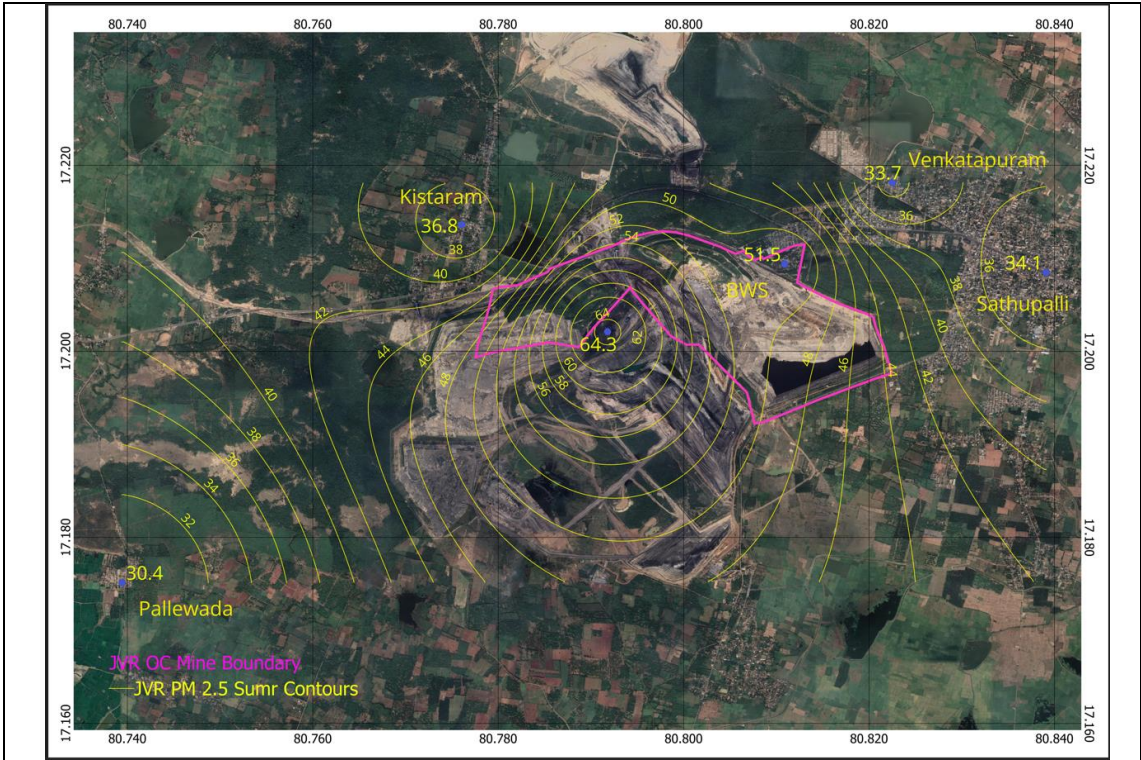


Figure 4.23(a) Image of PM_{2.5} contours during summer season in and around JVR OC

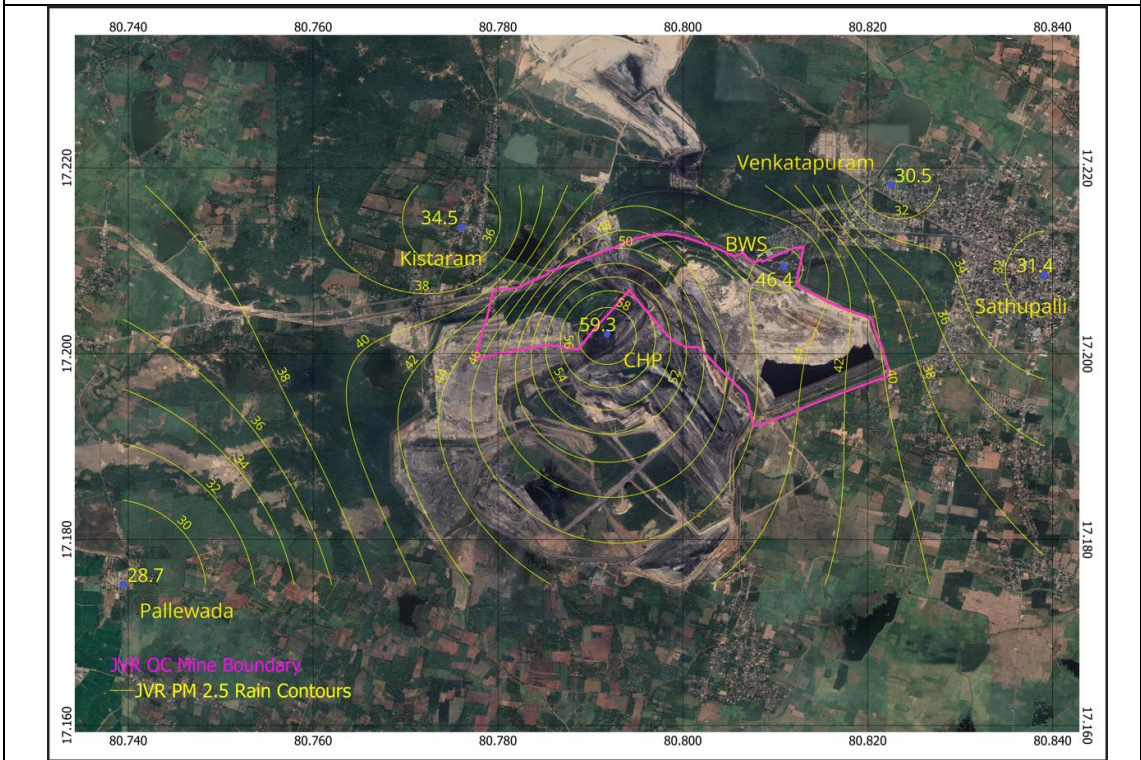


Figure 4.23(b) Image of PM_{2.5} contours during rainy season in and around JVR OC

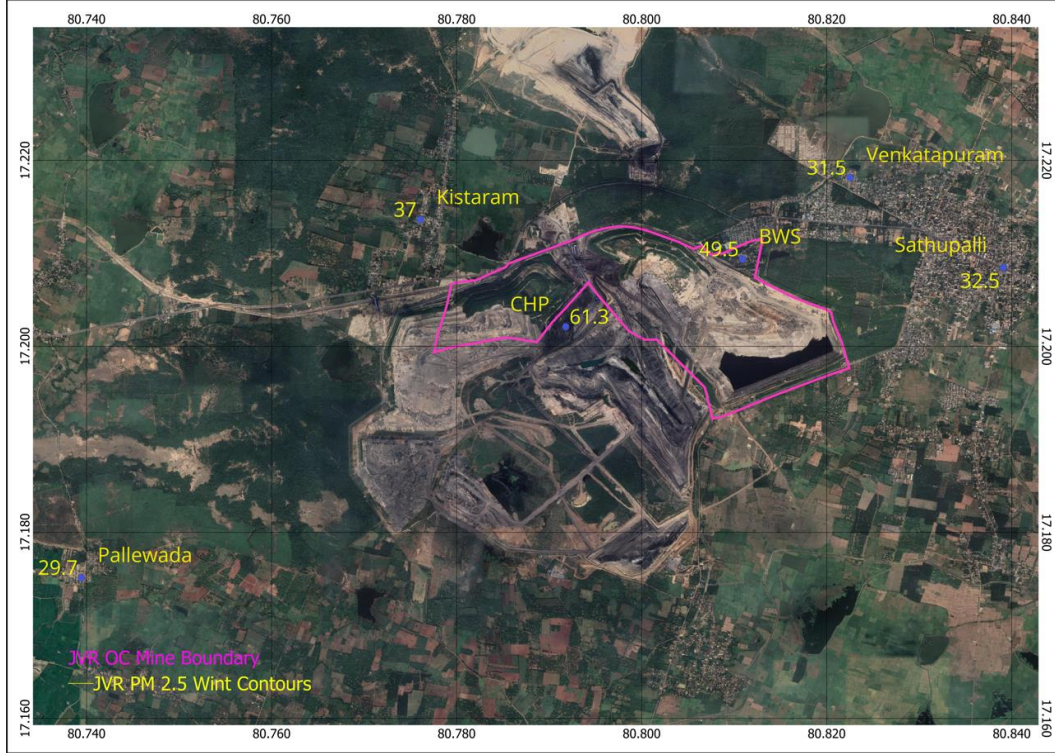


Figure 4.23(c) Image of PM_{2.5} contours during winter season in and around JVR OC

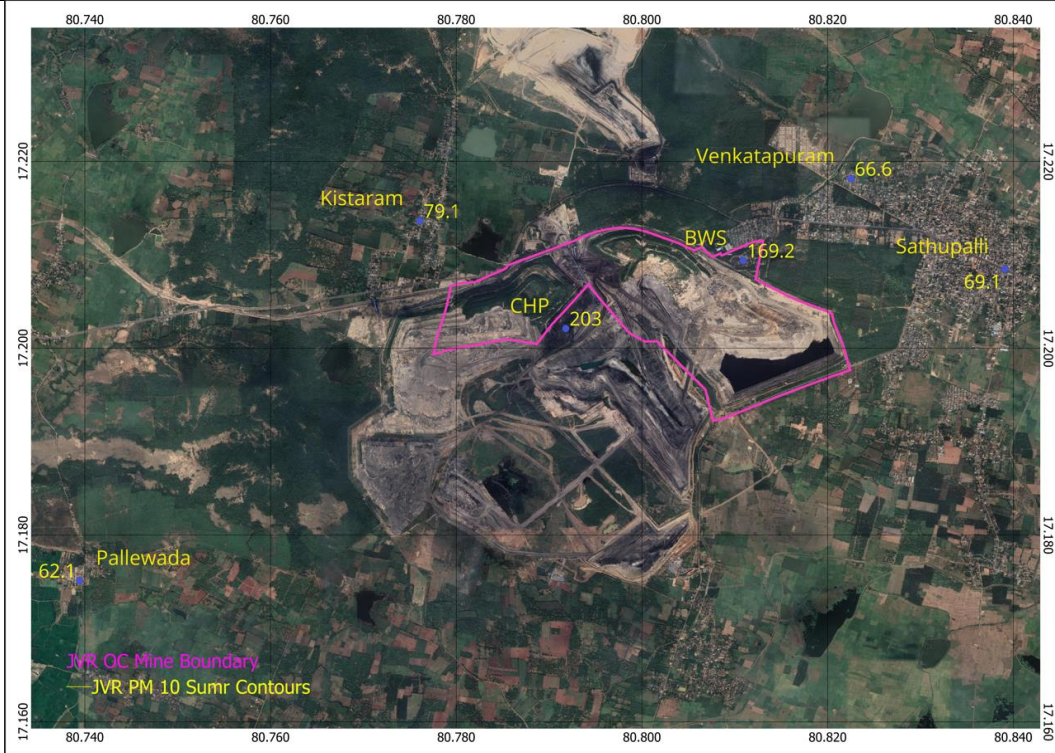


Figure 4.23(d) Image of PM₁₀ contours during summer season in and around JVR OC

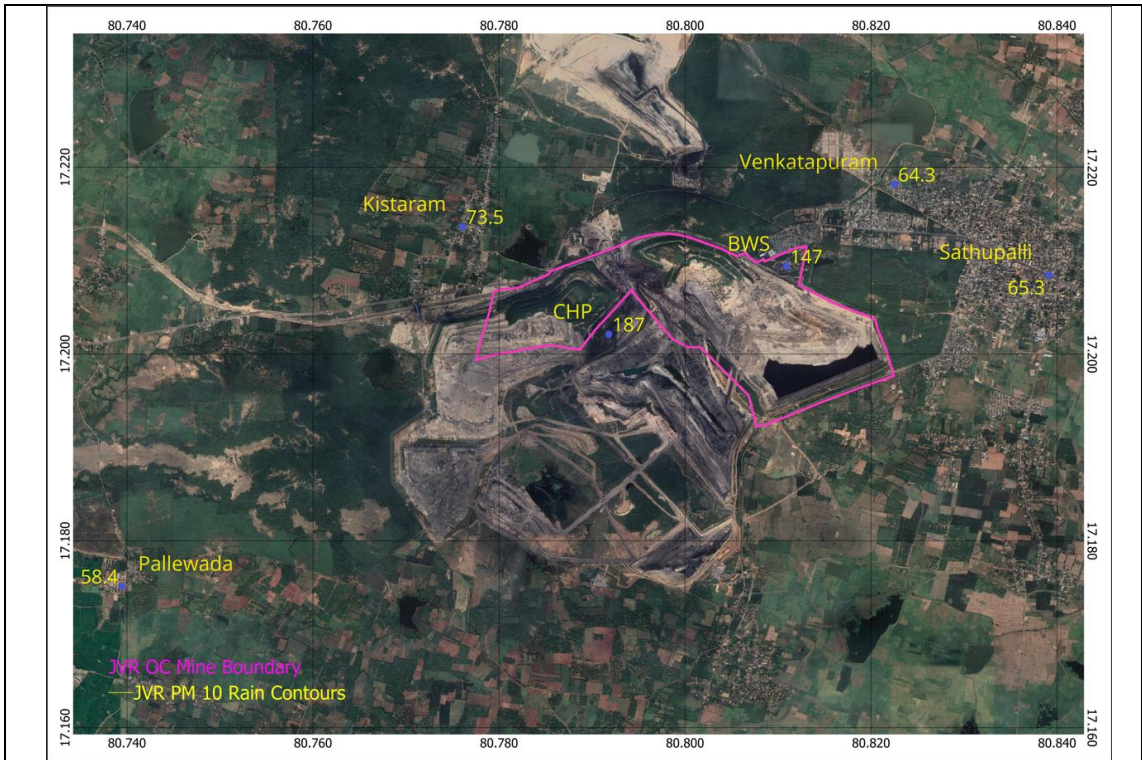


Figure 4.23(e) Image of PM₁₀ contours during rainy season in and around JVR OC

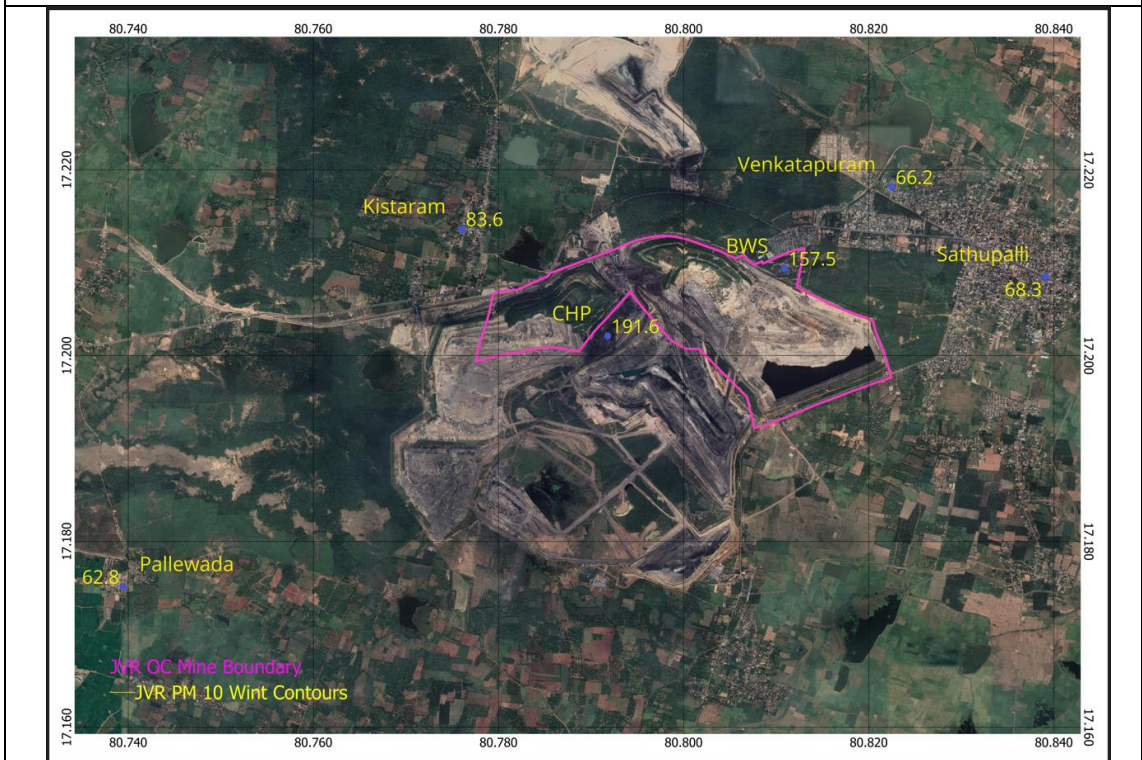


Figure 4.23(f) Image of PM₁₀ contours during winter season in and around JVR OC

Figure 4.23 Images of PM_{2.5} and PM₁₀ during 3 seasons in and around JVR OC

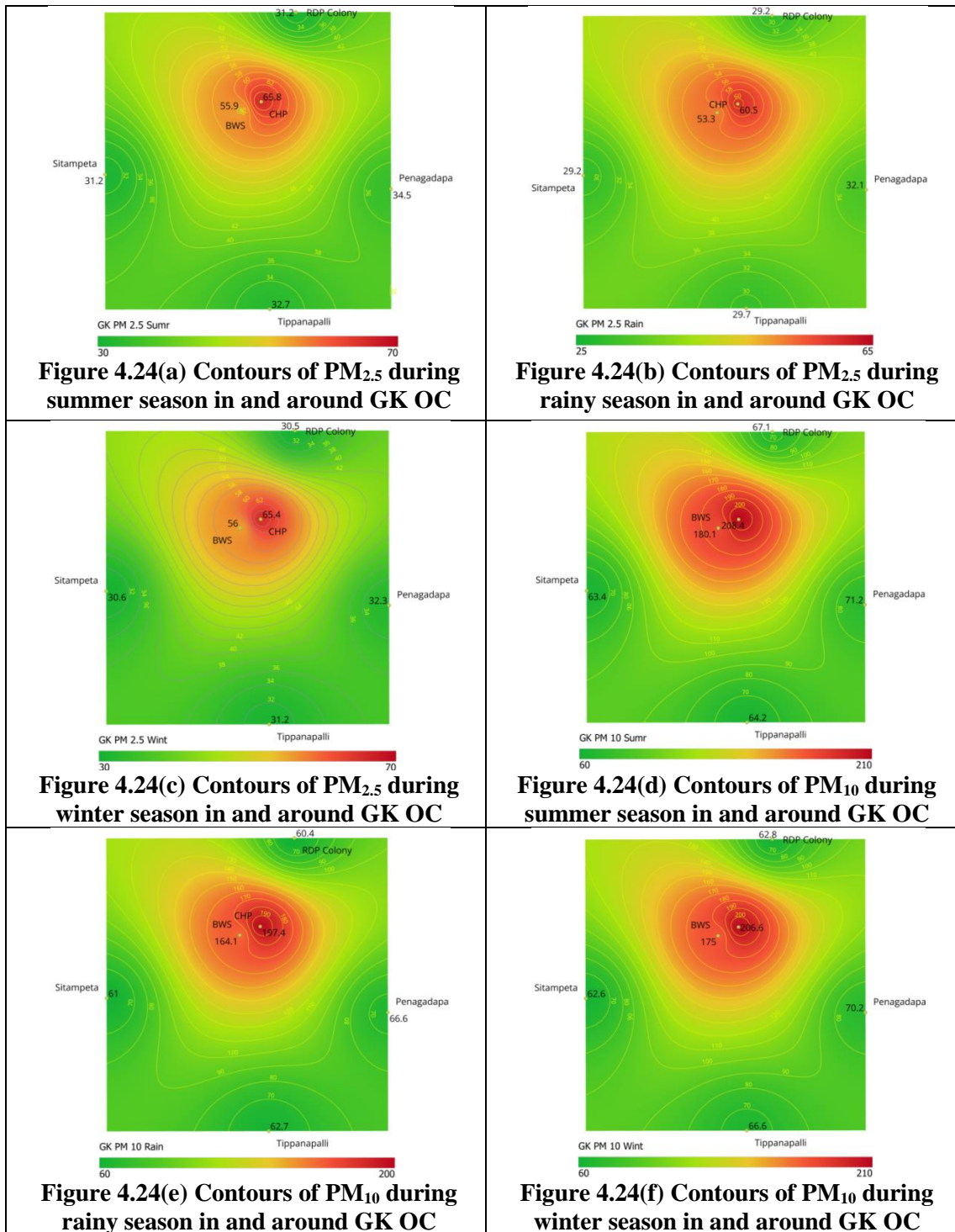


Figure 4.24 Contours of PM_{2.5} and PM₁₀ during 3 seasons in and around GK OC

From the above contour plots of GK OC, the highest and lowest values of PM_{2.5} are 65.8 $\mu\text{g}/\text{m}^3$ in summer and 29.2 $\mu\text{g}/\text{m}^3$ in rainy. Similarly, highest and lowest values of PM₁₀ are 208.4 $\mu\text{g}/\text{m}^3$ in summer and 60.4 $\mu\text{g}/\text{m}^3$ in rainy season.

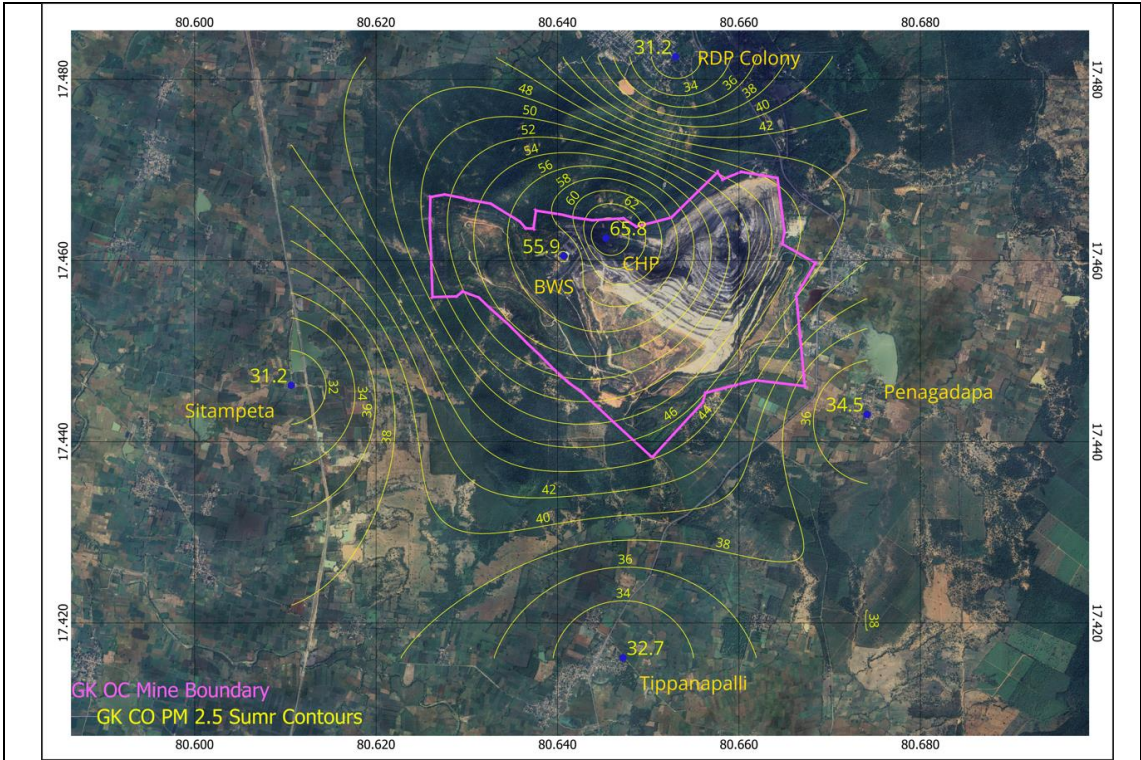


Figure 4.25(a) Image of PM_{2.5} contours during summer season in and around GK OC

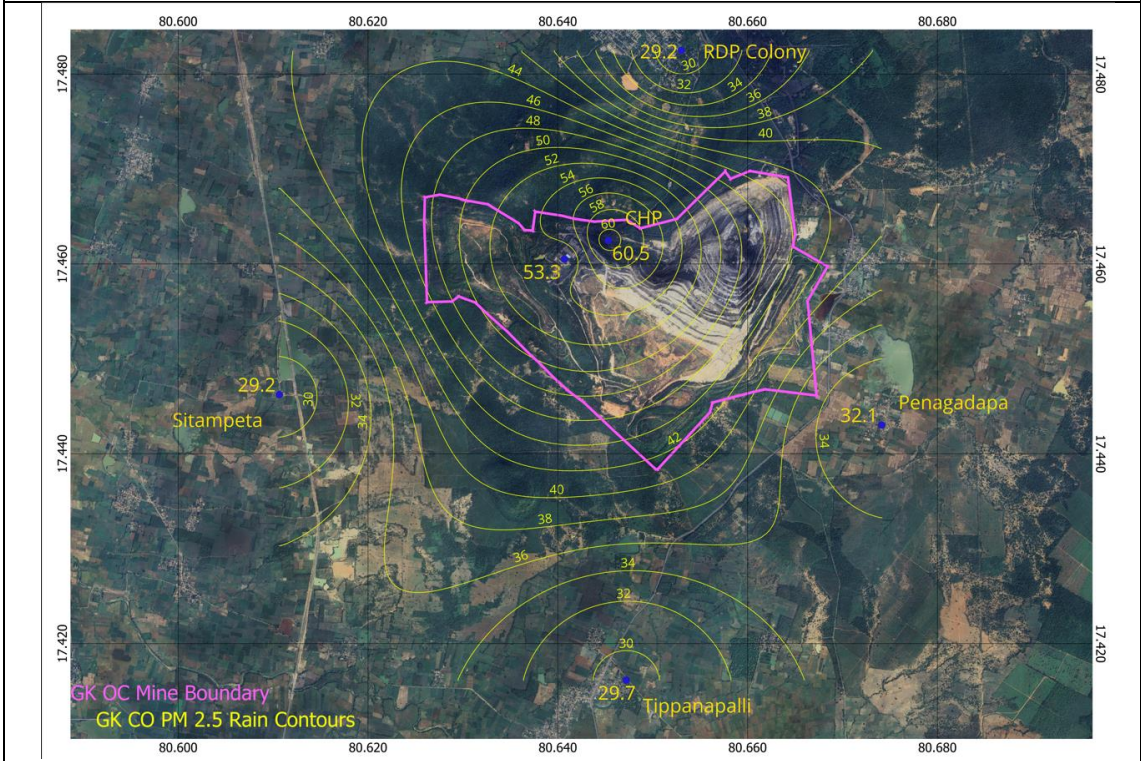


Figure 4.25(b) Image of PM_{2.5} contours during rainy season in and around GK OC

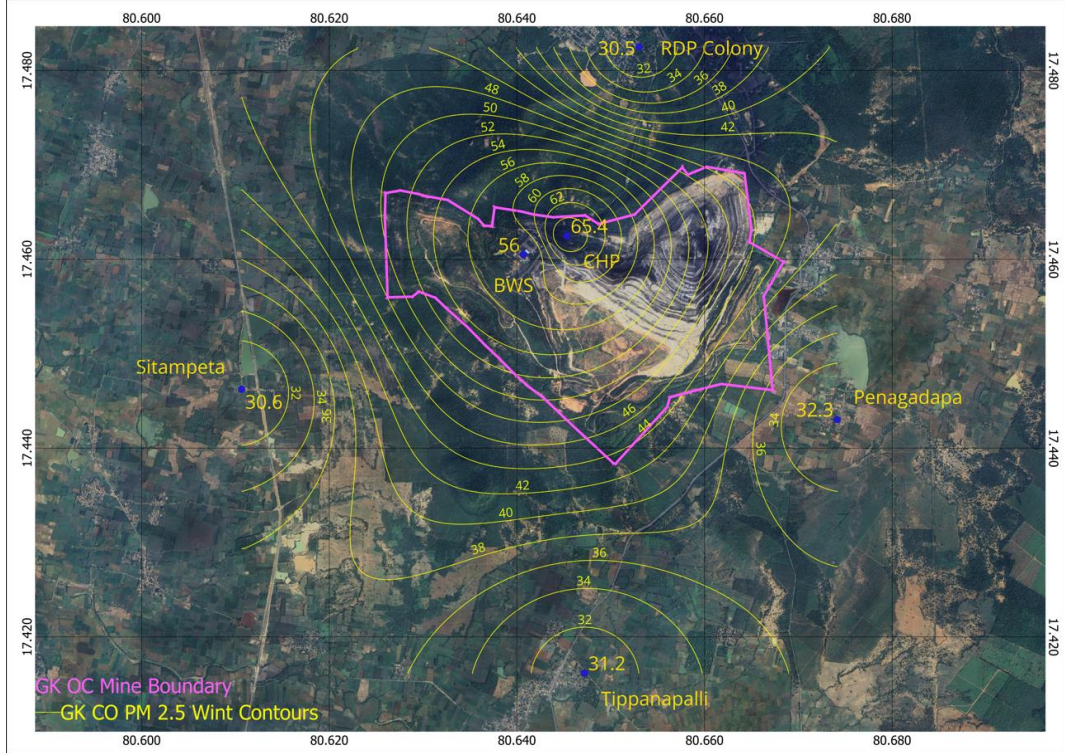


Figure 4.25(c) Image of PM_{2.5} contours during winter season in and around GK OC

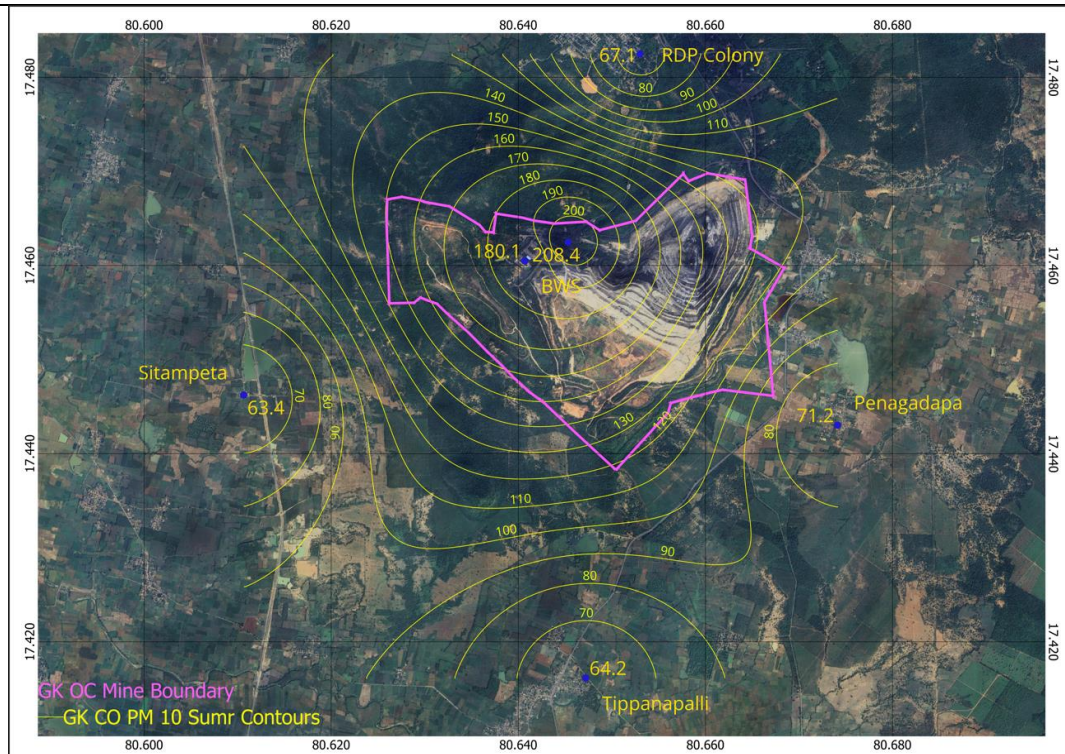


Figure 4.25(d) Image of PM₁₀ contours during summer season in and around GK OC

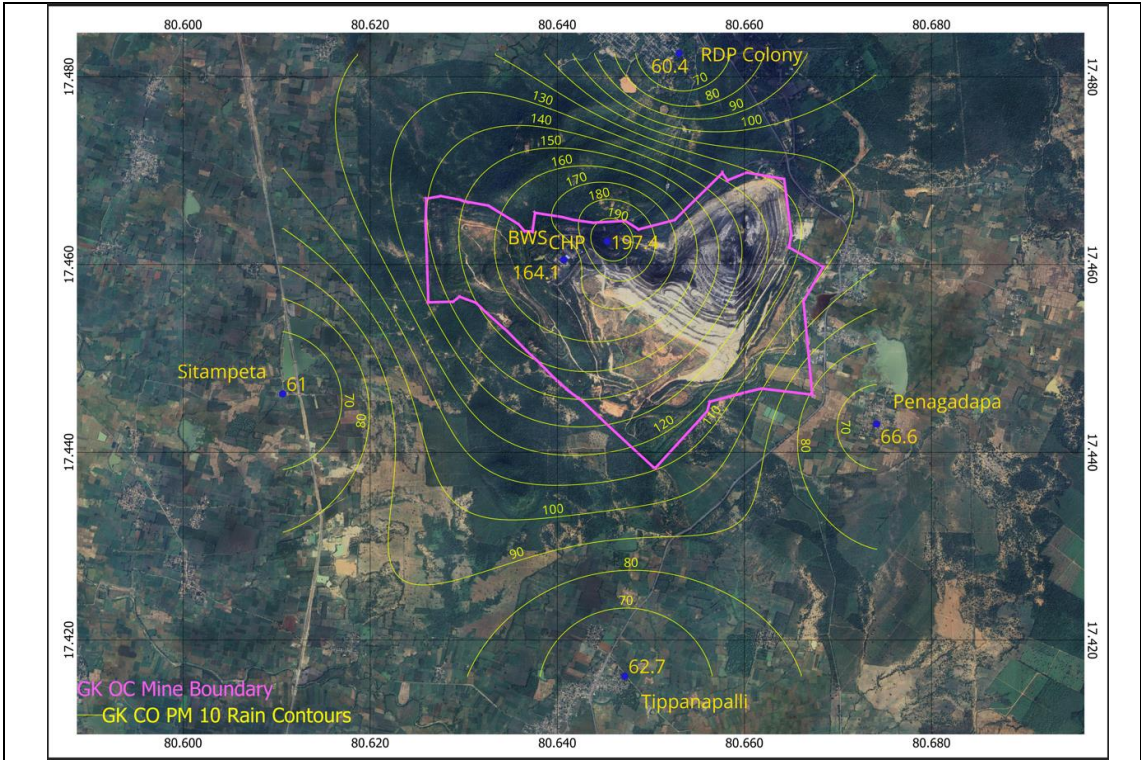


Figure 4.25(e) Image of PM₁₀ contours during rainy season in and around GK OC

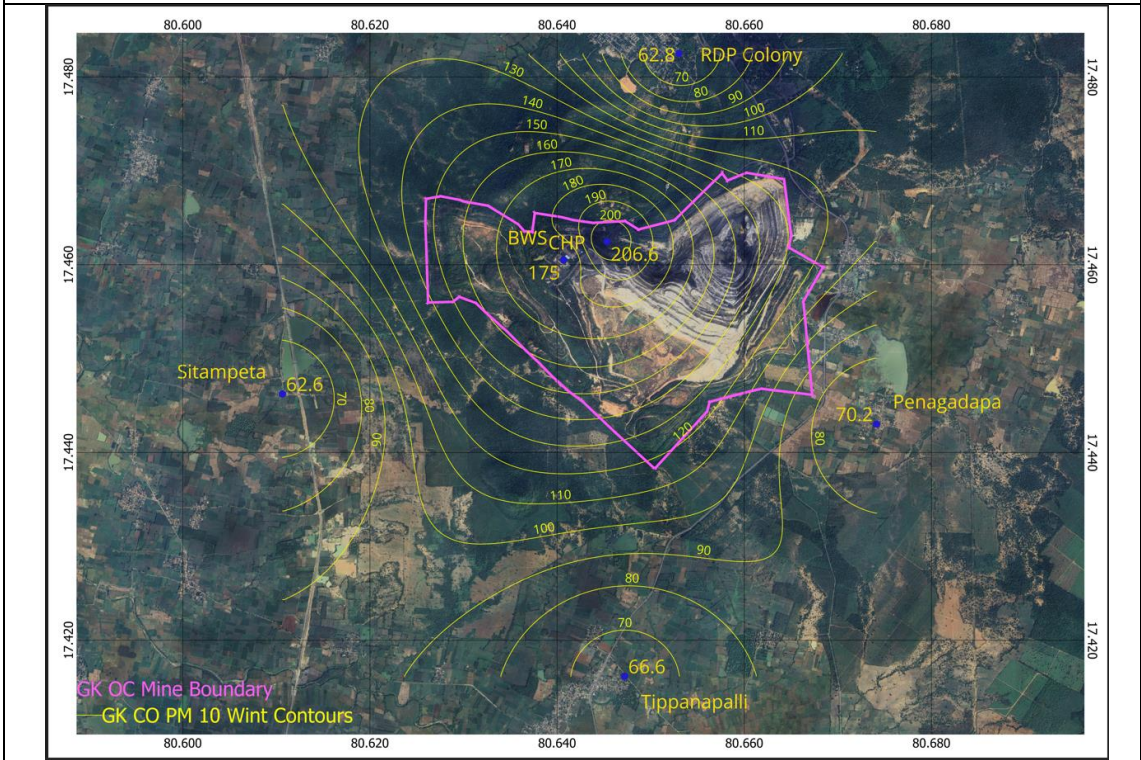


Figure 4.25(f) Image of PM₁₀ contours during winter season in and around GK OC

Figure 4.25 Images of PM_{2.5} and PM₁₀ during 3 seasons in and around GK OC

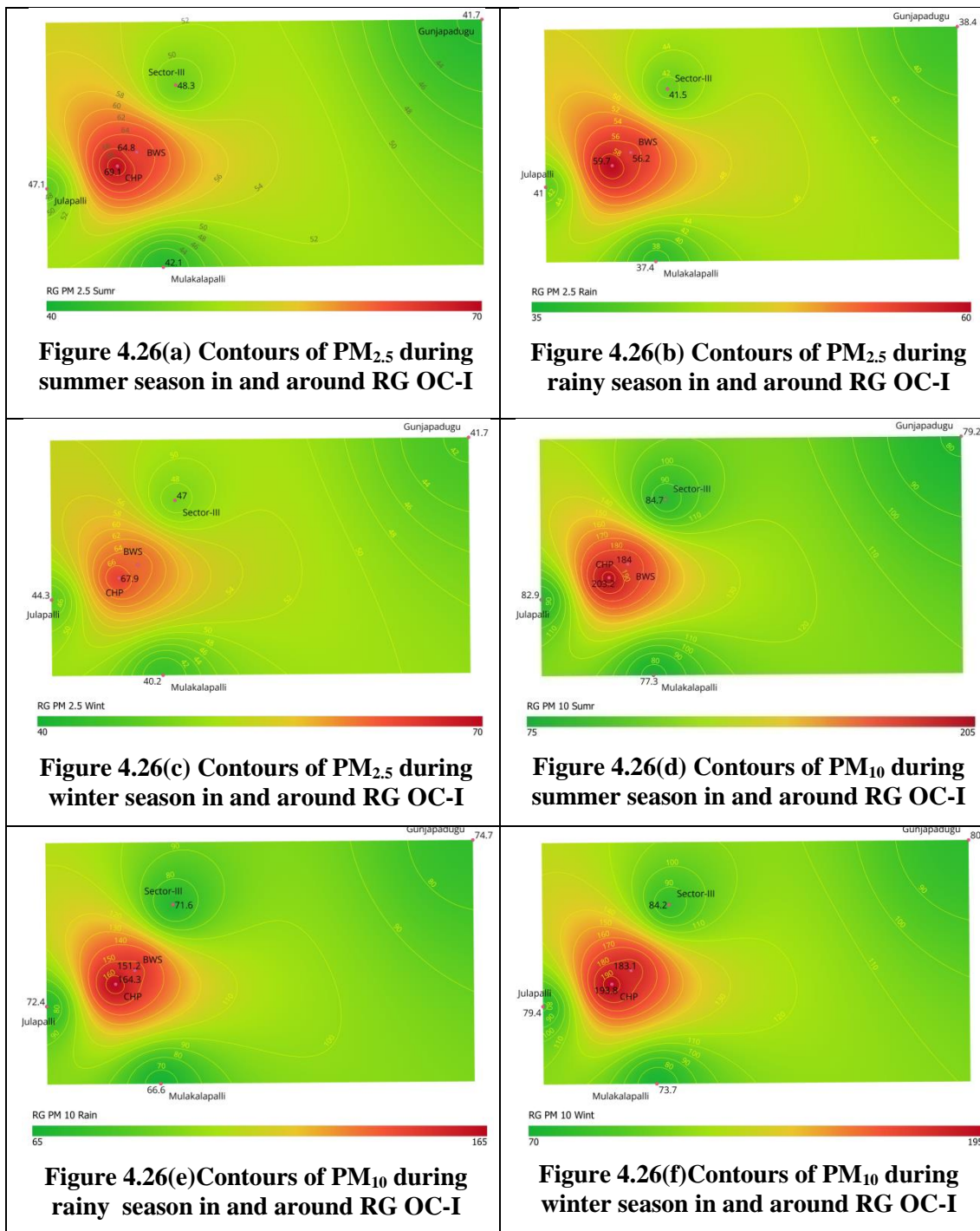


Figure 4.26 Contours of PM_{2.5} and PM₁₀ during 3 seasons in and around RG OC-I

Contour plots are generated for all 6 locations of RG OC-I for three seasons. The highest and lowest values for PM_{2.5} are 69.1 in summer and 37.4 in rainy. Similarly, highest and lowest values for PM₁₀ are 208.4 in summer and 197.4 in rainy season.

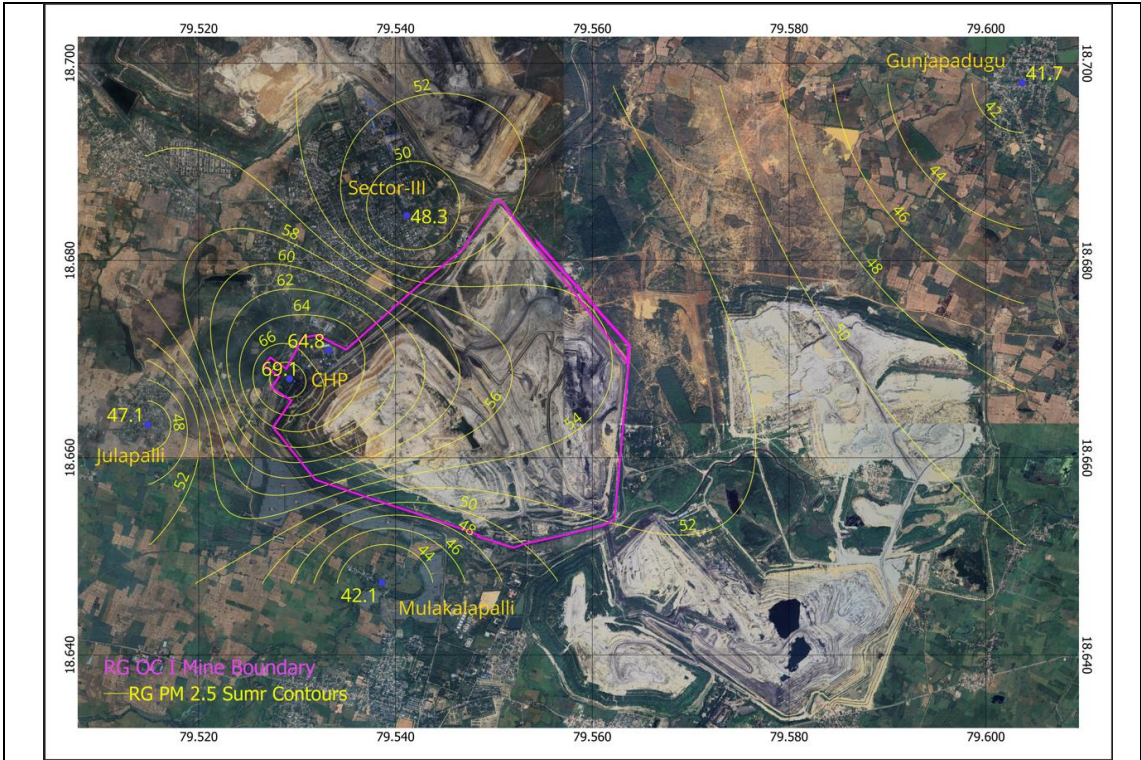


Figure 4.27(a) Image of PM_{2.5} contours during summer season in and around RG OC-I

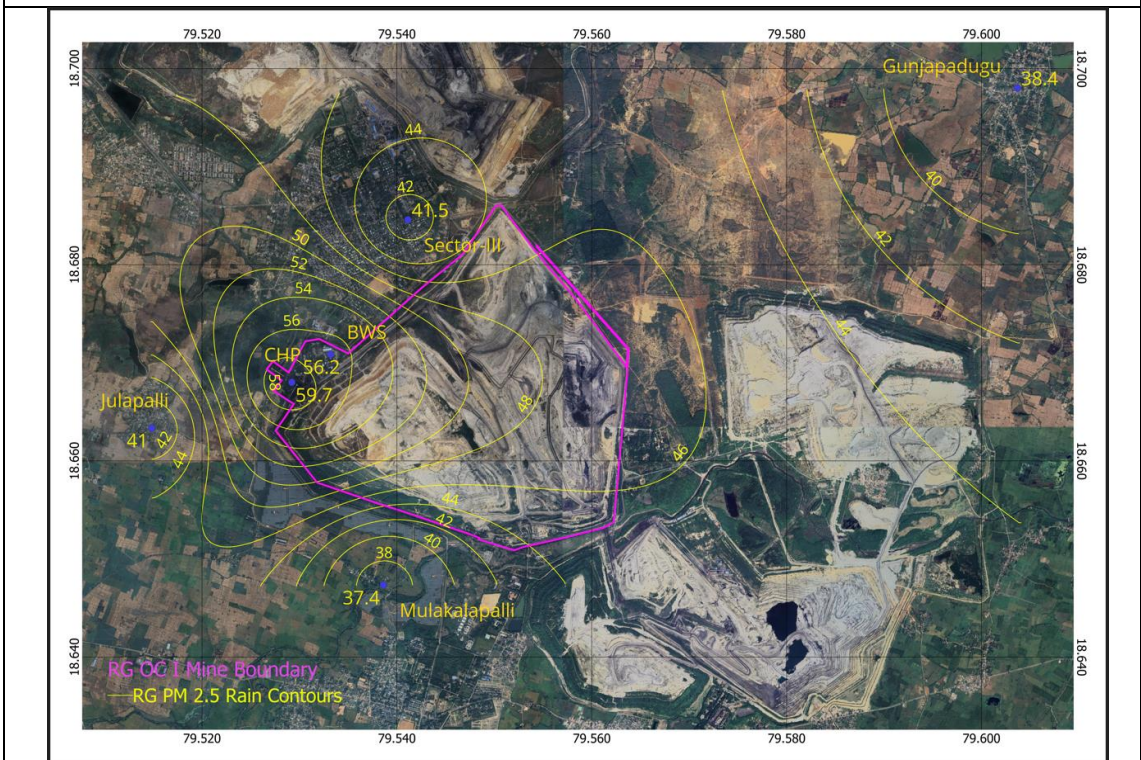


Figure 4.27(b) Image of PM_{2.5} contours during rainy season in and around RG OC-I

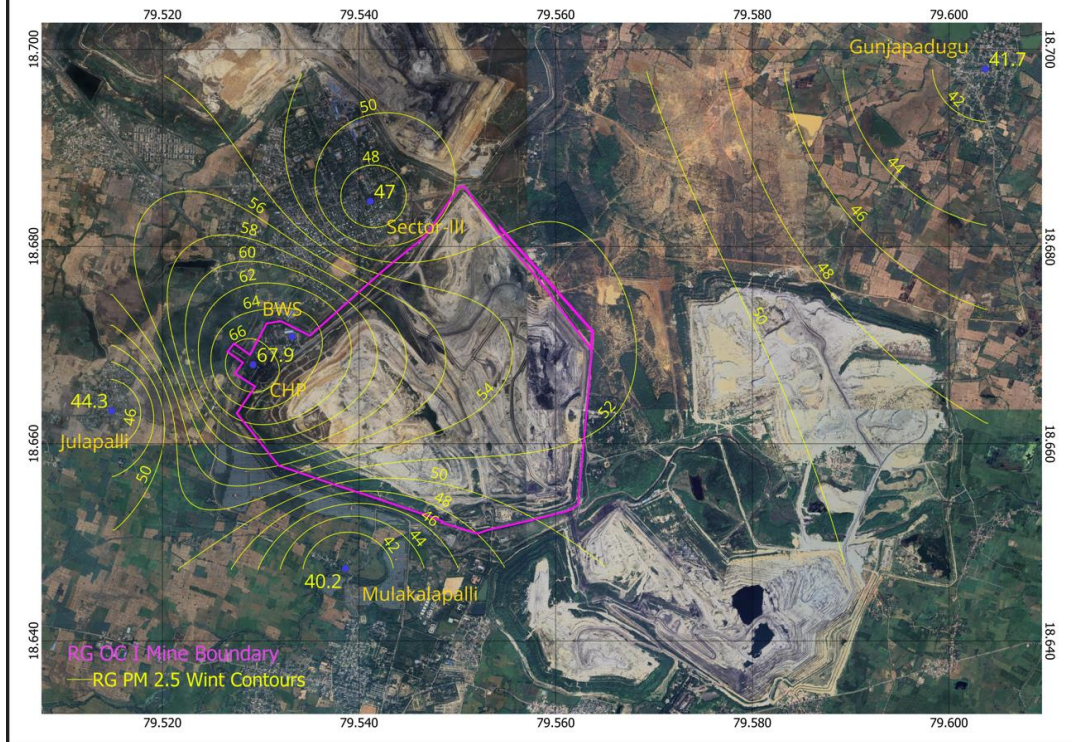


Figure 4.27(c) Image of PM_{2.5} contours during winter season in and around RG OC-I

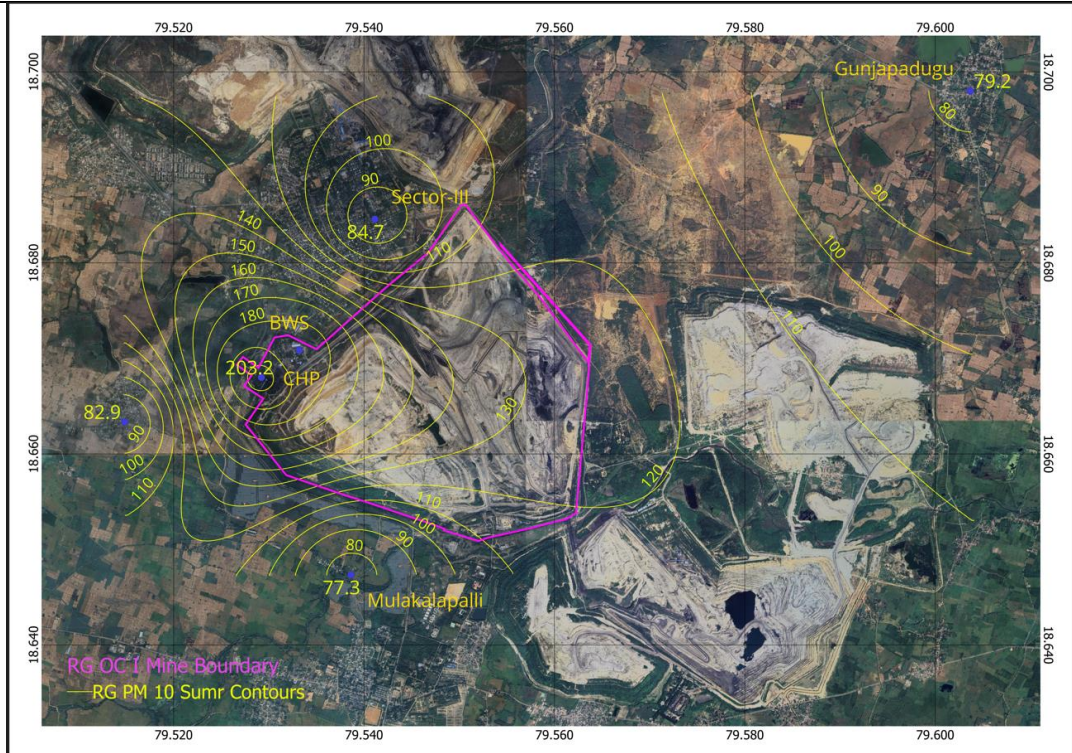


Figure 4.27(d) Image of PM₁₀ contours during summer season in and around RG OC-I

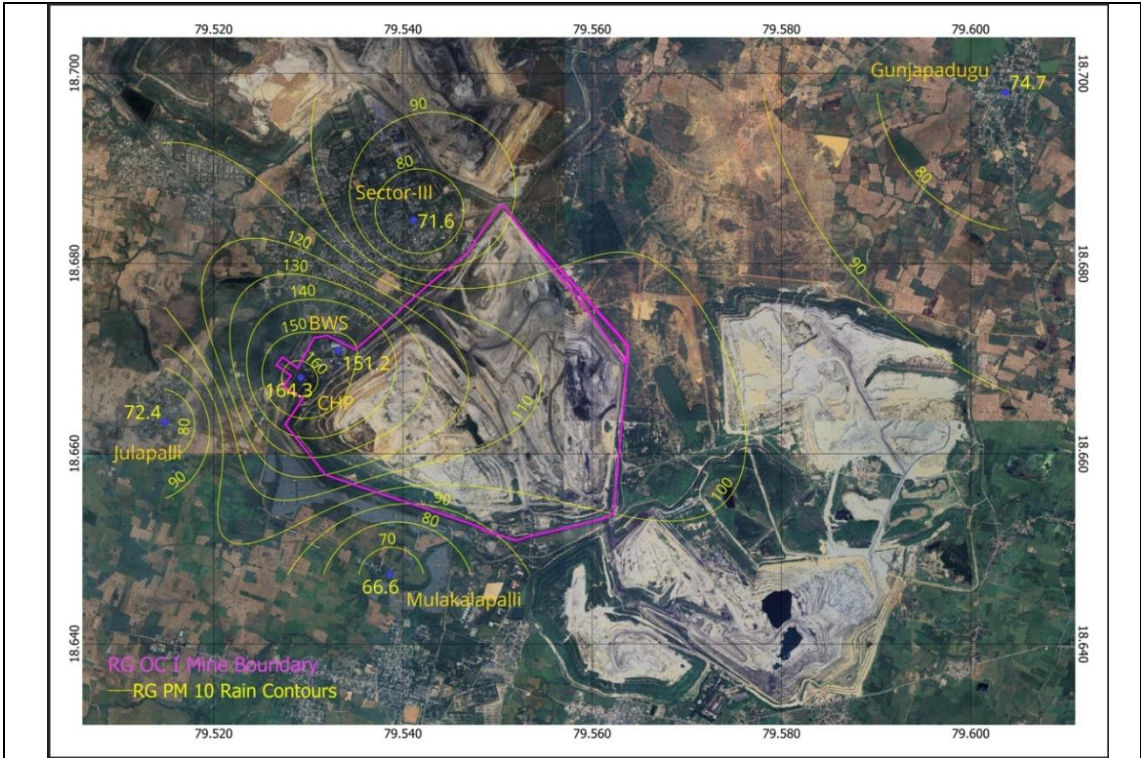


Figure 4.27(e) Image of PM₁₀ contours during rainy season in and around RG OC-I

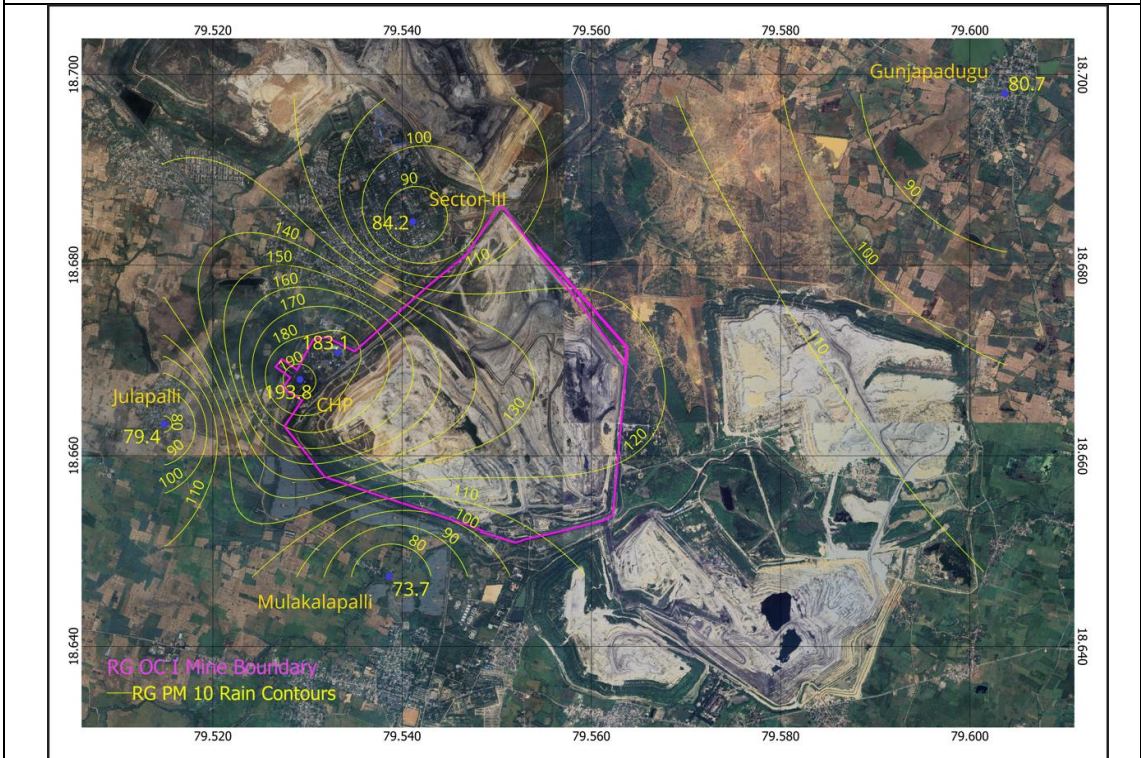


Figure 4.27(f) Image of PM₁₀ contours during winter season in and around RG OC-I

Figure 4.27 Images of PM_{2.5} and PM₁₀ during 3 seasons in and around RG OC-I

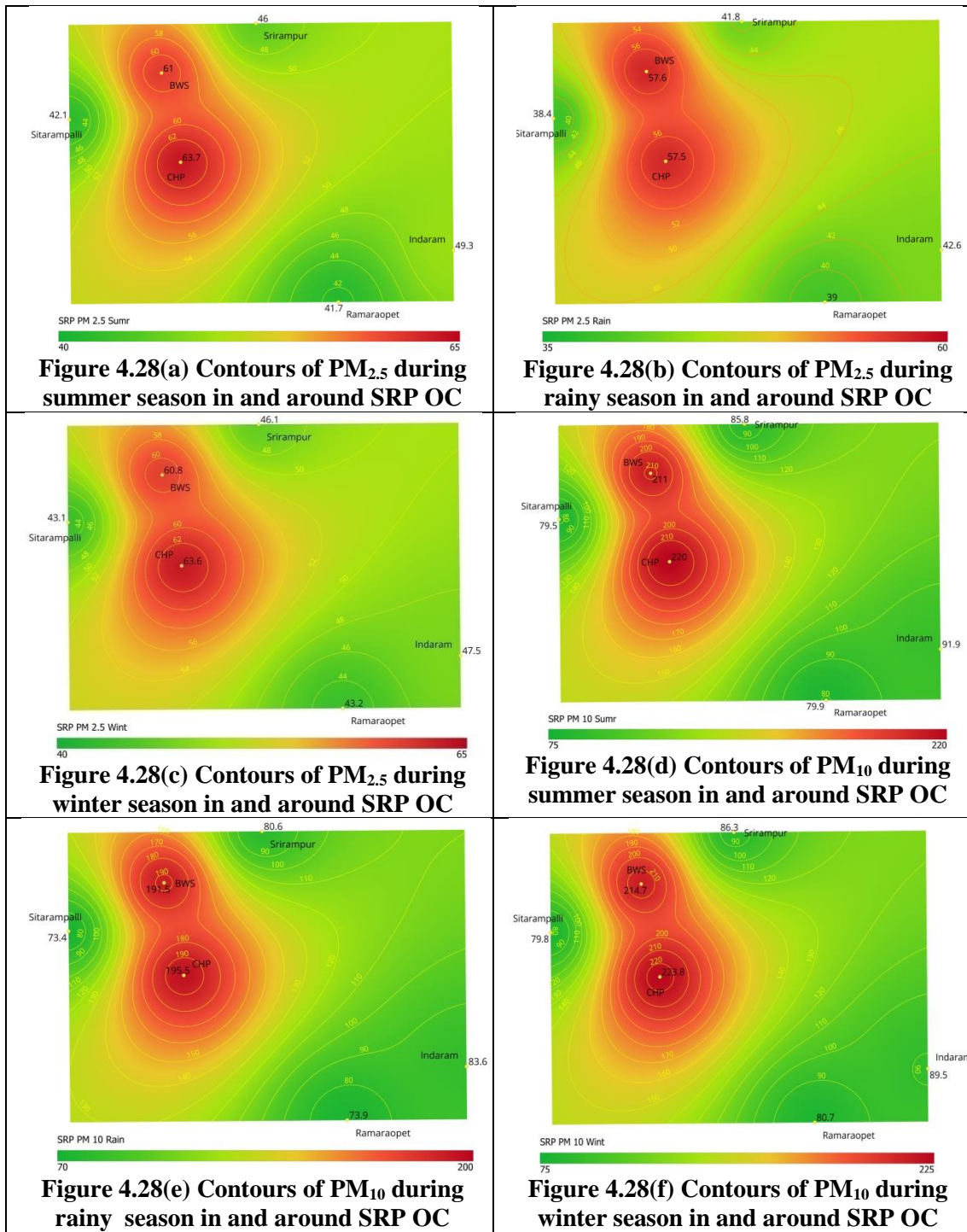


Figure 4.28 Contours of PM_{2.5} and PM₁₀ during 3 seasons in and around SRP OC

From the above contour plots of SRP OC, the highest and lowest values of PM_{2.5} are 63.7 $\mu\text{g}/\text{m}^3$ in summer and 38.4 $\mu\text{g}/\text{m}^3$ in rainy. Similarly, highest and lowest values of PM₁₀ are 223.8 $\mu\text{g}/\text{m}^3$ in summer and 73.4 $\mu\text{g}/\text{m}^3$ in rainy season.

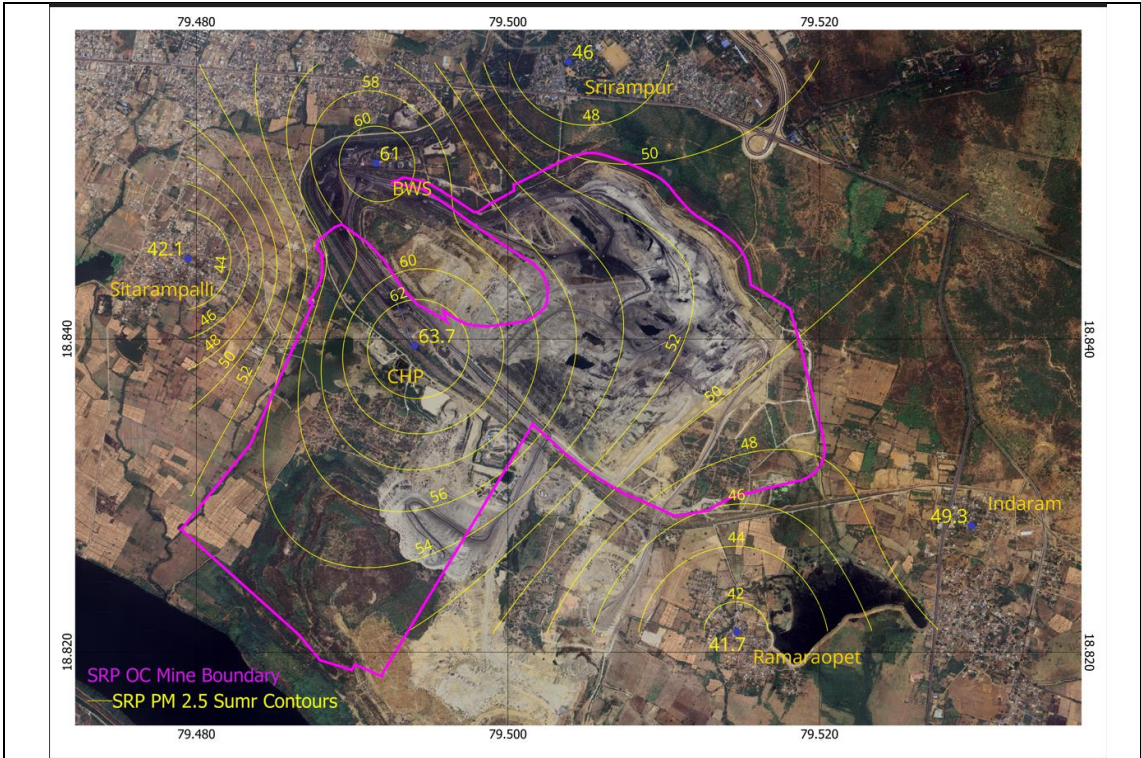


Figure 4.29(a) Image of PM_{2.5} contours during summer season in and around SRP OC

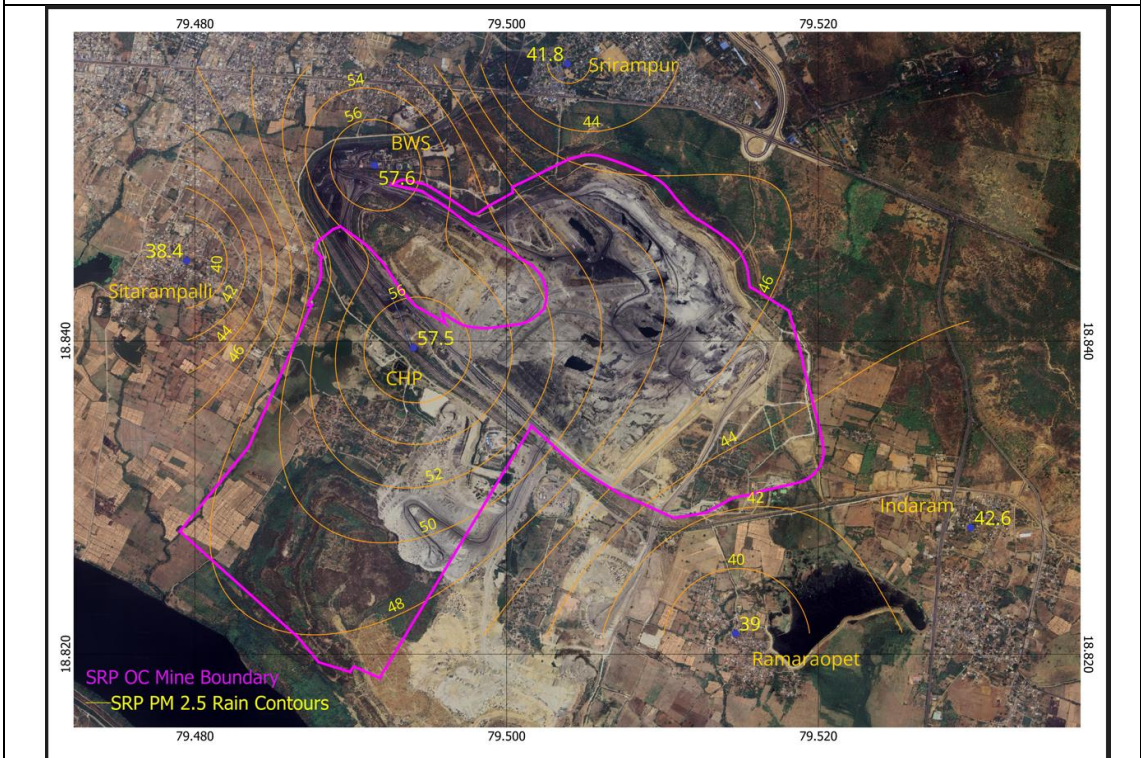


Figure 4.29(b) Image of PM_{2.5} contours during rainy season in and around SRP OC

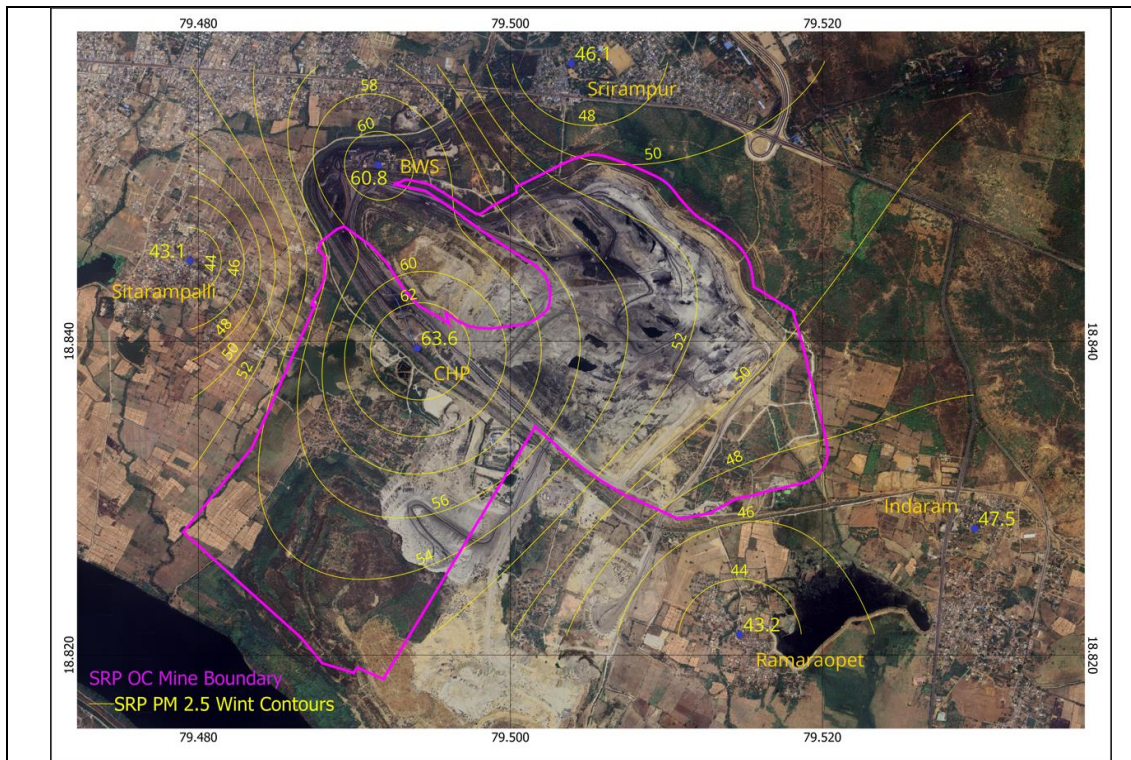


Figure 4.29(c) Image of PM_{2.5} contours during winter season in and around SRP OC

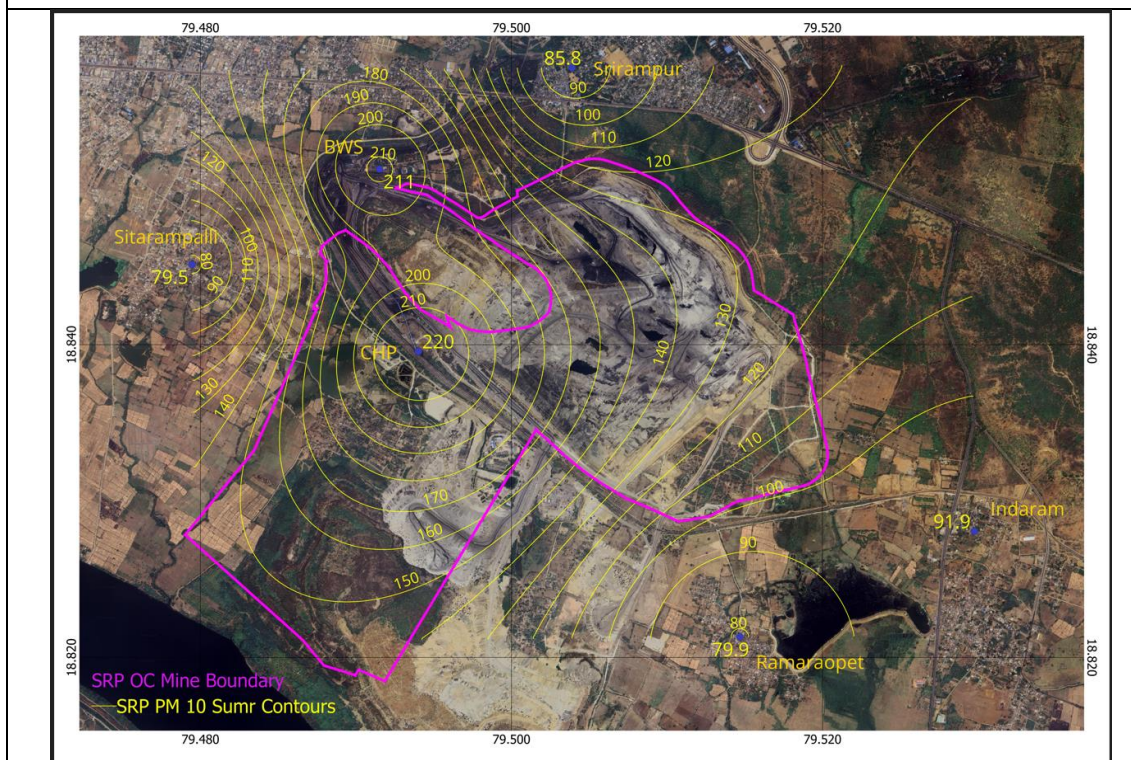


Figure 4.29(d) Image of PM₁₀ contours during summer season in and around SRP OC

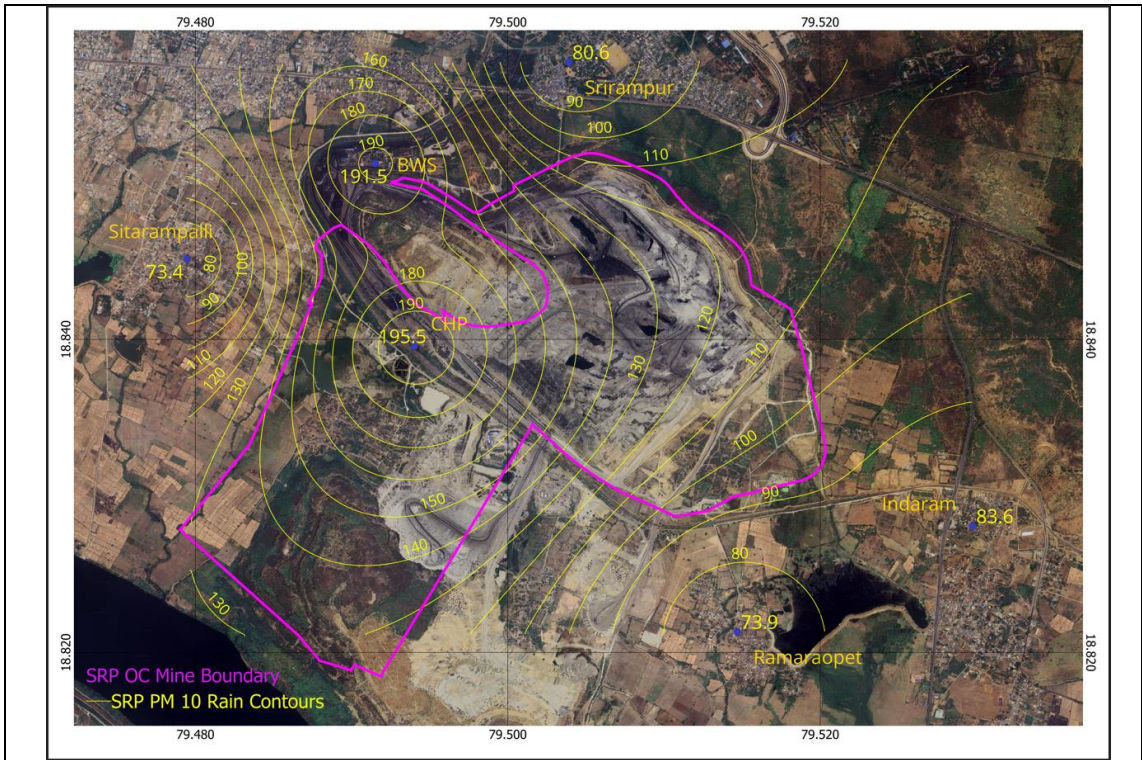


Figure 4.29(e) Image of PM₁₀ contours during rainy season in and around SRP OC

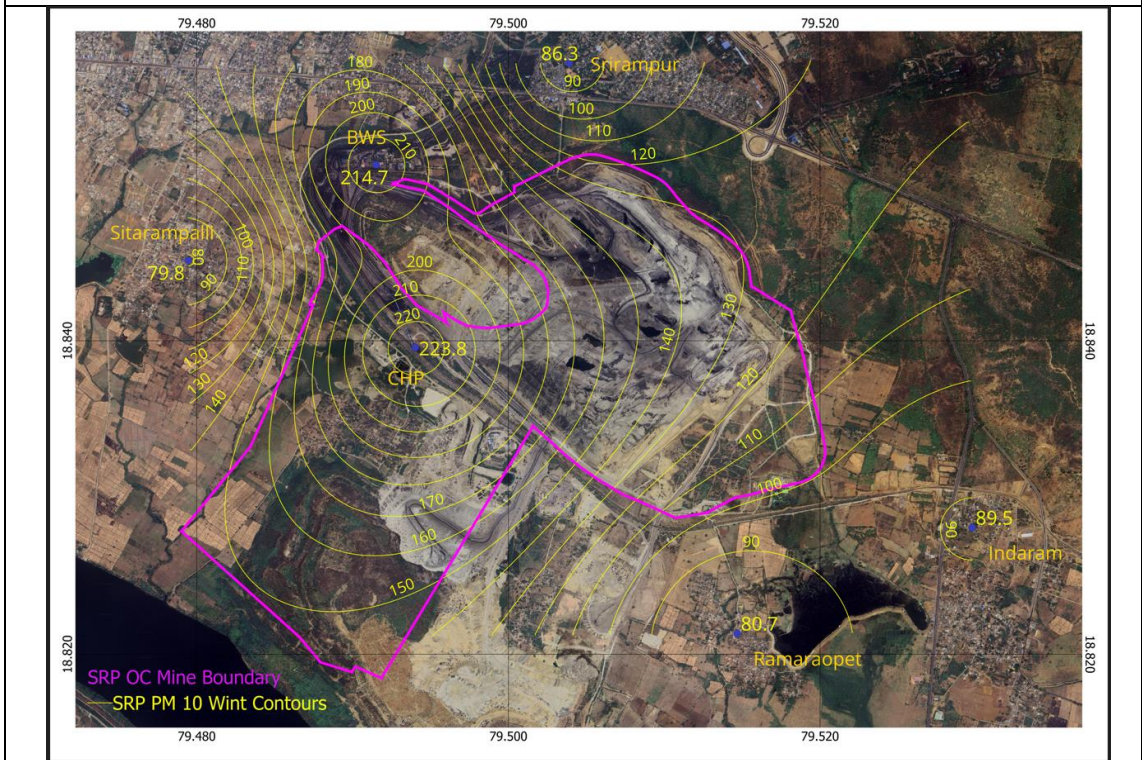


Figure 4.29(f) Image of PM₁₀ contours during winter season in and around SRP OC

Figure 4.29 Images of PM_{2.5} and PM₁₀ during 3 seasons in and around SRP OC

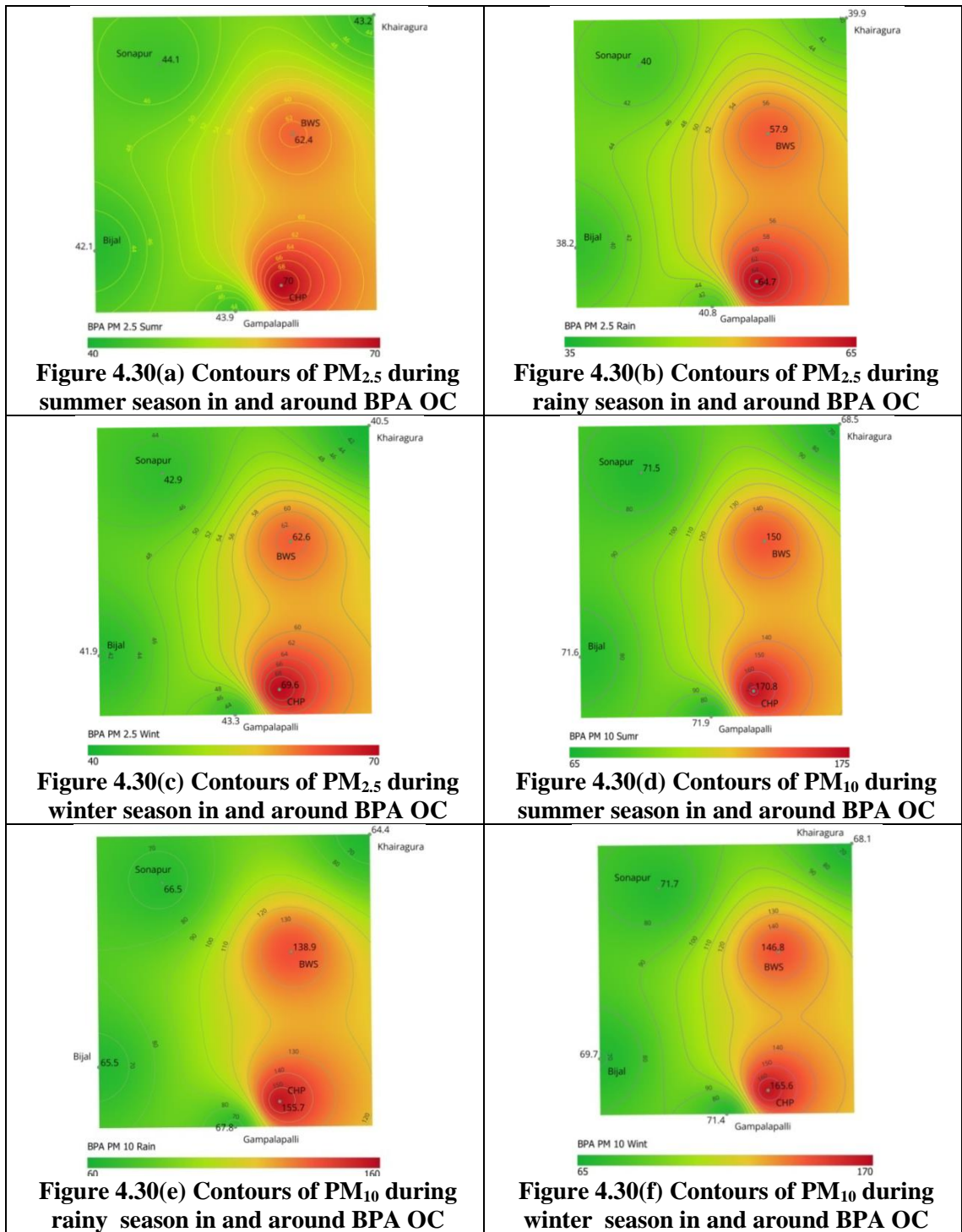


Figure 4.30 Contours of PM_{2.5} and PM₁₀ during 3 seasons in and around BPA OC

From the above contour plots of BPA OC, the highest and lowest values of PM_{2.5} are 70 $\mu\text{g}/\text{m}^3$ in summer and 38.2 $\mu\text{g}/\text{m}^3$ in rainy. Similarly, highest and lowest values of PM₁₀ are 170.8 $\mu\text{g}/\text{m}^3$ in summer and 64.4 $\mu\text{g}/\text{m}^3$ in rainy season.

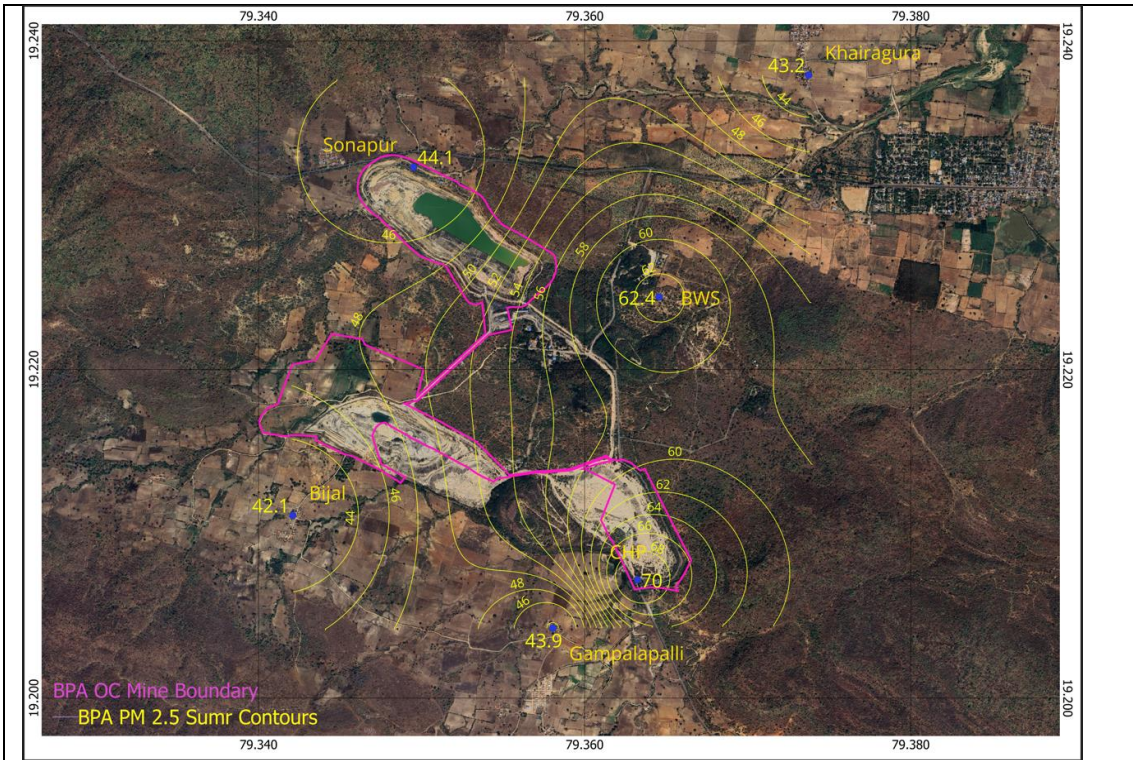


Figure 4.31(a) Image of PM_{2.5} contours during summer season in and around BPA OC

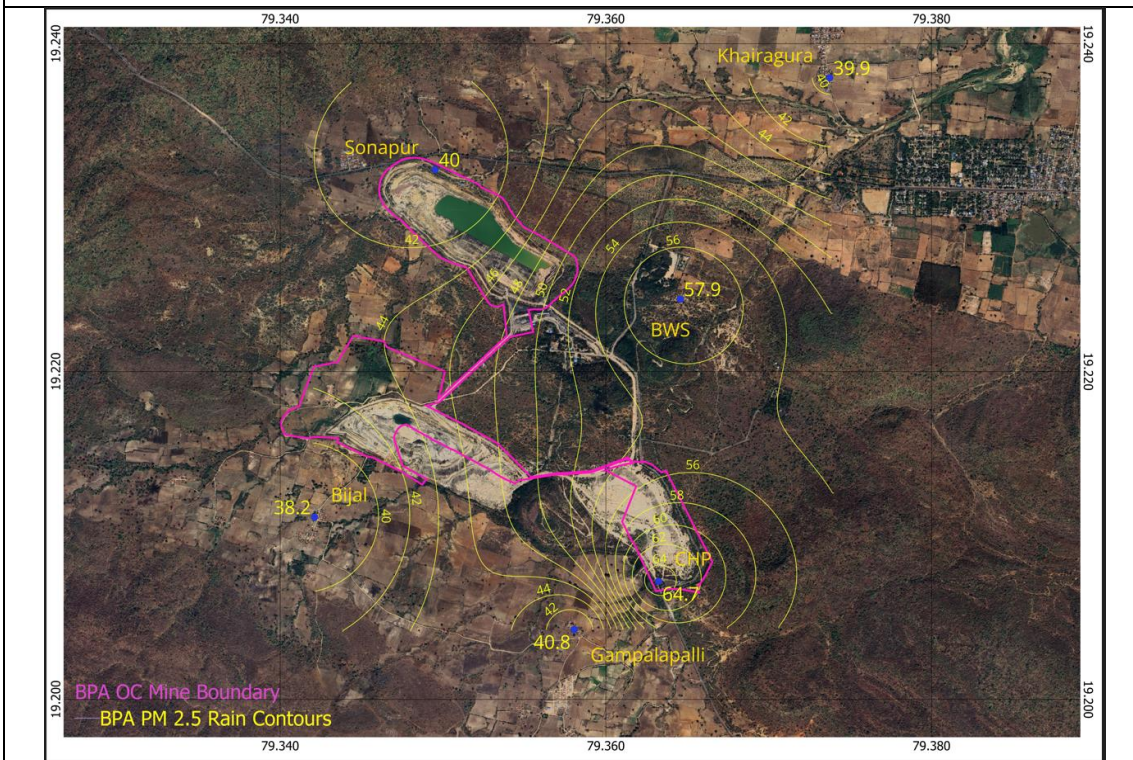


Figure 4.31(b) Image of PM_{2.5} contours during rainy season in and around BPA OC

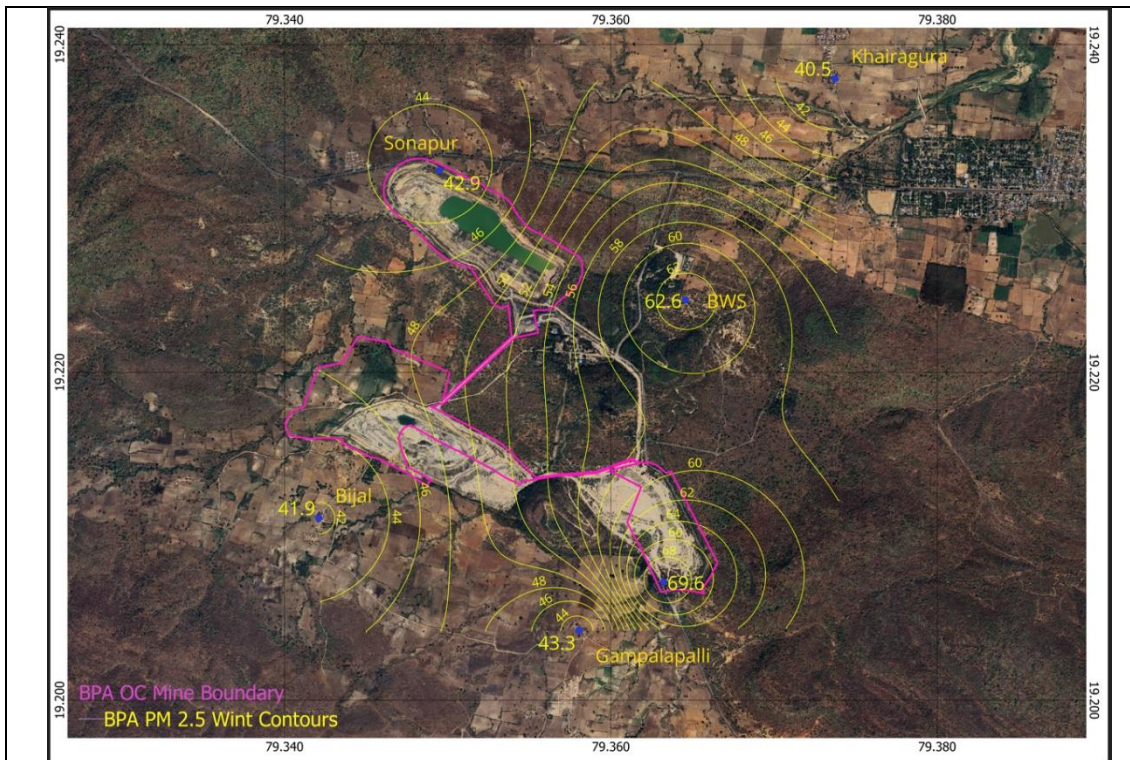


Figure 4.31(c) Image of PM_{2.5} contours during winter season in and around BPA OC

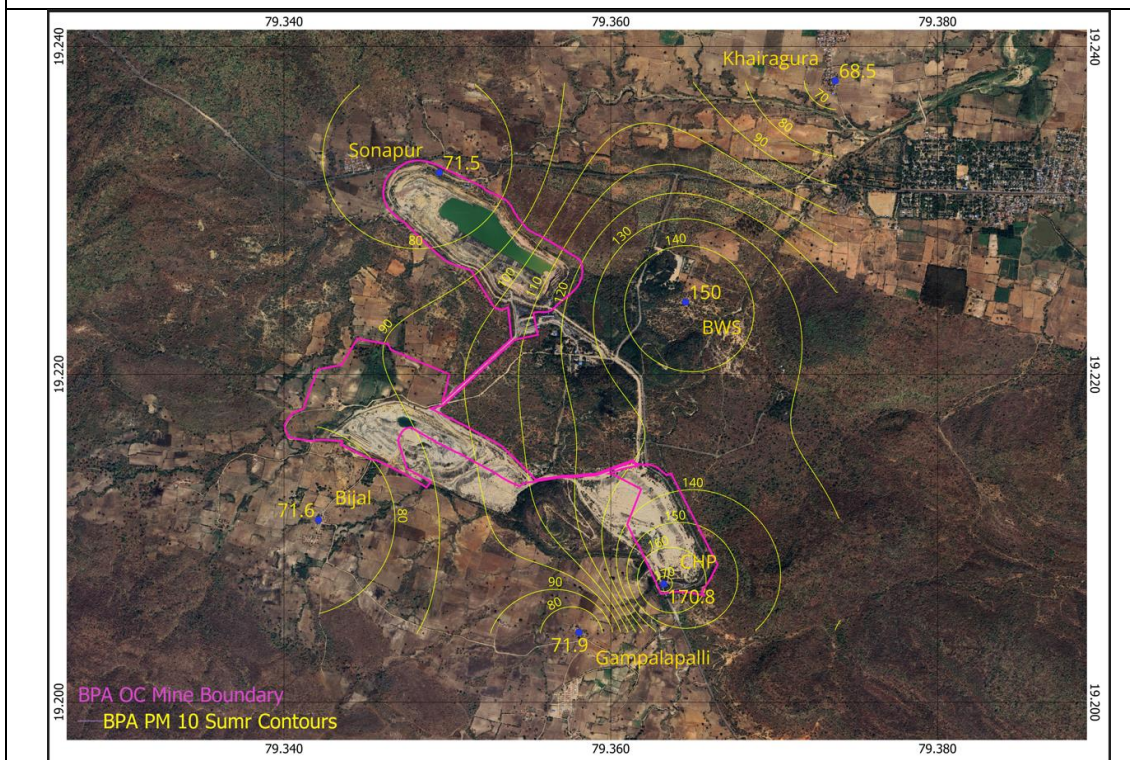


Figure 4.31(d) Image of PM₁₀ contours during summer season in and around BPA OC

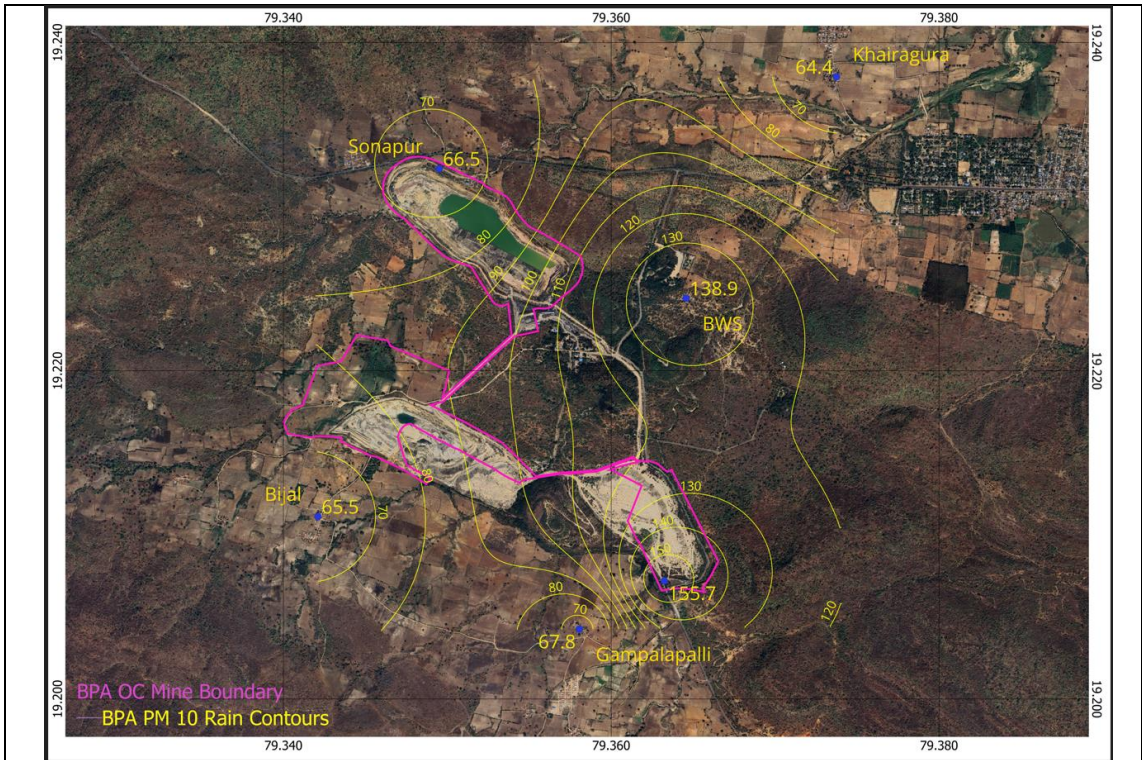


Figure 4.31(e) Image of PM₁₀ contours during rainy season in and around BPA OC

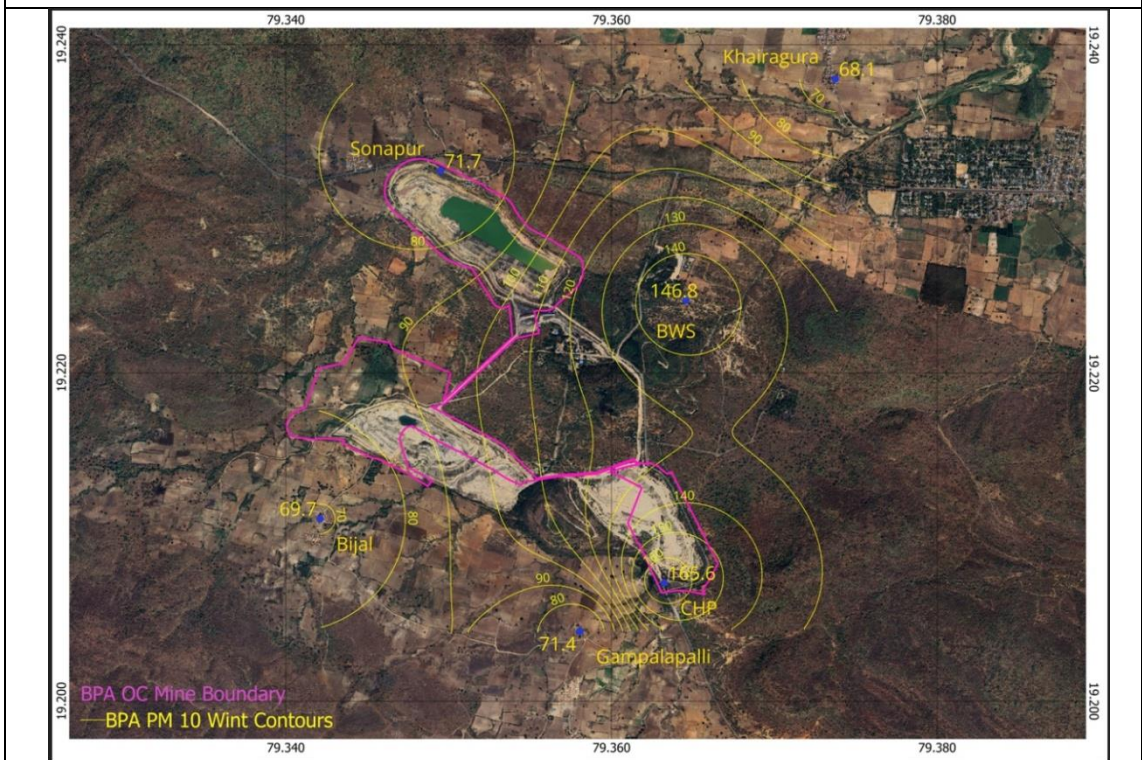


Figure 4.31(f) Image of PM₁₀ contours during winter season in and around BPA OC

Figure 4.31 Images of PM_{2.5} and PM₁₀ during 3 seasons in and around BPA OC

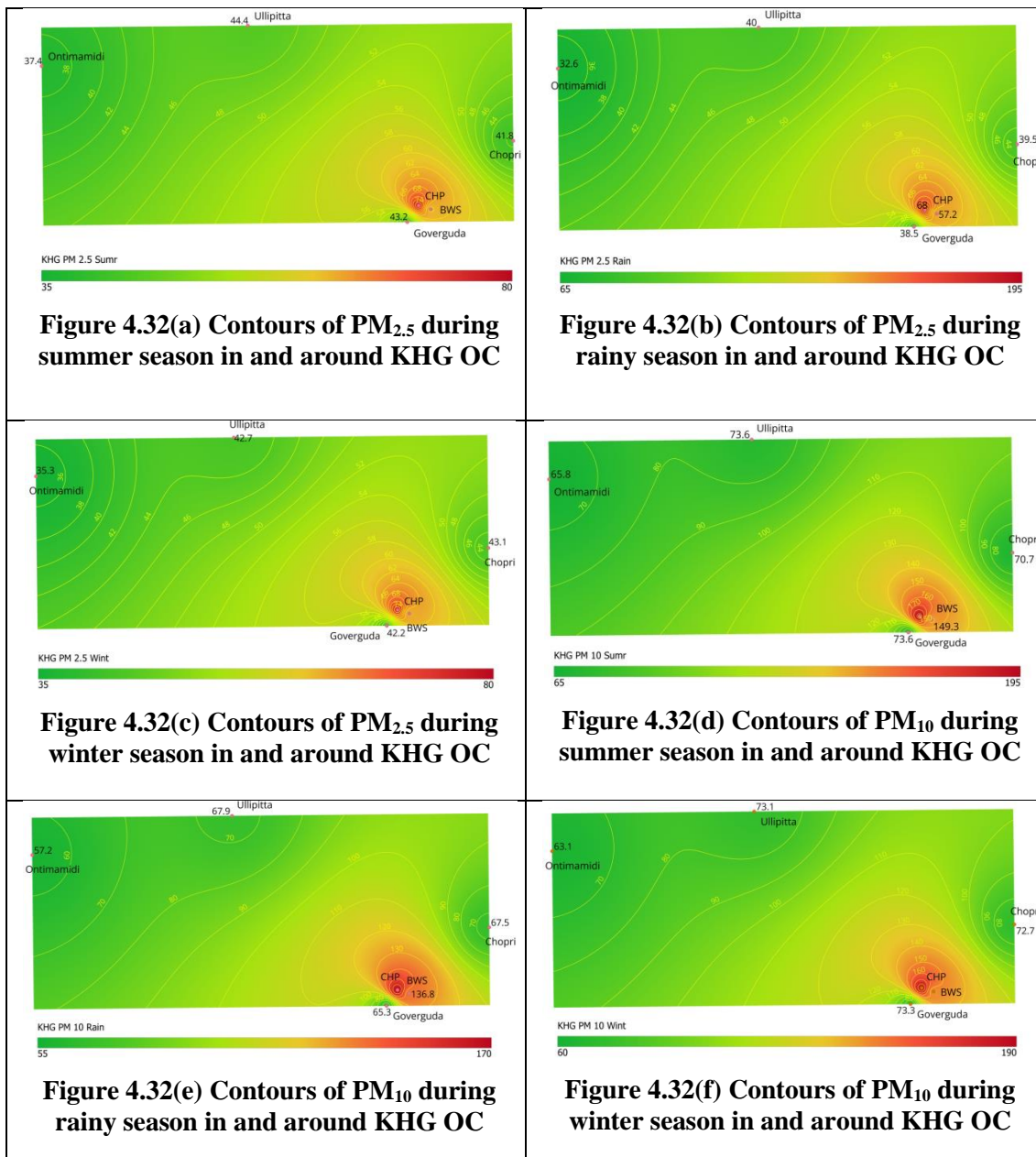


Figure 4.32 Contours of PM_{2.5} and PM₁₀ during 3 seasons in and around KHG OC

Contour plots are generated for 2 locations in core and 4 locations in the buffer zones of KHG OC for three seasons. The highest value for PM_{2.5} is 75.6 in summer and the lowest value is 32.6 $\mu\text{g}/\text{m}^3$ in rainy season. Similarly, highest value for PM₁₀ is 193.6 $\mu\text{g}/\text{m}^3$ in summer and the lowest value is 57.2 $\mu\text{g}/\text{m}^3$ in rainy season.

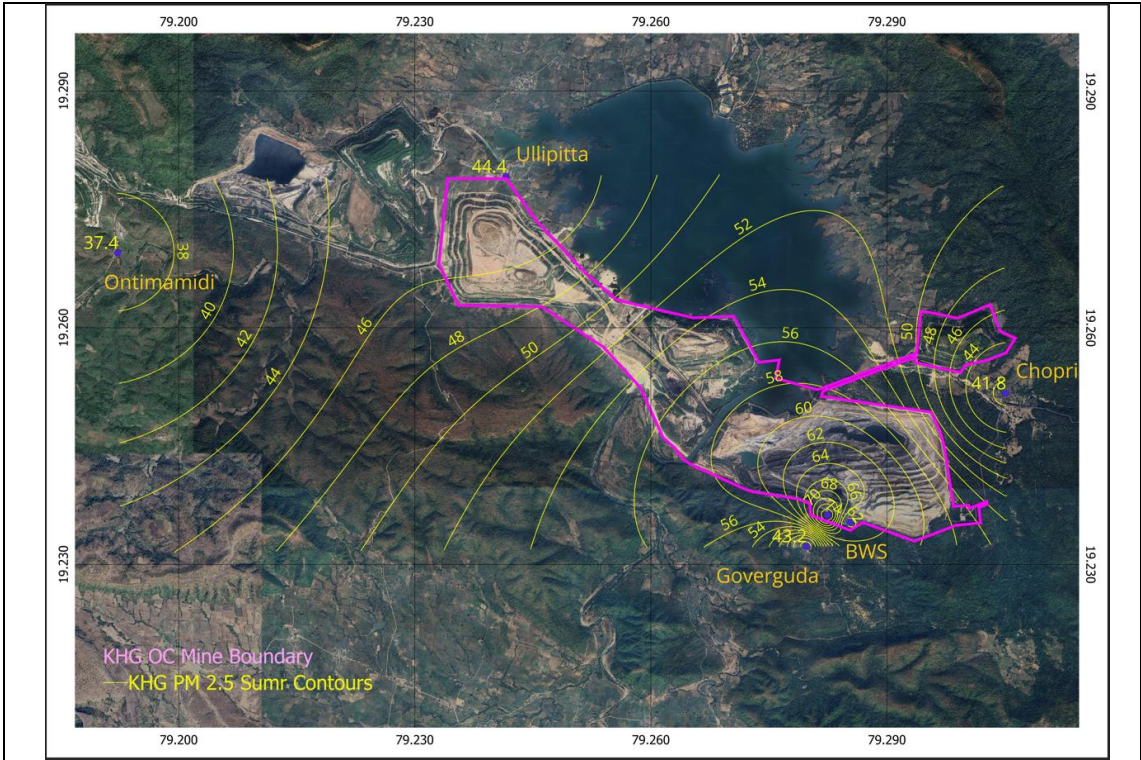


Figure 4.33(a) Image of PM_{2.5} contours during summer season in and around KHG OC

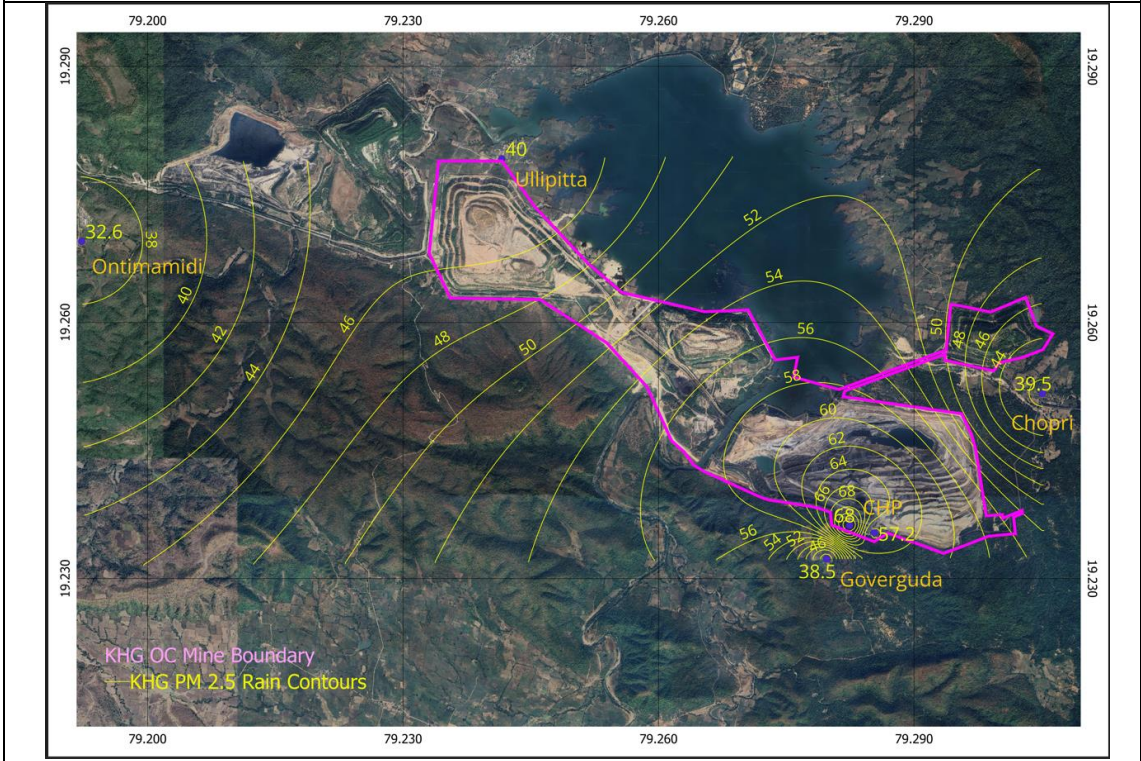


Figure 4.33(b) Image of PM_{2.5} contours during rainy season in and around KHG OC

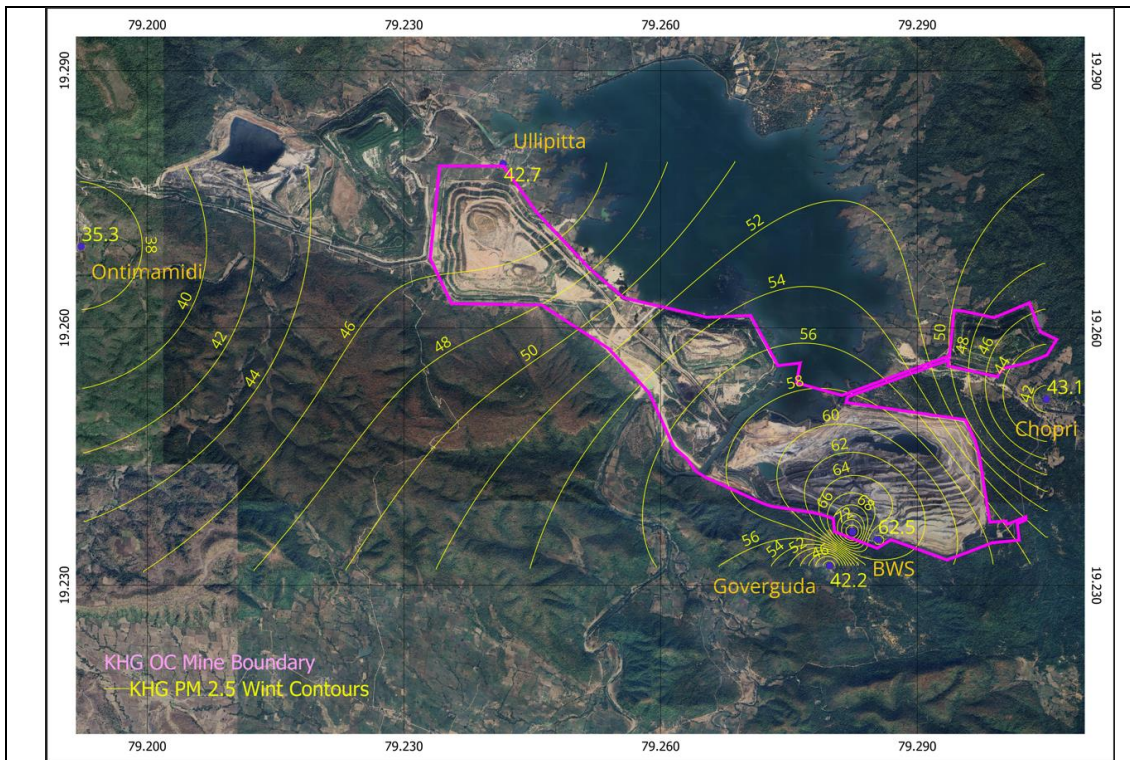


Figure 4.33(c) Image of PM_{2.5} contours during winter season in and around KHG OC

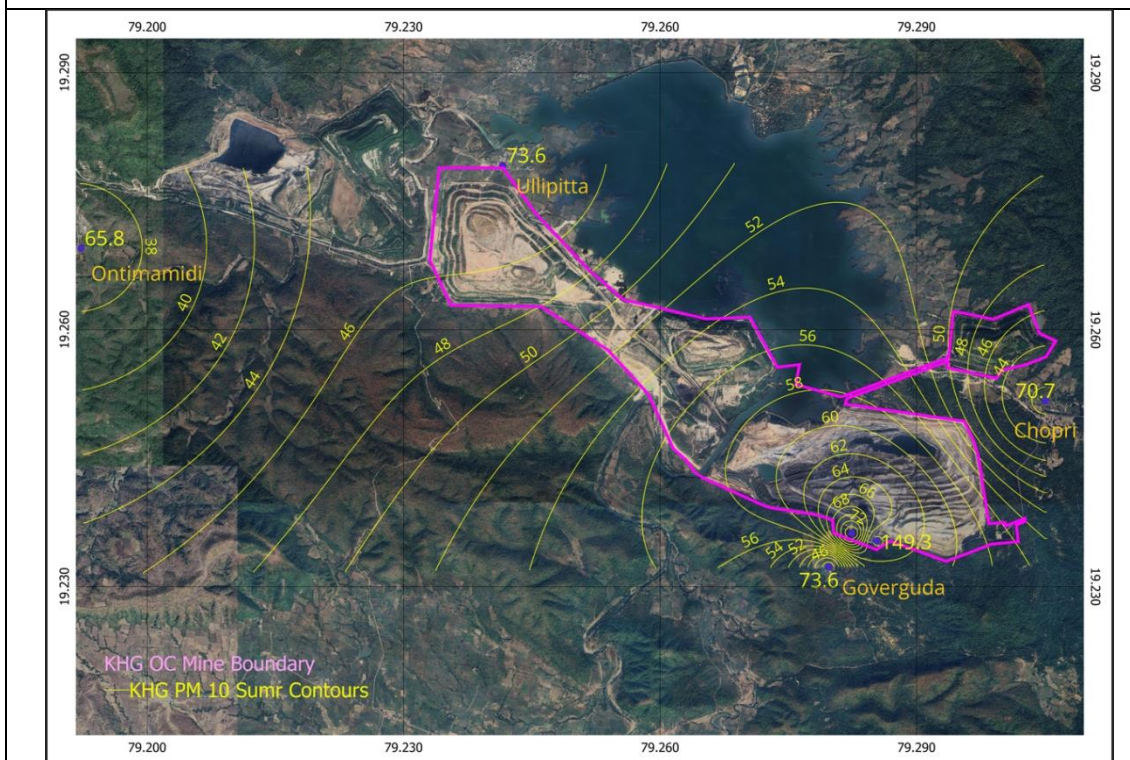


Figure 4.33(d) Image of PM₁₀ contours during summer season in and around KHG OC

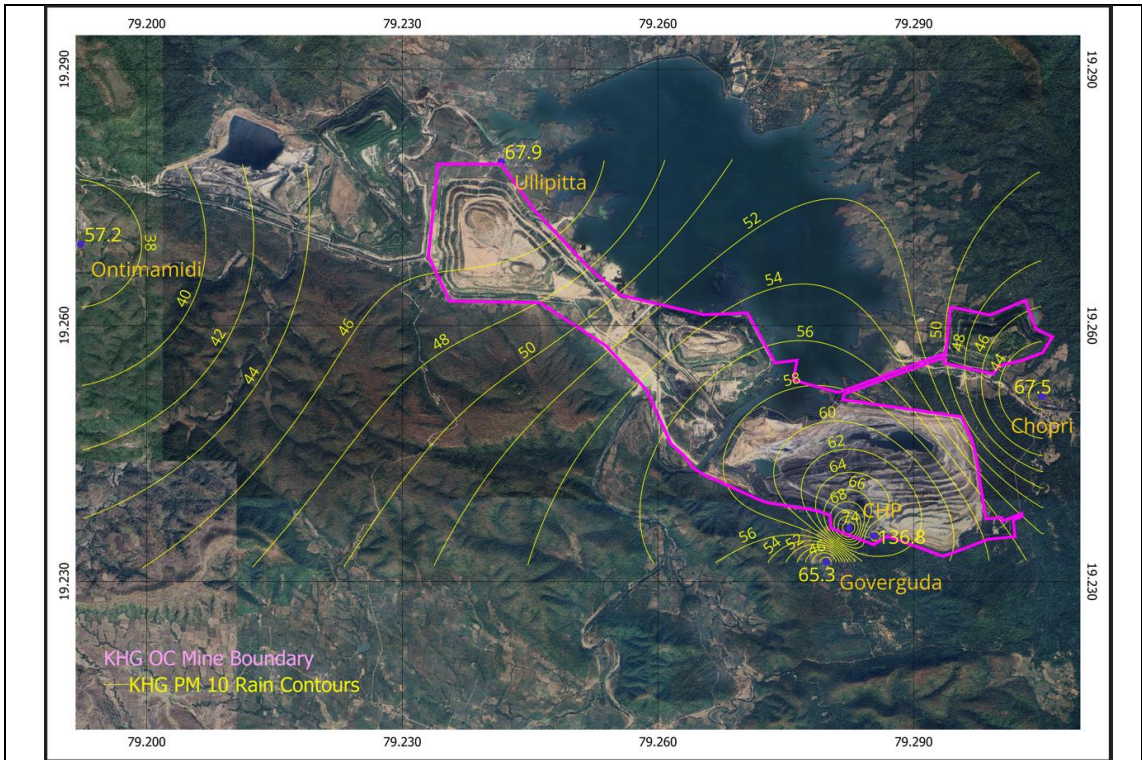


Figure 4.33(e) Image of PM₁₀ contours during rainy season in and around KHG OC

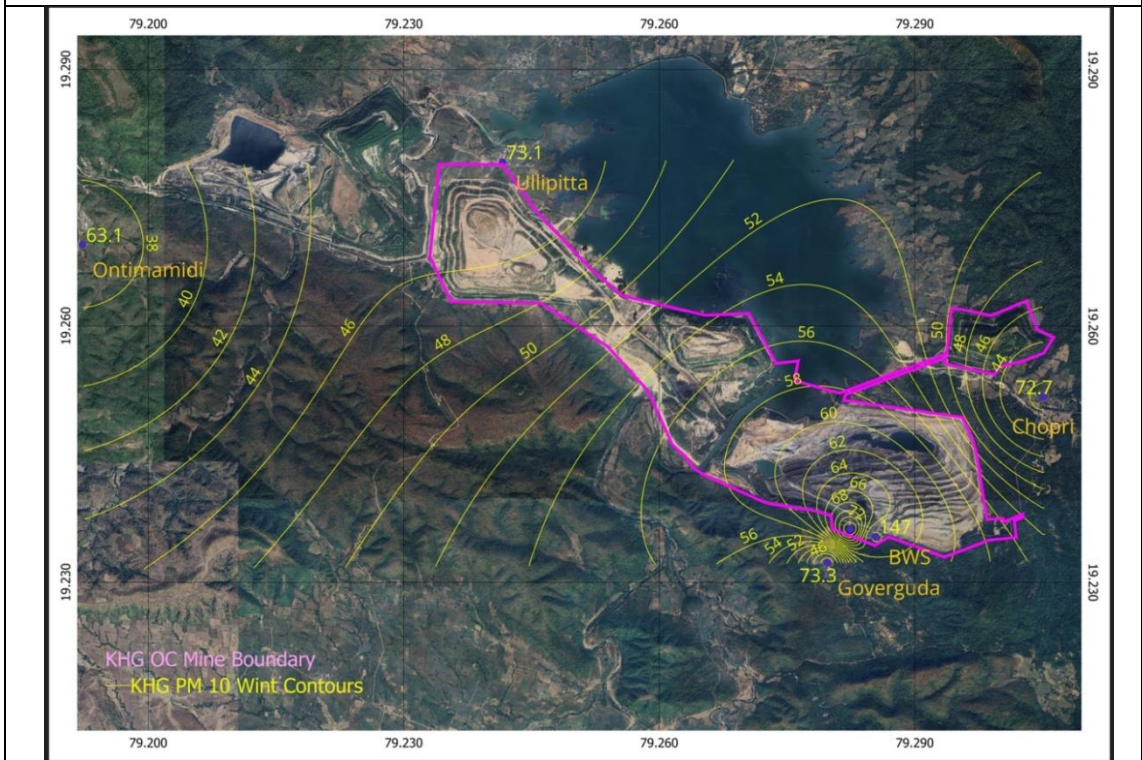


Figure 4.33(f) Image of PM₁₀ contours during winter season in and around KHG OC

Figure 4.33 Contours of PM_{2.5} and PM₁₀ during 3 seasons in and around KHG OC

4.6 PM_{2.5}/PM₁₀ Ratio

The ratio of PM_{2.5}/PM₁₀ is helpful in arriving at the concentration of PM_{2.5} from PM₁₀ and vice-versa in case of non-measurement of any one parameter. The ratio is dependent on various meteorological parameters as well as mine specific parameters. Meteorological and mine data has been collected from 4 mines over a period of 10 years and analysed.

4.6.1 Co-efficient of determination for GK OC

The values of PM₁₀ versus PM_{2.5} are plotted and the plots of GK OC mine in the core zones and buffer zones are given in Figure 4.34.

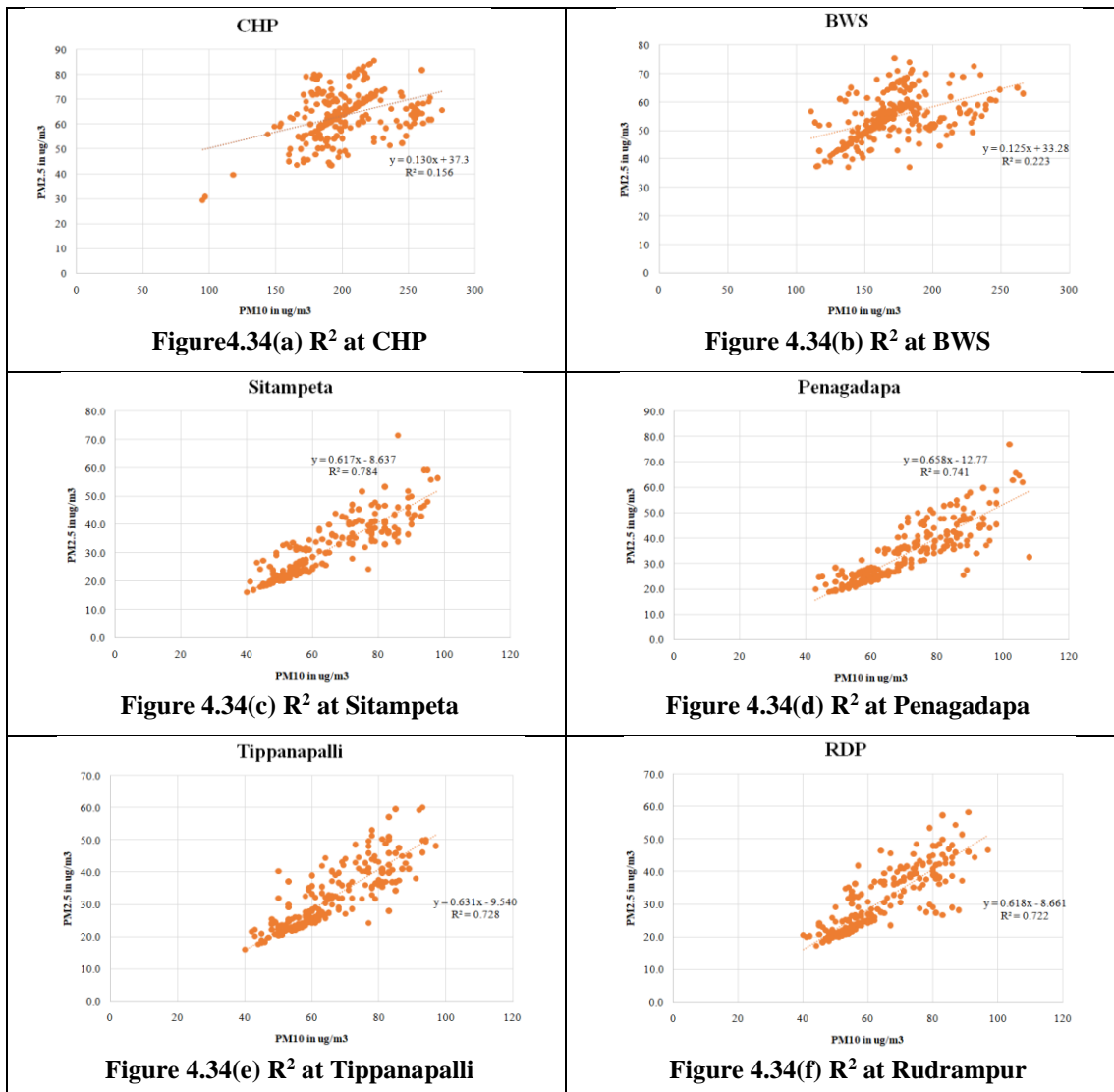


Figure 4.34 PM_{2.5} Vs PM₁₀ at core and buffer zones of GK OC

4.6.2 Co-efficient of determination for JVROC

The values of PM₁₀ versus PM_{2.5} are plotted and the plots of JVR OC mine in the core and buffer zones are given in Figure 4.35.

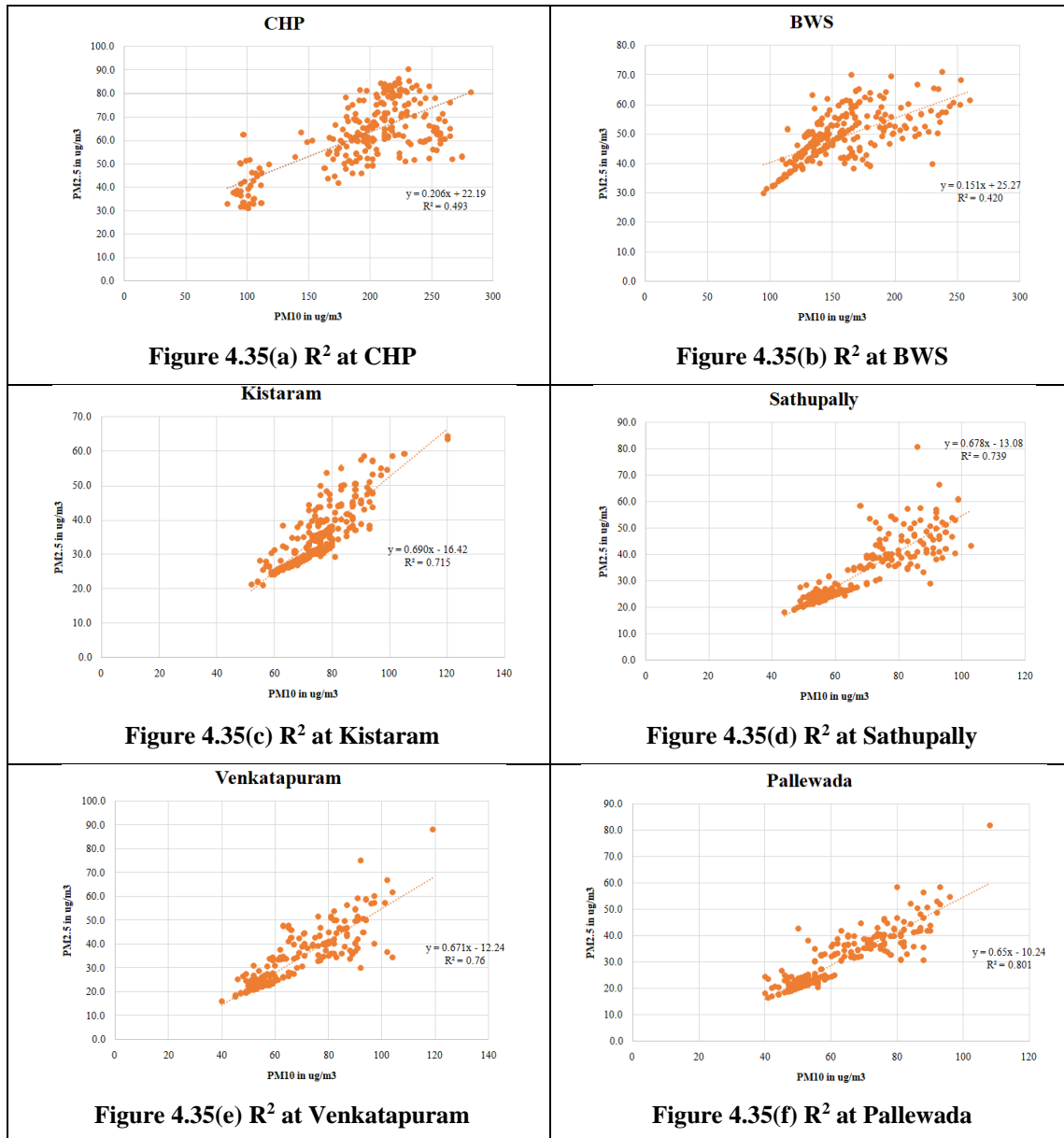


Figure 4.35 PM_{2.5} Vs PM₁₀ at core and buffer zones of JVR OC

For JVR OC, the R² values in the core zone ranged from 0.4206 to 0.4932 and 0.7150 to 0.8013 in the buffer zone which indicates that there is a poor relationship for establishing a ratio in the core zone. However, a ratio can be established in the buffer zone.

4.6.3 Co-efficient of determination for RG OC-I

The values of PM₁₀ versus PM_{2.5} are plotted and the plots of RG OC-I mine in the core and buffer zones are given in Figure 4.36.

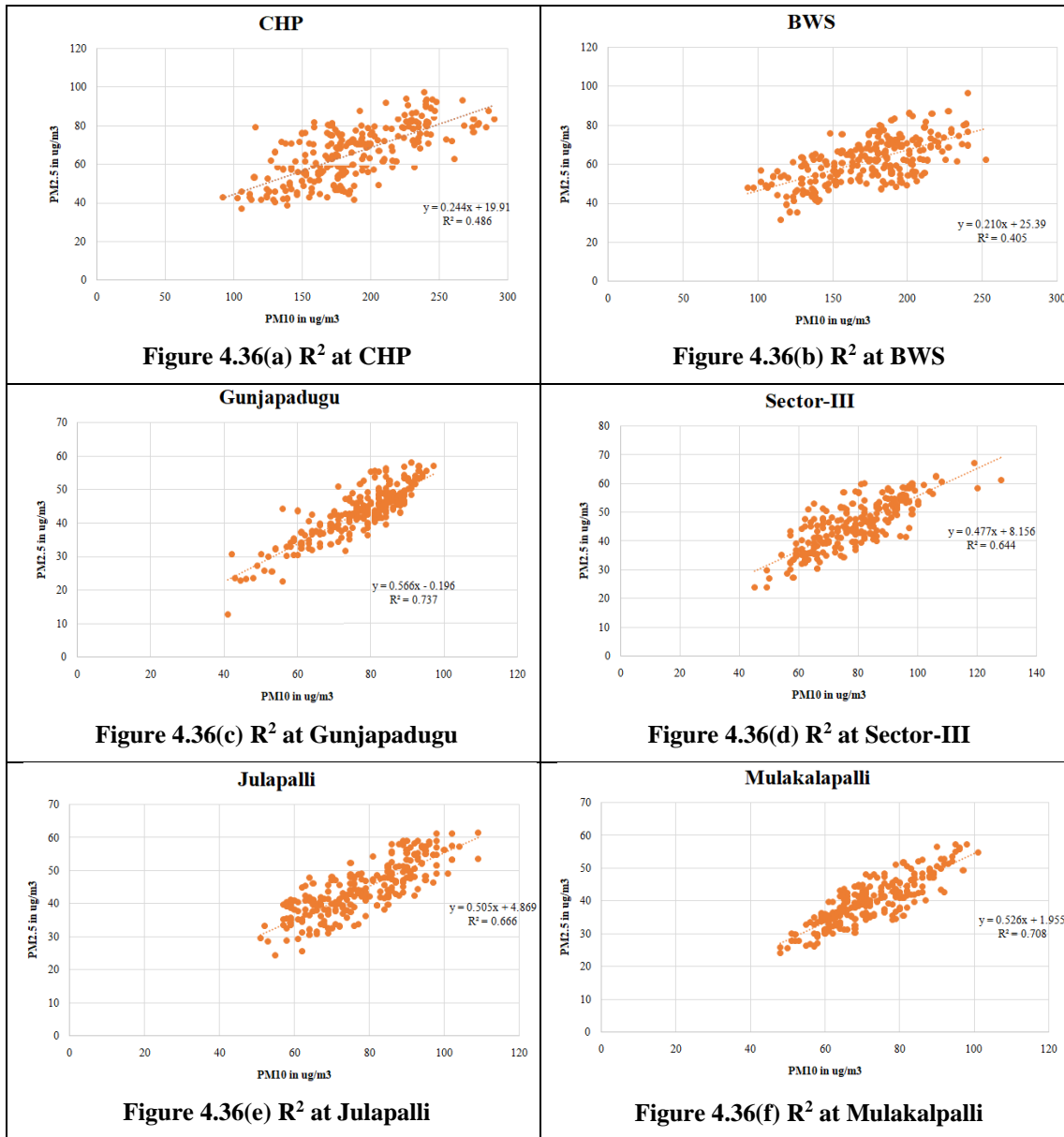


Figure 4.36 PM_{2.5} Vs PM₁₀ at core and buffer zones of RG OC-I

In case of RG OC-I, R² values in the core zone ranged from 0.4051 to 0.4865 and in the buffer zone from 0.6440 to 0.7370 which indicates that there is a poor relationship for establishing a ratio in the core zone. However, a ratio can be established in the buffer zone.

4.6.4 Co-efficient of determination for SRP OC

The values of PM₁₀ versus PM_{2.5} are plotted and the plots of RG OC-I mine in the core and buffer zones are given in Figure 4.37.

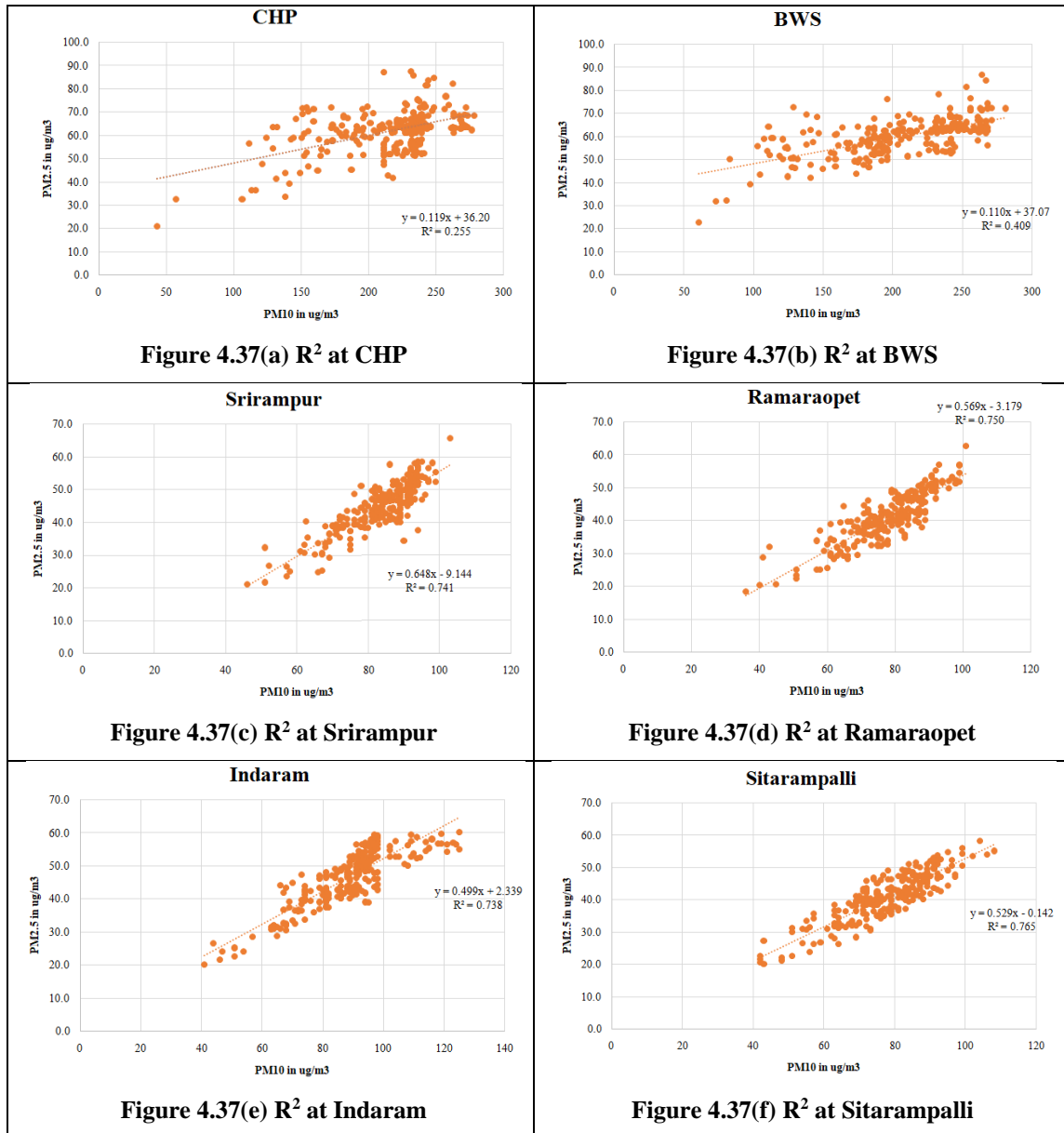


Figure 4.37 PM_{2.5} Vs PM₁₀ at core and buffer zones of SRP OC

The R² values ranged from 0.2556 to 0.4091 in the core zone and 0.7380 to 0.7650 in buffer zone for SRP OC which indicates that there is a poor relationship for establishing a ratio in the core zone. However, a ratio can be established in the buffer zone.

The R^2 values of $PM_{2.5}/PM_{10}$ ratio in 4 opencast projects at 6 different locations are given in Table 4.8.

Table 4.7 R^2 values of $PM_{2.5}/PM_{10}$ ratio in 4 OC mines at 6 different locations

Name of the mine	R^2 value					
	CHP	BWS	Buffer 1	Buffer 2	Buffer 3	Buffer 4
GK OC	0.1569	0.2236	0.7846	0.7414	0.7283	0.7220
JVR OC	0.4932	0.4206	0.7150	0.7393	0.7600	0.8013
RG OC-I	0.4865	0.4051	0.7370	0.6440	0.6660	0.7080
SRP OC	0.2556	0.4091	0.7410	0.7500	0.7380	0.7650

4.7 Summary

Different models like multivariate regression and machine learning were used for predicting the PM values at core and buffer areas of 6 opencast mines. R^2 values of all the prediction models have been computed and compared for better accuracy. RF has shown more accuracy in terms of predictions and the predicted values versus the actual have been plotted to demonstrate the versatility of the RF method in air quality predictions. The analysis shows a positive correlation between production rate and pollution area, indicating proportional increase in PM concentrations. Conversely, there is a weak inverse correlation with quarry depth and dump height, suggesting lower PM concentrations at greater depths and heights due to pit retention and enhanced dispersion.

A software named PMPOM (Particulate Matter Prediction in Opencast Mines), has been developed which is useful to predict pollution levels at selected locations based on the input parameters.

Contour plots have been developed using QGIS software to know the PM concentrations at unmonitored locations. These contour plots have also been exported to Google earth for better visualisation and analysis.

The $PM_{2.5}$ to PM_{10} ratio is also analyzed and it is observed that the correlation (R^2 values) in the core zone suggests a weak relationship between $PM_{2.5}$ to PM_{10} for determining their ratio, whereas establishing a ratio of these parameters in the buffer zone appears to be more feasible.

CHAPTER 5

CHAPTER 5

5. CONCLUSIONS AND SCOPE FOR FURTHER WORK

5.1 Conclusions

- Field investigations are carried out in 6 opencast coal mines of the Singareni Collieries Company Limited. In each mine, dust dispersion ($PM_{2.5}$ & PM_{10}) at 2 locations in core area and 4 locations in buffer area are collected for a period of 10 years, starting from 2012. 31,680 data sets are collected for processing and predictions of models.
- Data is analyzed using different techniques like Multivariate Regression (MVR) and Machine Learning (ML) techniques. Influence of mining parameters (production, area contributing to pollution, quarry depth, dump height and lead distance) and meteorological parameters (temperature, humidity, rainfall, wind direction and wind speed) along with particulate matter.

Based on the results obtained from the experimental studies, the following conclusions are drawn:

Influence of mining and meteorological parameters on dust dispersion

- In order to find the best method of dust prediction, R^2 values of all the methods including MVR, Decision Tree, Bagging and Random Forest (RF) are compared, and it was found that R^2 values of RF algorithm is the highest in all cases. RF algorithm outperformed all other methods in which R^2 values for PM_{10} varied from 0.65 to 0.97 and $PM_{2.5}$ varied from 0.67 to 0.97 due to its ability in handling non-linearity, capture complex and non-linear relationships among air quality parameters, meteorological conditions and mining parameters. Hence, the predictions are made at core and buffer locations of 6 mines using RF algorithm.

Dust dispersion models using machine learning techniques

- Based on the RF algorithm, a software has been developed using Python due to its extensive libraries and frameworks, particularly well-suited for ML tasks.

- A software named “PMPOM” (Particulate Matter Prediction in Opencast Mines) has been developed for prediction of PM, in order to process large volume of complex data, and create a user-friendly environment to obtain prediction of dust values. Also, this model can be used in other opencast mines of GVCF or any other coal fields by providing datasets of relevant mine for air quality predictions.
- The analysis reveals that a positive correlation between production rate and area contributing to pollution suggesting that these factors contribute proportionally to increased particulate matter (PM) concentrations. Conversely, a weak inverse correlation exists with quarry depth and dump height, indicating that PM concentrations tend to decrease slightly at greater depths and heights potentially due to pit retention and enhanced dispersion respectively. Core zones experienced slight increase in dust concentrations in case of lead distance, particularly when the lead distance is around 2km which is due to proximity of dumping point. Subsequently, the values reduced with the increase of lead distance. Same is the case in buffer zone, where villages near to dumping point represented slight increase in dust concentrations.

Developing dust contours using QGIS

- To assess the PM values at non-monitoring locations, Quantum Geographic Information System (QGIS) has been used to develop contour plots and the plots have been further exported to Google earth so as to have better visualisation and analysis.
- This will be useful for the mine management to identify the locations of dust dispersion for taking necessary dust mitigation measures.

PM_{2.5}/PM₁₀ Ratio

- The R² value of PM_{2.5}/PM₁₀ ratio varied from 0.1569 to 0.4932 in the core area of 4 opencast coal mines and 0.6440 to 0.8013 in buffer area of these mines.

- Hence, it can be concluded that a relationship is not possible to establish between $PM_{2.5}$ and PM_{10} for the core area as these locations are lying within the mine boundary, whereas establishing a ratio of these parameters in the buffer area is feasible as they are away from the mine premises.
- Prediction of PM will help the industry as well as regulatory authorities to visualise the PM dispersion in and around opencast mine with changes in production, area contributing to pollution, quarry depth, dump height and lead distance and arrive at implementing or suggesting suitable pollution control measures to contain the dust within permissible standards.
- This research clearly indicates that expansion of an opencast coal mine in terms of production or pit dimensions cannot increase the dust concentration levels significantly within the mine or surroundings.

5.2 Scope for Further Work

- i. The present research utilised RF as a better tool for predicting PM data. However, with a larger data set, more complicated models such as deep learning approaches possibly enhance the accuracy of predicted PM values.
- ii. The current approach utilizes only six data points for contour generation in QGIS. By leveraging additional data available from the surrounding industries, robustness of predicted PM values can be enhanced across the entire geospatial region. This expanded dataset would provide a more comprehensive picture of spatial variations in PM concentration, leading to more reliable and informative predictions.
- iii. The $PM_{2.5}/PM_{10}$ ratio has been calculated using regression analysis. However, other machine learning tools can be used for more accuracy. Further, by offering an informative assessment of potential sources, the $PM_{2.5}/PM_{10}$ ratio plays a significant role in guiding source related air quality management.

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APPENDICES
(I TO IX)

Appendix I

The Environment (Protection) Rules, 1986

¹[90. STANDARDS FOR COAL MINES

1. AIR QUALITY STANDARDS

The Suspended Particulate Matter (SPM), Respirable Particulate Matter (RPM), Sulphur dioxide (SO₂) and Oxides of Nitrogen (NO_x) concentration in downwind direction considering predominant wind direction, at a distance of 500 metres from the following dust generating sources shall not exceed the standards specified in the Tables I, II and III given below:

Dust Generating Sources

Loading or unloading, Haul road, coal transportation road, Coal handling plant (CHP), Railway sliding, Blasting, Drilling, Overburden dumps, or any other dust generating external sources like coke ovens (hard as well as soft), briquette industry, nearby road etc.

Table-I

Category	Pollutant	Time weighted average	Concentration in Ambient Air	Method of Measurement
1	2	3	4	5
I New Coal Mines (Coal Mines commenced operation after the date of publication of this notification)	Suspended Particulate Matter (SPM)	Annual Average * 24 hours **	360 µg/m ³ 500 µg/m ³	- High Volume Sampling (Average flow rate not less than 1.1 m ³ /min)
	Respirable Particulate Matter (size less than 10 µm) (RPM)	Annual Average * 24 hours **	180 µg/m ³ 250 µg/m ³	Respirable Particulate Matter sampling and analysis
	Sulphur Dioxide (SO ₂)	Annual Average * 24 hours **	80 µg/m ³ 120 µg/m ³	- Improved west and Gaeke method - Ultraviolet fluorescense
	Oxide of Nitrogen as NO ₂	Annual Average * 24 hours **	80 µg/m ³ 120 µg/m ³	- Jacob & Hochheiser Modified (Na-Arsenic) Method - Gas phase Chemiluminescence

¹ Serial No.90 to 93 and entries relating thereto were inserted by Rule 2(1) of the Environment (Protection) Amendment Rules, 2000 notified vide notification G.S.R. 742(E), dated 25.9.2000.

Table-II

Category	Pollutant	Time weighted average	Concentration in Ambient Air	Method of Measurement
1	2	3	4	5
II Existing coal fields/mines given below: Karanpura, Ramgarh, Giridih, Rajhara, Wardha, Nagpur, Silewara, PENCH Kanhan, Patharkhera, Umrer, Korba, Chirimiri, Central India Coalfields, (including Baikunthpur, Bistrampur), Singrauli, Ib Valley, Talcher, Godavary Valley and any other	Suspended Particulate Matter (SPM)	Annual Average * 24 hours **	430 $\mu\text{g}/\text{m}^3$ 600 $\mu\text{g}/\text{m}^3$	- High Volume Sampling (Average flow rate not less than 1.1 m^3/minute)
	Respirable Particulate Matter (size less than 10 μm) (RPM)	Annual Average * 24 hours **	215 $\mu\text{g}/\text{m}^3$ 300 $\mu\text{g}/\text{m}^3$	Respirable Particulate Matter sampling and analysis
	Sulphur Dioxide (SO_2)	Annual Average * 24 hours **	80 $\mu\text{g}/\text{m}^3$ 120 $\mu\text{g}/\text{m}^3$	1. Improved wet and Gaeke method 2. Ultraviolet fluorescene
	Oxide of Nitrogen as NO_2	Annual Average * 24 hours **	80 $\mu\text{g}/\text{m}^3$ 120 $\mu\text{g}/\text{m}^3$	1. Jacob & Hochheiser Modified (Na-Arsenic) Method 2. Gas phase Chemiluminescence

Table-III

Category	Pollutant	Time weighted average	Concentration in Ambient Air	Method of Measurement
1	2	3	4	5
III Coal mines located in the coal fields of · Jharia · Raniganj · Bokaro	Suspended Particulate Matter (SPM)	Annual Average * 24 hours **	500 µg/m ³ 700 µg/m ³	- High Volume Sampling (Average flow rate not less than 1.1 m ³ /minute)
	Respirable Particulate Matter (size less than 10 µm) (RPM)	Annual Average * 24 hours **	250 µg/m ³ 300 µg/m ³	Respirable Particulate Matter sampling and analysis
	Sulphur Dioxide (SO ₂)	Annual Average * 24 hours **	80 µg/m ³ 120 µg/m ³	1.Improved west and Gaeke method 2.Ultraviolet fluorescene
	Oxide of Nitrogen as NO ₂	Annual Average * 24 hours **	80 µg/m ³ 120 µg/m ³	1. Jacob & Hochheiser Modified (Na-Arsenic) Method 2. Gas phase Chemiluminescence

Note:

* Annual Arithmetic mean for the measurements taken in a year, following the guidelines for frequency of sampling laid down in clause 2.

** 24 hourly / 8 hourly values shall be met 92% of the time in a year. However, 8% of the time it may exceed but not on two consecutive days.

Unauthorized construction shall not be taken as a reference of nearest residential or commercial place for monitoring.

In case any residential or commercial or industrial place falls within 500 metres of any dust generating sources, the National Ambient Air Quality Standards notified under schedule VII shall be applicable.

2. FREQUENCY OF SAMPLING

- Air quality monitoring at a frequency of once in a fortnight at the dust generating sources given in clause 1 shall be carried out.

- As a result of monthly monitoring, if it is found that the value of the pollutant is less than 50% of the specified standards for three consecutive months, then the sampling frequency may be shifted to two days in a quarter year (3 months).

- In case, the value has exceeded the specified standards, the air quality sampling shall be done twice a week. If the results of four consecutive weeks indicate that the concentration of pollutants is within the specified standards, then fortnight monitoring may be reverted to.

NATIONAL AMBIENT AIR QUALITY STANDARDS CENTRAL POLLUTION CONTROL BOARD NOTIFICATION

New Delhi, the 18th November, 2009

No.B-29016/20/90/PCI-L---In exercise of the powers conferred by Sub-section (2) (h) of section 16 of the Air (Prevention and Control of Pollution) Act, 1981 (Act No. 14 of 1981), and in super session of the Notification No(s). S.O. 384(E), dated 11th April, 1994 and S.O. 935(E), dated 14th October, 1998, the Central Pollution Control Board hereby notify the National Ambient Air Quality Standards with immediate effect, namely:-

NATIONAL AMBIENT AIR QUALITY STANDARDS

S. No.	Pollutant	Time Weighted average	Concentration in Ambient Air		Methods of Measurement
			Industrial, Residential, Rural and other Area	Ecologically sensitive area (notified by Central Govt.)	
(1)	(2)	(3)	(4)	(5)	(6)
1	Sulphur Dioxide (SO ₂), µg/m ³	Annual *	50	20	Improved West and Geake Ultraviolet fluorescence
		24 hours **	80	80	
2	Nitrogen Dioxide (NO ₂), µg/m ³	Annual *	40	30	Modified Jacob & Hochheiser (Na-Arsenite Chemiluminescence
		24 hours **	80	80	
3	Particulate Matter (size less than 10 microns) or PM ₁₀ µg/m ³	Annual *	60	60	Gravimetric TOEM Beta attenuation
		24 hours **	100	100	
4	Particulate Matter (size less than 2.5 microns) or PM _{2.5} µg/m ³	Annual *	40	40	Gravimetric TOEM Beta attenuation
		24 hours **	60	60	
5	Ozone (O ₃) µg/m ³	8 hours **	100	100	UV photometric Chemiluminescence Chemical method
		1 hour **	180	180	
6	Lead (Pb)) µg/m ³	Annual *	0.5	0.5	ASS / ICP method after sampling on EPM 2000 or equivalent filter paper ED - XRF using Teflon filters
		24 hours **	1.0	1.0	

(1)	(2)	(3)	(4)	(5)	(6)
7	Carbon Monoxide (CO) mg/m ³	8 hours **	2	2	Non-Dispersive Infra-RED (NDIR) Spectroscopy
		1 hour **	4	4	
8	Ammonia (NH ₃) µg/m ³	Annual *	100	100	Chemiluminescence Indophenol blue method
		24 hours **	400	400	
9	Benzene (C ₆ H ₆) µg/m ³	Annual *	5	5	Gas chromatography based continuous analyzer Adsorption and desorption followed by GC analysis
10	Benzo (a) Pyrene (BaP) – particulate phase only ng/m ³	Annual *	1	1	Solvent extraction followed by HPLC / GC analysis
11	Arsenic (As) ng/m ³	Annual *	6	6	AAS / ICP method after sampling on EPM 2000 or equivalent filter paper
12	Nickel (Ni) ng/m ³	Annual *	20	20	AAS / ICP method after sampling on EPM 2000 or equivalent filter paper

* Annual arithmetic mean of minimum 104 measurements in a year at a particular site taken twice a week 24 hourly at uniform intervals.

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

Note: Whenever and wherever monitoring results on two consecutive days of monitoring exceed the limits specified above for the respective category, it shall be considered adequate reason to institute regular or continuous monitoring and further investigations.

Appendix II

Table 1. JVR OC Mine parameters

JVR OC	Production (Coal+OB)	Area contributing to pollution	Max. Quarry depth	Max. Dump height	Lead distance
Date	(t)	(Ha)	(m)	(m)	(km)
10.04.2012	48,129	127.9	103.0	90.0	3.5
24.04.2012	55,004	128.7	103.3	90.0	3.5
09.05.2012	45,096	129.6	103.6	90.0	3.5
24.05.2012	48,102	130.4	103.8	90.0	3.4
11.06.2012	43,509	131.3	104.1	90.0	3.4
25.06.2012	49,724	132.1	104.4	90.0	3.4
06.07.2012	38,715	133.0	104.7	90.0	3.4
21.07.2012	41,296	133.8	105.0	90.0	3.4
06.08.2012	38,172	134.7	105.2	90.0	3.3
21.08.2012	40,717	135.5	105.5	90.0	3.3
07.09.2012	35,503	136.3	105.8	90.0	3.3
22.09.2012	40,575	137.2	106.1	90.0	3.3
09.10.2012	31,192	138.0	106.4	90.0	3.3
22.10.2012	33,272	138.9	106.6	90.0	3.2
09.11.2012	25,643	139.7	106.9	90.0	3.2
23.11.2012	29,306	140.6	107.2	90.0	3.2
08.12.2012	14,593	141.4	107.5	90.0	3.2
24.12.2012	15,566	142.2	107.8	90.0	3.1
07.01.2013	14,620	143.1	108.0	90.0	3.1
23.01.2013	15,595	143.9	108.3	90.0	3.1
08.02.2013	18,600	144.8	108.6	90.0	3.1
23.02.2013	18,600	145.6	108.9	90.0	3.1
08.03.2013	79,644	146.5	109.2	90.0	3.0
23.03.2013	84,954	147.3	109.4	90.0	3.0
08.04.2013	90,116	149.0	110.0	90.0	3.0
22.04.2013	102,990	149.1	110.2	90.0	3.0
08.05.2013	98,169	149.2	110.4	90.0	3.0
23.05.2013	104,714	149.3	110.6	90.0	3.0
05.06.2013	87,068	149.4	110.8	90.0	3.0
20.06.2013	99,507	149.5	111.0	90.0	3.0
05.07.2013	64,542	149.6	111.2	90.0	3.0
19.07.2013	68,845	149.7	111.4	90.0	2.9
05.08.2013	82,325	149.8	111.6	90.0	2.9
20.08.2013	87,813	149.9	111.8	90.0	2.9
05.09.2013	75,464	150.0	112.0	90.0	2.9
19.09.2013	86,245	150.1	112.2	90.0	2.9
04.10.2013	74,283	150.2	112.4	90.0	2.9
19.10.2013	79,235	150.2	112.6	90.0	2.9
05.11.2013	84,010	150.3	112.8	90.0	2.9
20.11.2013	96,011	150.4	113.0	90.0	2.9
05.12.2013	89,232	150.5	113.2	90.0	2.9
19.12.2013	95,181	150.6	113.4	90.0	2.9
04.01.2014	82,475	150.7	113.6	90.0	2.9
20.01.2014	87,973	150.8	113.8	90.0	2.9
05.02.2014	81,820	150.9	114.0	90.0	2.8
20.02.2014	81,820	151.0	114.2	90.0	2.8
05.03.2014	71,235	151.1	114.4	90.0	2.8
20.03.2014	75,984	151.2	114.6	90.0	2.8
04.04.2014	34,561	151.4	115.0	90.0	2.8
19.04.2014	39,498	153.4	115.0	90.0	2.8
05.05.2014	40,955	155.4	115.0	90.0	2.8

JVR OC	Production (Coal+OB)	Area contributing to pollution	Max. Quarry depth	Max. Dump height	Lead distance
Date	(t)	(Ha)	(m)	(m)	(km)
20.05.2014	43,685	157.4	115.0	90.0	2.8
05.06.2014	71,443	159.4	115.0	90.0	2.8
19.06.2014	81,649	161.5	115.0	90.0	2.8
04.07.2014	51,978	163.5	115.0	90.0	2.8
19.07.2014	55,444	165.5	115.0	90.0	2.8
05.08.2014	72,489	167.5	115.0	90.0	2.8
22.08.2014	77,322	169.5	115.0	90.0	2.8
04.09.2014	75,539	171.5	115.0	90.0	2.8
25.09.2014	86,330	173.5	115.0	90.0	2.8
08.10.2014	103,406	175.5	115.0	90.0	2.8
24.10.2014	110,300	177.5	115.0	90.0	2.8
06.11.2014	113,553	179.6	115.0	90.0	2.8
27.11.2014	129,775	181.6	115.0	90.0	2.8
04.12.2014	114,643	183.6	115.0	90.0	2.8
19.12.2014	122,286	185.6	115.0	90.0	2.8
05.01.2015	116,213	187.6	115.0	90.0	2.8
20.01.2015	123,960	189.6	115.0	90.0	2.8
05.02.2015	110,897	191.6	115.0	90.0	2.8
19.02.2015	110,897	193.6	115.0	90.0	2.8
05.03.2015	122,769	195.6	115.0	90.0	2.8
20.03.2015	130,954	197.6	115.0	90.0	2.8
07.04.2015	82,444	201.7	115.0	90.0	2.9
20.04.2015	94,222	202.8	115.2	90.0	2.9
05.05.2015	87,884	203.9	115.4	90.0	2.9
22.05.2015	93,743	205.0	115.6	90.0	2.9
03.06.2015	87,433	206.1	115.8	90.0	2.9
19.06.2015	99,924	207.2	116.0	90.0	2.9
06.07.2015	146,294	208.3	116.2	90.0	2.9
20.07.2015	156,047	209.5	116.4	90.0	2.9
06.08.2015	134,085	210.6	116.6	90.0	2.9
21.08.2015	143,024	211.7	116.8	90.0	2.9
05.09.2015	141,125	212.8	117.0	90.0	2.9
21.09.2015	161,286	213.9	117.2	90.0	2.9
07.10.2015	156,434	215.0	117.4	90.0	2.9
20.10.2015	166,863	216.1	117.6	90.0	2.9
06.11.2015	178,606	217.2	117.8	90.0	2.9
20.11.2015	204,121	218.4	118.0	90.0	2.9
05.12.2015	173,134	219.5	118.2	90.0	2.9
19.12.2015	184,676	220.6	118.4	90.0	2.9
07.01.2016	124,779	221.7	118.6	90.0	2.9
21.01.2016	133,097	222.8	118.8	90.0	2.9
06.02.2016	135,766	223.9	119.0	90.0	2.9
22.02.2016	145,463	225.0	119.2	90.0	2.9
05.03.2016	125,619	226.1	119.4	90.0	2.9
19.03.2016	133,994	227.2	119.6	90.0	3.0
06.04.2016	124,977	229.5	120.0	90.0	3.0
20.04.2016	142,831	228.8	120.0	90.0	2.9
06.05.2016	123,839	228.2	120.0	90.0	2.9
19.05.2016	132,095	227.5	120.0	90.0	2.9
06.06.2016	77,774	226.8	120.0	90.0	2.9
20.06.2016	88,884	226.2	120.0	90.0	2.9
06.07.2016	115,025	225.5	120.0	90.0	2.8
20.07.2016	122,693	224.9	120.0	90.0	2.8
08.08.2016	115,402	224.2	120.0	90.0	2.8
22.08.2016	123,096	223.6	120.0	90.0	2.8

JVR OC	Production (Coal+OB)	Area contributing to pollution	Max. Quarry depth	Max. Dump height	Lead distance
Date	(t)	(Ha)	(m)	(m)	(km)
07.09.2016	72,369	222.9	120.0	90.0	2.8
21.09.2016	82,708	222.2	120.0	90.0	2.8
06.10.2016	113,695	221.6	120.0	90.0	2.7
20.10.2016	121,275	220.9	120.0	90.0	2.7
05.11.2016	122,631	220.3	120.0	90.0	2.7
22.11.2016	140,149	219.6	120.0	90.0	2.7
13.12.2016	122,374	219.0	120.0	90.0	2.7
21.12.2016	130,532	218.3	120.0	90.0	2.6
05.01.2017	109,531	217.6	120.0	90.0	2.6
23.01.2017	116,833	217.0	120.0	90.0	2.6
06.02.2017	134,065	216.3	120.0	90.0	2.6
20.02.2017	134,065	215.7	120.0	90.0	2.6
07.03.2017	145,580	215.0	120.0	90.0	2.6
21.03.2017	155,285	214.4	120.0	90.0	2.5
06.04.2017	123,208	213.1	120.0	90.0	2.5
20.04.2017	140,809	213.0	120.0	90.0	2.5
05.05.2017	120,723	213.0	120.0	90.0	2.5
19.05.2017	128,771	213.0	120.0	90.0	2.6
04.06.2017	92,537	213.0	120.0	90.0	2.6
19.06.2017	105,756	212.9	120.0	90.0	2.6
03.07.2017	82,871	212.9	120.0	90.0	2.6
18.07.2017	88,396	212.9	120.0	90.0	2.6
02.08.2017	76,645	212.9	120.0	90.0	2.7
17.08.2017	81,755	212.9	120.0	90.0	2.7
02.09.2017	82,874	212.8	120.0	90.0	2.7
18.09.2017	94,713	212.8	120.0	90.0	2.7
05.10.2017	88,335	212.8	120.0	90.0	2.8
17.10.2017	94,224	212.8	120.0	90.0	2.8
04.11.2017	77,217	212.7	120.0	90.0	2.8
17.11.2017	88,248	212.7	120.0	90.0	2.8
06.12.2017	64,898	212.7	120.0	90.0	2.8
19.12.2017	69,225	212.7	120.0	90.0	2.9
02.01.2018	75,842	212.7	120.0	90.0	2.9
18.01.2018	80,898	212.6	120.0	90.0	2.9
03.02.2018	100,367	212.6	120.0	90.0	2.9
17.02.2018	100,367	212.6	120.0	90.0	2.9
02.03.2018	80,858	212.6	120.0	90.0	3.0
25.03.2018	86,249	212.6	120.0	90.0	3.0
10.04.2018	106,213	212.5	120.0	90.0	3.0
26.04.2018	121,387	212.4	120.4	90.0	3.1
10.05.2018	90,700	212.2	120.8	90.0	3.1
25.05.2018	96,746	212.0	121.2	90.0	3.2
11.06.2018	86,418	211.9	121.6	90.0	3.2
20.06.2018	98,764	211.7	122.0	90.0	3.3
03.07.2018	55,486	211.6	122.4	90.0	3.3
17.07.2018	59,185	211.4	122.8	90.0	3.4
04.08.2018	55,521	211.2	123.2	90.0	3.4
17.08.2018	59,222	211.1	123.6	90.0	3.5
04.09.2018	84,493	210.9	124.0	90.0	3.5
18.09.2018	96,563	210.8	124.4	90.0	3.6
04.10.2018	95,014	210.6	124.8	90.0	3.6
27.10.2018	101,348	210.4	125.2	90.0	3.7
05.11.2018	92,465	210.3	125.6	90.0	3.7
21.11.2018	105,674	210.1	126.0	90.0	3.8
07.12.2018	106,180	210.0	126.4	90.0	3.8

JVR OC	Production (Coal+OB)	Area contributing to pollution	Max. Quarry depth	Max. Dump height	Lead distance
Date	(t)	(Ha)	(m)	(m)	(km)
19.12.2018	113,258	209.8	126.8	90.0	3.9
02.01.2019	88,645	209.6	127.2	90.0	3.9
22.01.2019	94,554	209.5	127.6	90.0	4.0
02.02.2019	92,709	209.3	128.0	90.0	4.0
18.02.2019	92,709	209.2	128.4	90.0	4.1
02.03.2019	76,001	209.0	128.8	90.0	4.1
17.03.2019	81,068	208.8	129.2	90.0	4.2
02.04.2019	75,588	208.5	130.0	90.0	4.3
20.04.2019	86,387	208.1	130.0	90.0	4.3
07.05.2019	64,263	207.7	130.0	90.0	4.3
16.05.2019	68,548	207.3	130.0	90.0	4.3
02.06.2019	70,963	206.8	130.0	90.0	4.3
28.06.2019	81,101	206.4	130.0	90.0	4.3
06.07.2019	61,949	206.0	130.0	90.0	4.3
18.07.2019	66,079	205.6	130.0	90.0	4.3
02.08.2019	59,089	205.2	130.0	90.0	4.3
17.08.2019	63,028	204.8	130.0	90.0	4.3
04.09.2019	62,321	204.4	130.0	90.0	4.3
18.09.2019	71,224	203.9	130.0	90.0	4.3
03.10.2019	57,713	203.5	130.0	90.0	4.3
17.10.2019	61,561	203.1	130.0	90.0	4.3
02.11.2019	51,681	202.7	130.0	90.0	4.3
18.11.2019	59,064	202.3	130.0	90.0	4.3
03.12.2019	47,956	201.9	130.0	90.0	4.4
17.12.2019	51,154	201.4	130.0	90.0	4.4
02.01.2020	34,552	201.0	130.0	90.0	4.4
20.01.2020	36,855	200.6	130.0	90.0	4.4
03.02.2020	18,022	200.2	130.0	90.0	4.4
18.02.2020	19,310	199.8	130.0	90.0	4.4
03.03.2020	8,350	199.4	130.0	90.0	4.4
18.03.2020	8,907	198.9	130.0	90.0	4.4
03.04.2020	3,888	198.1	130.0	90.0	4.4
17.04.2020	4,443	195.7	130.0	90.0	4.4
04.05.2020	3,184	193.4	130.0	90.0	4.3
18.05.2020	3,396	191.0	130.0	90.0	4.3
02.06.2020	8,750	188.7	130.0	90.0	4.2
17.06.2020	10,000	186.3	130.0	90.0	4.2
02.07.2020	3,334	183.9	130.0	90.0	4.1
17.07.2020	3,556	181.6	130.0	90.0	4.0
03.08.2020	1,236	179.2	130.0	90.0	4.0
18.08.2020	1,318	176.8	130.0	90.0	3.9
07.09.2020	-	174.5	130.0	90.0	3.9
22.09.2020	-	172.1	130.0	90.0	3.8
08.10.2020	-	169.7	130.0	90.0	3.8
22.10.2020	-	167.4	130.0	90.0	3.7
07.11.2020	-	165.0	130.0	90.0	3.7
20.11.2020	-	162.7	130.0	90.0	3.6
09.12.2020	-	160.3	130.0	90.0	3.6
25.12.2020	-	157.9	130.0	90.0	3.5
10.01.2021	-	155.6	130.0	90.0	3.5
26.01.2021	-	153.2	130.0	90.0	3.4
11.02.2021	-	150.8	130.0	90.0	3.4
21.02.2021	-	148.5	130.0	90.0	3.3
10.03.2021	-	146.1	130.0	90.0	3.3
22.03.2021	-	143.7	130.0	90.0	3.2

JVR OC	Production (Coal+OB)	Area contributing to pollution	Max. Quarry depth	Max. Dump height	Lead distance
Date	(t)	(Ha)	(m)	(m)	(km)
06.04.2021	-	139.0	130.0	90.0	3.1
22.04.2021	-	121.8	130.0	90.0	3.1
05.05.2021	-	121.8	130.0	90.0	3.1
20.05.2021	-	121.8	130.0	90.0	3.1
07.06.2021	-	121.8	130.0	90.0	3.1
22.06.2021	-	121.8	130.0	90.0	3.0
07.07.2021	-	121.8	130.0	90.0	3.0
22.07.2021	-	121.8	130.0	90.0	3.0
07.08.2021	-	121.8	130.0	90.0	3.0
23.08.2021	-	121.8	130.0	90.0	3.0
07.09.2021	-	121.8	130.0	90.0	3.0
22.09.2021	-	121.8	130.0	90.0	3.0
13.10.2021	-	121.8	130.0	90.0	2.9
22.10.2021	-	121.8	130.0	90.0	2.9
06.11.2021	-	121.8	130.0	90.0	2.9
22.11.2021	-	121.8	130.0	90.0	2.9
06.12.2021	-	121.8	130.0	90.0	2.9
22.12.2021	-	121.8	130.0	90.0	2.9
07.01.2022	-	121.8	130.0	90.0	2.9
25.01.2022	-	121.8	130.0	90.0	2.8
07.02.2022	-	121.8	130.0	90.0	2.8
21.02.2022	-	121.8	130.0	90.0	2.8
10.03.2022	-	121.8	130.0	90.0	2.8
23.03.2022	-	121.8	130.0	90.0	2.8

Table 2. JVR OC Meteorological data

JVR OC	Predominant wind direction	Avg. Temp	Avg. Humidity	Avg. Rainfall	Avg. Wind speed
Date	(degrees)	(^o c)	(%)	(mm)	(m/s)
10.04.2012	123	38.2	61.0	0.0	1.3
24.04.2012	263	40.1	57.8	0.0	1.5
09.05.2012	161	42.6	59.4	0.0	0.7
24.05.2012	113	41.2	25.4	0.0	2.8
11.06.2012	131	40.0	76.5	0.1	0.6
25.06.2012	125	39.8	64.8	0.1	0.6
06.07.2012	258	38.0	78.1	0.9	1.5
21.07.2012	133	36.6	92.3	1.1	0.4
06.08.2012	196	35.5	88.3	0.2	1.6
21.08.2012	204	35.0	55.4	0.0	1.2
07.09.2012	124	33.2	91.3	0.2	0.1
22.09.2012	232	33.4	88.1	4.0	0.2
09.10.2012	327	32.8	88.6	0.4	0.4
22.10.2012	343	32.1	75.4	0.0	0.2
09.11.2012	220	30.5	65.1	0.0	0.2
23.11.2012	37	31.2	75.5	0.0	0.3
08.12.2012	23	29.8	71.6	0.0	0.0
24.12.2012	285	28.5	56.8	0.0	0.0
07.01.2013	43	27.9	73.0	0.0	5.6
23.01.2013	48	25.3	66.0	0.0	2.8
08.02.2013	5	25.0	71.8	0.0	4.6
23.02.2013	99	25.1	55.4	0.0	4.0
08.03.2013	102	26.5	71.9	0.0	4.8
23.03.2013	85	29.4	66.8	0.0	5.3
08.04.2013	118	33.5	66.5	0.0	4.6
22.04.2013	45	38.8	65.5	0.1	9.8
08.05.2013	125	41.7	61.1	0.1	5.4
23.05.2013	59	38.6	54.5	0.2	5.4
05.06.2013	23	28.5	86.0	45.8	6.4

JVR OC	Predominant wind direction	Avg. Temp	Avg. Humidity	Avg. Rainfall	Avg. Wind speed
Date	(degrees)	(°c)	(%)	(mm)	(m/s)
20.06.2013	114	33.2	58.8	0.0	6.9
05.07.2013	221	28.7	92.6	28.2	3.2
19.07.2013	250	23.9	92.1	10.0	5.0
05.08.2013	304	29.6	89.6	0.0	4.4
20.08.2013	226	28.3	90.6	4.8	8.3
05.09.2013	306	29.7	91.8	0.0	7.0
19.09.2013	277	29.9	91.9	22.0	5.1
04.10.2013	221	24.7	93.8	5.0	6.4
19.10.2013	49	29.8	70.8	0.0	2.5
05.11.2013	90	27.0	66.9	0.0	8.7
20.11.2013	354	26.5	70.6	0.0	7.7
05.12.2013	75	23.7	59.5	0.0	6.8
19.12.2013	45	22.2	64.3	0.0	3.7
04.01.2014	128	24.4	65.6	0.0	8.5
20.01.2014	300	25.5	65.6	0.0	14.3
05.02.2014	166	26.1	59.3	2.4	6.7
20.02.2014	311	25.4	61.2	0.0	18.5
05.03.2014	289	26.4	65.2	0.0	12.4
20.03.2014	328	30.3	59.1	0.0	12.9
04.04.2014	257	31.1	61.3	0.0	13.4
19.04.2014	357	32.2	60.2	0.0	10.0
05.05.2014	131	31.0	60.2	0.0	7.1
20.05.2014	352	30.9	64.0	0.0	5.7
05.06.2014	177	32.8	66.6	0.0	4.7
19.06.2014	242	30.3	67.3	1.8	9.0
04.07.2014	228	35.0	42.9	0.0	7.6
19.07.2014	295	28.9	70.7	0.0	8.6
05.08.2014	33	28.5	74.7	46.2	18.7
22.08.2014	355	31.4	67.4	0.0	10.1
04.09.2014	356	30.3	72.3	0.0	14.6
25.09.2014	202	30.0	75.0	0.0	3.0
08.10.2014	47	29.6	70.3	0.0	2.6
24.10.2014	259	27.6	70.3	0.0	3.3
06.11.2014	282	24.5	66.1	0.0	4.0
27.11.2014	301	23.2	61.0	0.0	0.0
04.12.2014	312	22.5	58.3	0.0	0.0
19.12.2014	281	22.4	65.5	0.0	0.0
05.01.2015	241	27.2	66.7	0.0	0.0
20.01.2015	291	23.8	57.1	0.0	0.0
05.02.2015	353	23.5	56.4	0.0	0.0
19.02.2015	13	28.7	59.8	0.0	4.6
05.03.2015	339	28.6	67.4	0.0	1.8
20.03.2015	57	29.3	53.9	0.0	3.8
07.04.2015	310	31.7	62.8	0.0	6.6
20.04.2015	315	31.7	64.2	0.0	5.2
05.05.2015	320	32.1	61.5	0.0	5.1
22.05.2015	360	37.5	48.6	0.0	5.8
03.06.2015	310	31.8	56.2	0.0	6.5
19.06.2015	320	26.5	85.0	50.2	0.0
06.07.2015	360	31.6	63.7	0.0	7.9
20.07.2015	340	30.7	70.6	0.0	4.9
06.08.2015	360	30.5	66.8	2.2	6.0
21.08.2015	10	29.9	71.5	0.0	4.0
05.09.2015	230	30.8	73.9	0.0	2.3
21.09.2015	240	24.5	94.2	74.2	5.3
07.10.2015	20	29.6	69.1	0.0	2.2
20.10.2015	15	30.1	69.6	0.0	1.1
06.11.2015	45	28.5	69.4	0.0	2.8
20.11.2015	50	25.7	72.0	0.0	5.9
05.12.2015	50	27.7	67.2	0.0	1.8
19.12.2015	180	26.6	66.3	0.0	1.5
07.01.2016	90	25.4	63.6	0.0	0.0
21.01.2016	180	25.3	69.3	0.0	0.6
06.02.2016	270	27.4	63.5	0.0	0.0
22.02.2016	90	29.9	61.2	0.0	0.2

JVR OC	Predominant wind direction	Avg. Temp	Avg. Humidity	Avg. Rainfall	Avg. Wind speed
Date	(degrees)	(°c)	(%)	(mm)	(m/s)
05.03.2016	270	29.1	61.3	0.0	0.1
19.03.2016	330	31.4	64.1	0.0	0.3
06.04.2016	114	32.8	59.7	0.2	0.2
20.04.2016	208	33.1	59.2	0.0	0.1
06.05.2016	181	32.3	53.4	0.2	1.1
19.05.2016	66	30.5	70.0	0.1	1.1
06.06.2016	202	34.4	61.2	2.4	0.1
20.06.2016	245	33.5	58.7	0.0	0.0
06.07.2016	264	33.5	60.7	0.0	2.2
20.07.2016	193	27.0	83.3	0.0	0.5
08.08.2016	286	30.1	68.8	0.0	1.6
22.08.2016	193	32.8	62.5	0.0	0.2
07.09.2016	193	27.8	72.8	0.0	1.2
21.09.2016	166	28.6	79.5	0.6	0.0
06.10.2016	178	30.1	73.2	0.0	0.3
20.10.2016	163	26.7	66.2	0.0	0.2
05.11.2016	166	28.0	70.8	0.0	0.4
22.11.2016	180	24.8	66.5	0.0	0.3
13.12.2016	219	26.0	65.4	0.0	0.0
21.12.2016	220	23.0	57.5	0.0	0.3
05.01.2017	168	22.8	67.4	0.0	0.1
23.01.2017	162	24.7	58.2	0.0	0.1
06.02.2017	176	25.0	61.6	0.0	0.3
20.02.2017	197	27.2	60.4	0.0	0.0
07.03.2017	315	28.7	69.9	0.0	0.4
21.03.2017	194	30.1	63.1	0.0	0.0
06.04.2017	305	31.5	67.3	0.0	0.2
20.04.2017	289	32.6	64.0	0.0	0.4
05.05.2017	262	32.5	59.3	0.0	0.5
19.05.2017	148	37.5	39.5	0.0	0.1
04.06.2017	185	30.2	72.5	0.6	0.4
19.06.2017	161	27.0	87.1	0.4	0.0
03.07.2017	136	28.0	78.5	0.0	0.4
18.07.2017	134	24.0	99.1	0.0	2.5
02.08.2017	122	27.2	89.0	0.0	0.5
17.08.2017	180	27.8	83.6	0.0	0.3
02.09.2017	134	29.5	80.9	0.0	0.0
18.09.2017	112	27.0	86.0	0.0	0.8
05.10.2017	203	27.8	88.7	0.0	0.0
17.10.2017	222	28.8	78.3	0.0	0.3
04.11.2017	88	25.2	74.0	0.0	0.0
17.11.2017	183	26.7	79.6	0.0	0.4
06.12.2017	156	23.4	75.9	0.0	0.0
19.12.2017	269	22.0	70.6	0.0	0.0
02.01.2018	167	23.6	73.0	0.0	0.0
18.01.2018	213	22.7	73.8	0.0	0.0
03.02.2018	261	23.7	59.6	0.0	0.2
17.02.2018	209	26.3	65.9	0.0	0.0
02.03.2018	161	28.3	60.7	0.0	0.0
25.03.2018	318	29.6	72.3	0.0	0.0
10.04.2018	307	29.8	66.0	0.0	0.3
26.04.2018	214	31.9	66.8	0.0	0.2
10.05.2018	180	32.8	62.5	0.0	0.3
25.05.2018	162	32.0	69.1	0.0	0.1
11.06.2018	241	26.9	88.5	0.0	0.9
20.06.2018	203	33.6	55.0	0.0	2.4
03.07.2018	188	28.2	80.5	0.0	0.3
17.07.2018	217	27.9	84.9	0.0	1.0
04.08.2018	201	30.6	70.5	0.0	1.0
17.08.2018	174	27.0	86.9	0.0	0.5
04.09.2018	232	28.7	80.9	0.0	0.6
18.09.2018	246	26.6	88.1	0.2	0.3
04.10.2018	209	29.3	76.6	0.0	0.0
27.10.2018	300	25.7	59.3	0.0	0.2
05.11.2018	194	27.8	81.6	0.0	0.0

JVR OC	Predominant wind direction	Avg. Temp	Avg. Humidity	Avg. Rainfall	Avg. Wind speed
Date	(degrees)	(°c)	(%)	(mm)	(m/s)
21.11.2018	193	25.4	75.5	0.1	0.1
07.12.2018	213	25.0	85.4	0.0	0.2
19.12.2018	217	19.3	72.7	0.0	0.4
02.01.2019	67	19.8	78.1	0.0	0.0
22.01.2019	149	23.3	77.6	0.0	0.0
02.02.2019	139	23.3	78.3	0.0	0.0
18.02.2019	187	27.8	76.3	0.0	0.2
02.03.2019	115	27.5	79.5	0.0	0.2
17.03.2019	200	28.3	67.3	0.0	0.4
02.04.2019	187	30.6	68.6	0.0	0.3
20.04.2019	180	32.1	66.2	0.0	0.3
07.05.2019	233	33.2	64.7	0.2	0.2
16.05.2019	192	33.0	60.5	0.2	0.3
02.06.2019	174	34.4	66.0	0.0	0.2
28.06.2019	182	33.0	54.7	0.0	1.5
06.07.2019	112	29.2	71.9	0.2	0.9
18.07.2019	148	30.7	70.9	0.0	0.3
02.08.2019	138	23.9	100.0	1.2	1.0
17.08.2019	113	27.6	90.8	1.3	0.3
04.09.2019	149	26.3	94.8	0.4	0.2
18.09.2019	138	27.4	89.4	0.2	0.1
03.10.2019	230	27.3	87.4	0.0	0.0
17.10.2019	146	27.2	86.4	0.1	0.1
02.11.2019	81	28.3	66.4	0.0	0.2
18.11.2019	71	26.3	78.6	0.0	0.0
03.12.2019	225	25.4	78.6	0.0	0.0
17.12.2019	189	24.1	79.3	0.0	0.0
02.01.2020	195	24.6	78.9	0.0	0.0
20.01.2020	172	23.5	72.1	0.0	0.1
03.02.2020	182	25.2	77.4	0.0	0.2
18.02.2020	184	26.2	71.3	0.0	0.0
03.03.2020	134	26.9	72.6	0.0	0.2
18.03.2020	100	29.1	68.1	0.1	0.2
03.04.2020	163	30.2	68.3	0.0	0.1
17.04.2020	135	30.8	65.7	0.0	0.3
04.05.2020	117	32.2	65.5	0.0	0.1
18.05.2020	134	33.8	47.8	0.1	4.4
02.06.2020	179	30.8	71.7	0.1	0.0
17.06.2020	172	28.0	82.9	0.0	0.3
02.07.2020	228	27.9	91.2	0.1	0.0
17.07.2020	181	29.0	76.0	0.1	0.1
03.08.2020	155	27.7	85.7	0.3	0.3
18.08.2020	229	27.3	84.8	0.5	0.3
07.09.2020	80	30.6	72.2	0.0	0.0
22.09.2020	213	27.1	81.7	0.0	0.5
08.10.2020	176	26.6	81.7	0.0	0.0
22.10.2020	210	28.2	77.7	0.0	0.1
07.11.2020	293	26.5	84.1	0.0	0.0
20.11.2020	304	25.9	78.2	0.0	0.0
09.12.2020	161	22.5	68.6	0.0	0.0
25.12.2020	151	21.4	73.1	0.0	0.0
10.01.2021	154	23.7	63.6	0.0	0.0
26.01.2021	189	24.8	66.3	0.0	0.0
11.02.2021	175	24.7	66.9	0.0	0.0
21.02.2021	108	25.4	59.4	0.0	0.0
10.03.2021	172	28.0	60.7	0.0	0.0
22.03.2021	182	29.8	54.2	0.0	0.0
06.04.2021	169	30.0	58.8	0.0	0.0
22.04.2021	153	30.1	59.5	0.0	0.0
05.05.2021	160	31.3	57.4	0.0	0.0
20.05.2021	176	31.4	61.1	0.0	0.0
07.06.2021	121	33.1	53.3	0.0	0.0
22.06.2021	108	31.5	53.8	0.0	0.0
07.07.2021	204	29.4	73.5	0.2	0.0
22.07.2021	167	23.5	100.0	0.0	0.0

JVR OC	Predominant wind direction	Avg. Temp	Avg. Humidity	Avg. Rainfall	Avg. Wind speed
Date	(degrees)	(°c)	(%)	(mm)	(m/s)
07.08.2021	175	30.8	60.9	0.0	0.0
23.08.2021	179	29.8	68.2	0.0	0.0
07.09.2021	122	26.5	83.3	0.2	0.0
22.09.2021	160	28.2	74.8	0.0	0.0
13.10.2021	148	29.0	71.1	0.0	0.0
22.10.2021	36	27.2	61.9	0.0	0.0
06.11.2021	171	26.3	75.3	0.0	0.0
22.11.2021	166	28.3	74.6	0.9	0.0
06.12.2021	38	25.4	66.0	0.0	0.1
22.12.2021	59	20.0	56.8	0.0	0.0
07.01.2022	182	27.2	66.7	0.0	0.0
25.01.2022	190	23.8	57.1	0.1	0.0
07.02.2022	235	27.4	63.5	0.0	0.0
21.02.2022	145	26.3	65.9	0.0	0.0
10.03.2022	174	28.6	67.4	0.0	0.0
23.03.2022	243	30.1	63.1	0.0	0.0

Table 3. PM₁₀ and PM_{2.5} in core and buffer zones of JVR OC

JVR OC	PM ₁₀ (µg/m ³)						PM _{2.5} (µg/m ³)					
	Date	CHP	WS	Kista ram	Pallewada	Sathu pally	Venkatapuram	CHP	WS	Kista ram	Palle wada	Sathu pally
10.04.2012	178	165	76	70	89	66	58.9	70.1	43.8	38.7	40.7	46.0
24.04.2012	181	172	81	82	77	71	57.2	60.8	42.3	36.2	38.8	40.2
09.05.2012	190	168	84	76	88	67	59.7	55.8	50.2	37.1	44.1	39.8
24.05.2012	198	180	78	65	91	69	61.1	61.6	48.4	36.6	42.6	42.5
11.06.2012	203	193	83	60	94	65	60.1	64.3	44.2	35.8	38.7	46.9
25.06.2012	189	140	80	81	98	76	54.8	40.0	37.0	37.3	40.6	33.0
06.07.2012	198	126	79	72	93	88	49.0	38.4	36.0	35.0	41.0	37.3
21.07.2012	205	145	87	85	90	92	55.9	43.0	26.5	36.0	29.0	30.0
06.08.2012	170	125	73	83	88	85	52.0	42.0	31.0	33.0	33.5	36.0
21.08.2012	183	124	75	76	81	90	58.3	42.3	35.8	36.7	38.8	37.1
07.09.2012	163	123	73	62	84	87	48.1	43.3	35.4	36.9	39.0	43.6
22.09.2012	139	114	103	90	92	102	52.8	51.6	38.5	41.9	38.2	36.7
09.10.2012	257	218	82	88	76	62	75.0	66.7	37.5	30.7	46.1	37.6
22.10.2012	173	131	81	92	97	82	54.2	45.8	29.2	53.1	46.9	53.8
09.11.2012	167	140	93	88	103	104	50.0	54.2	37.5	35.7	43.5	34.4
23.11.2012	186	157	72	67	74	71	45.8	41.7	33.3	39.9	44.1	44.5
08.12.2012	179	178	85	76	89	80	50.0	39.7	34.8	45.8	48.8	40.3
24.12.2012	193	180	88	92	74	91	45.8	39.1	47.2	48.7	50.0	42.2
07.01.2013	178	168	96	90	94	79	64.6	55.3	35.5	43.8	52.2	37.4
23.01.2013	172	164	96	86	91	76	62.5	61.1	41.6	50.5	40.4	51.7
08.02.2013	182	178	93	89	95	84	68.1	56.1	48.7	41.8	48.6	46.6
23.02.2013	194	191	97	88	87	82	65.2	62.2	55.0	56.5	57.8	50.0
08.03.2013	198	197	94	84	91	87	68.1	69.6	57.1	44.5	45.6	56.2
23.03.2013	259	238	97	93	97	94	73.9	71.1	30.4	58.3	54.1	58.7
08.04.2013	282	253	121	108	93	119	90.5	68.2	47.6	81.8	66.7	88.0
22.04.2013	253	235	105	93	92	102	68.1	65.2	38.3	51.8	57.1	66.7
08.05.2013	265	230	114	80	86	92	76.1	39.7	45.8	58.5	80.9	75.0
23.05.2013	241	204	104	78	73	81	60.9	51.1	34.8	40.0	43.7	51.6
05.06.2013	198	167	76	73	80	84	58.3	38.3	34.0	36.4	41.7	46.8
20.06.2013	212	187	63	57	73	65	71.6	57.3	38.4	32.6	52.4	41.2
05.07.2013	182	136	66	53	71	66	73.9	58.6	50.0	38.1	53.6	42.8
19.07.2013	191	146	78	63	83	77	76.9	62.0	53.9	42.0	57.4	46.7
05.08.2013	180	134	63	50	68	63	78.2	63.1	55.2	42.8	58.5	47.6
20.08.2013	187	141	72	58	77	72	69.0	53.3	44.4	33.0	48.0	38.3
05.09.2013	202	157	88	72	92	87	65.7	50.8	50.4	38.4	54.1	43.2
19.09.2013	196	150	79	64	84	79	62.1	46.1	46.1	34.5	50.0	39.4
04.10.2013	144	136	81	66	74	75	56.5	44.4	39.9	33.8	43.0	42.6
19.10.2013	149	141	87	71	81	85	59.2	48.2	44.1	37.1	47.0	46.1
05.11.2013	153	146	91	76	85	86	59.8	48.1	43.0	37.2	47.0	46.6
20.11.2013	166	159	92	82	85	81	64.0	53.4	49.5	42.3	52.0	51.0
05.12.2013	189	144	83	67	87	82	64.3	49.6	49.0	37.1	53.0	42.2
19.12.2013	167	160	94	78	89	87	55.9	48.0	43.7	32.8	42.0	46.7
04.01.2014	176	169	94	82	93	91	60.0	53.2	48.0	37.6	47.0	51.5

JVRO C	PM ₁₀ (µg/m ³)						PM _{2.5} (µg/m ³)					
	Date	CHP	WS	Kista ram	Pallewada	Sathu pally	Venkatapuram	CHP	WS	Kista ram	Palle wada	Sathu pally
20.01.2014	195	189	99	87	98	96	65.1	59.1	54.5	43.1	53.0	57.0
05.02.2014	191	185	93	81	92	90	62.3	55.8	51.2	39.9	50.0	54.6
20.02.2014	195	188	94	82	93	91	59.5	52.2	47.8	35.8	46.0	50.1
05.03.2014	188	181	88	77	87	86	53.2	46.9	46.9	34.0	45.0	49.8
20.03.2014	195	189	94	82	92	91	62.0	55.0	57.2	45.2	56.0	59.2
04.04.2014	244	231	102	89	99	97	72.7	65.4	63.4	50.8	61.0	60.0
19.04.2014	265	260	102	85	95	93	69.0	61.4	64.3	41.2	51.5	50.6
05.05.2014	233	227	90	75	83	87	58.4	50.8	57.4	35.1	45.2	44.4
20.05.2014	241	236	91	79	85	90	61.4	54.1	58.6	39.8	47.6	49.8
05.06.2014	257	247	97	81	90	94	68.2	60.7	52.9	40.7	50.8	50.0
19.06.2014	260	221	84	81	86	90	64.4	56.7	42.8	30.9	41.2	40.5
04.07.2014	231	174	76	71	74	80	54.3	41.2	47.4	35.4	45.6	44.8
19.07.2014	202	184	72	74	70	83	49.2	46.0	36.4	40.0	35.0	34.4
05.08.2014	199	191	74	77	72	86	57.3	54.3	41.2	44.6	39.7	39.0
22.08.2014	224	199	84	71	83	88	52.7	50.2	35.4	38.5	34.6	33.7
04.09.2014	229	205	87	74	85	91	61.0	58.9	40.2	43.1	39.4	38.4
25.09.2014	267	252	105	96	95	101	61.8	59.9	59.3	54.8	42.2	57.2
08.10.2014	275	244	101	87	90	104	65.6	59.3	58.5	48.1	47.0	61.7
24.10.2014	265	212	94	79	75	97	61.8	55.3	53.3	42.6	42.2	57.2
06.11.2014	245	234	90	87	84	81	52.4	50.1	35.0	42.0	36.5	36.0
27.11.2014	118	172	78	86	71	89	39.6	45.3	34.6	41.5	36.1	35.6
04.12.2014	236	190	86	80	79	90	51.5	49.1	39.9	46.8	35.7	40.3
19.12.2014	248	196	90	84	83	93	55.3	53.0	45.0	52.2	40.4	44.8
05.01.2015	251	200	93	88	86	97	59.1	52.5	45.4	46.7	35.6	40.1
20.01.2015	254	211	87	76	80	83	66.7	55.9	44.9	40.4	40.3	44.7
05.02.2015	252	208	83	71	77	79	63.9	52.8	40.1	35.4	35.9	40.5
19.02.2015	224	192	86	76	83	78	54.5	52.3	33.6	34.5	35.1	34.7
05.03.2015	255	211	88	76	81	83	62.5	60.2	50.7	46.4	45.5	49.9
20.03.2015	261	216	87	75	80	82	60.4	49.1	40.8	36.1	36.5	36.0
07.04.2015	254	235	85	72	76	80	62.6	56.4	41.7	37.4	38.4	41.0
20.04.2015	257	238	87	74	78	82	64.1	57.3	45.3	40.6	40.3	40.2
05.05.2015	248	229	81	70	72	76	60.4	57.9	40.1	35.3	35.6	35.5
22.05.2015	254	241	85	75	76	80	64.1	57.3	39.5	40.4	40.1	35.0
03.06.2015	243	224	83	65	70	74	59.2	52.4	44.7	40.1	39.8	39.7
19.06.2015	196	206	76	68	66	71	55.3	48.3	39.4	34.6	35.1	35.0
06.07.2015	206	216	82	65	71	76	58.6	51.8	44.1	39.5	39.3	39.2
20.07.2015	189	196	72	66	64	67	54.2	46.6	38.1	33.5	34.1	33.9
06.08.2015	202	209	79	73	70	74	59.5	51.9	44.2	39.6	39.4	39.3
21.08.2015	190	197	75	69	66	70	63.2	55.7	43.7	44.8	34.2	38.9
05.09.2015	184	191	68	62	60	63	58.5	51.0	37.9	38.7	29.0	33.7
21.09.2015	199	219	59	55	78	69	60.9	50.0	39.0	35.0	38.1	36.4
07.10.2015	257	178	72	60	77	70	65.2	52.2	42.8	36.8	54.5	44.4
20.10.2015	254	192	88	64	84	78	65.2	56.5	48.9	36.4	50.0	40.0
06.11.2015	245	198	83	72	79	65	71.1	50.0	50.0	38.1	53.3	47.8
20.11.2015	261	177	79	75	81	76	68.2	42.8	47.6	38.9	51.7	43.5
05.12.2015	256	172	83	66	77	68	65.6	44.4	39.7	33.6	40.1	34.5
19.12.2015	248	168	86	69	71	63	66.1	41.9	39.9	32.2	39.1	34.8
07.01.2016	252	165	85	68	70	62	67.4	42.7	39.6	31.9	38.8	34.5
21.01.2016	212	162	88	63	75	60	60.5	41.7	40.1	30.6	37.3	31.1
06.02.2016	215	164	86	67	73	63	61.8	42.5	39.8	32.1	38.8	33.7
22.02.2016	220	166	88	67	72	62	62.2	43.1	39.9	31.7	38.5	33.5
05.03.2016	218	165	85	66	74	64	63.9	42.7	39.8	32.0	38.8	33.7
19.03.2016	216	170	87	62	72	59	60.9	48.9	39.5	33.4	39.9	34.3
06.04.2016	212	167	85	61	71	58	60.0	48.2	38.9	32.9	39.3	33.8
20.04.2016	215	166	87	64	73	61	63.1	43.7	39.7	32.2	38.9	33.6
06.05.2016	202	160	79	55	68	57	60.8	40.1	34.9	30.1	35.6	30.6
19.05.2016	198	164	72	60	69	59	58.1	45.2	38.3	32.2	34.5	33.1
06.06.2016	185	159	66	55	68	62	50.3	41.9	34.9	30.5	35.2	34.2
20.06.2016	166	112	55	40	51	49	43.5	36.2	28.2	24.6	28.4	27.6
06.07.2016	174	117	57	42	53	51	45.6	37.1	27.9	20.2	25.6	24.8
20.07.2016	171	110	59	46	55	54	44.7	34.7	30.3	25.1	29.7	28.9
08.08.2016	180	116	63	45	58	52	47.8	37.1	32.4	26.8	31.8	30.9
22.08.2016	189	121	60	41	49	46	51.1	38.8	31.3	23.7	27.7	25.4
07.09.2016	202	136	58	40	54	52	67.4	49.5	26.3	18.2	24.5	23.6
21.09.2016	173	120	62	43	57	50	55.7	39.3	28.1	20.8	25.9	22.7
06.10.2016	188	130	67	47	59	54	68.4	50.1	31.0	21.7	27.3	24.9

JVRO C	PM ₁₀ (µg/m ³)						PM _{2.5} (µg/m ³)					
	Date	CHP	WS	Kista ram	Pallewada	Sathu pally	Venkatapuram	CHP	WS	Kista ram	Palle wada	Sathu pally
20.10.2016	205	138	77	44	55	52	75.2	53.7	35.8	20.5	25.6	24.2
05.11.2016	209	122	73	49	51	56	79.0	46.1	34.2	22.9	23.9	26.2
22.11.2016	219	128	75	50	52	57	78.8	48.8	35.7	24.0	24.9	27.4
13.12.2016	211	134	78	52	55	53	80.2	50.6	37.1	24.7	26.1	25.2
21.12.2016	215	138	80	57	57	55	81.7	53.3	38.2	27.2	27.2	26.2
05.01.2017	205	131	76	51	50	56	79.5	50.8	36.2	24.3	23.8	26.7
23.01.2017	192	128	79	53	52	59	74.1	49.4	37.9	25.4	24.9	27.9
06.02.2017	217	146	77	50	55	51	80.5	56.5	36.5	23.7	26.1	24.2
20.02.2017	212	142	75	49	53	55	82.1	55.2	34.4	22.2	24.4	25.2
07.03.2017	209	155	78	50	49	55	80.5	59.7	36.0	23.1	22.6	25.4
21.03.2017	216	158	74	51	56	58	83.2	60.8	33.9	23.4	25.6	26.6
06.04.2017	220	161	77	50	58	53	84.0	61.5	35.3	22.9	26.6	24.3
20.04.2017	224	171	75	53	59	56	85.6	65.3	34.4	24.3	27.1	25.7
05.05.2017	221	169	78	55	61	58	84.4	64.6	36.3	25.6	28.4	27.0
19.05.2017	217	165	76	51	57	52	78.8	59.8	34.0	22.8	25.5	23.3
04.06.2017	216	148	71	48	58	50	79.1	58.2	32.2	21.1	26.1	22.3
19.06.2017	218	152	73	52	54	52	80.2	55.6	30.1	23.4	25.8	23.7
03.07.2017	214	158	76	56	56	51	81.6	51.3	31.0	21.5	24.7	21.8
18.07.2017	215	140	72	55	52	59	78.7	49.9	32.5	24.7	23.9	23.5
02.08.2017	212	132	77	51	61	57	77.9	50.0	30.3	21.0	25.2	22.8
17.08.2017	210	146	71	47	55	54	76.0	49.1	31.8	22.3	22.2	24.1
02.09.2017	212	133	70	50	56	52	74.6	46.8	29.6	20.3	22.4	21.3
18.09.2017	220	141	75	48	53	56	77.0	49.6	31.7	19.2	21.3	23.0
05.10.2017	238	161	78	50	57	52	83.3	56.7	33.0	20.3	22.8	21.3
17.10.2017	230	150	72	49	55	58	80.5	52.8	30.5	19.8	22.0	23.8
04.11.2017	225	146	74	51	59	55	79.9	51.8	31.0	21.4	24.7	23.0
17.11.2017	229	135	78	54	63	58	81.3	47.9	32.7	22.6	26.4	24.3
06.12.2017	218	155	73	50	59	56	77.4	55.0	30.6	21.0	24.7	23.5
19.12.2017	224	149	80	53	56	55	79.5	53.0	34.2	22.7	24.0	23.5
02.01.2018	232	158	76	56	60	52	83.3	56.1	32.6	24.0	25.7	22.3
18.01.2018	245	165	82	52	54	58	88.0	58.6	34.4	21.8	22.6	24.3
03.02.2018	220	171	74	50	57	55	78.1	60.7	31.2	20.6	23.6	22.7
17.02.2018	240	180	80	60	61	58	85.2	63.9	33.6	24.6	25.0	23.8
02.03.2018	234	188	88	56	70	66	78.4	63.0	37.0	23.5	29.4	27.7
25.03.2018	248	176	85	58	74	60	88.0	62.5	35.3	24.1	30.7	24.9
10.04.2018	211	166	90	50	60	77	72.6	57.1	38.8	21.6	25.9	33.2
26.04.2018	220	169	87	55	58	70	77.4	59.5	38.3	24.2	25.5	30.8
10.05.2018	224	154	85	58	62	65	77.1	53.0	36.6	25.0	26.7	28.0
25.05.2018	226	166	87	55	65	68	79.5	58.5	38.2	24.3	28.6	29.9
11.06.2018	206	117	80	50	59	56	70.9	40.2	34.5	21.6	24.2	24.1
20.06.2018	189	113	86	52	56	60	66.5	39.8	37.7	22.7	24.6	26.4
03.07.2018	175	103	60	41	44	40	56.7	32.3	24.2	16.5	18.2	16.1
17.07.2018	170	95	65	48	50	49	55.1	29.8	26.2	19.3	20.7	19.7
04.08.2018	189	104	63	44	48	45	61.2	32.7	25.4	17.7	19.8	18.1
17.08.2018	198	109	66	46	52	50	64.3	34.3	26.7	18.6	21.5	20.2
04.09.2018	212	143	71	49	56	52	68.7	44.9	28.6	19.7	23.1	21.0
18.09.2018	192	113	68	47	52	49	62.3	35.4	27.4	18.9	21.3	19.7
04.10.2018	218	154	77	56	59	55	70.6	48.4	31.0	22.6	24.4	22.2
27.10.2018	202	125	71	50	55	52	65.4	39.1	28.8	20.2	22.3	21.1
05.11.2018	212	141	75	53	63	59	68.7	44.3	30.5	21.7	26.0	24.1
21.11.2018	205	137	78	55	59	60	66.4	43.0	31.7	22.5	24.3	24.5
07.12.2018	218	144	72	58	61	57	70.6	45.2	29.3	23.7	25.2	23.3
19.12.2018	198	130	75	54	63	60	64.2	40.8	30.3	22.2	26.0	24.5
02.01.2019	203	140	79	50	60	55	65.8	44.2	32.3	20.3	24.7	22.5
22.01.2019	225	171	76	56	63	58	72.9	53.7	31.7	22.7	26.2	24.2
02.02.2019	214	143	72	50	60	56	69.6	45.0	29.0	20.6	24.9	22.6
18.02.2019	230	166	75	56	63	53	74.6	52.1	30.2	22.6	25.8	21.3
02.03.2019	212	148	76	53	60	57	68.6	46.4	30.7	21.3	25.0	23.1
17.03.2019	224	156	80	56	64	60	72.4	48.9	32.4	22.3	26.5	24.6
02.04.2019	231	155	76	56	63	58	87.9	59.7	29.5	20.6	24.4	22.9
20.04.2019	197	161	78	55	59	60	75.8	55.7	31.2	22.4	26.7	24.8
07.05.2019	217	160	78	55	66	58	82.6	50.2	31.4	22.1	27.4	23.7
16.05.2019	224	169	75	58	70	61	93.2	53.0	30.2	23.3	28.9	25.0
02.06.2019	223	156	79	56	73	65	86.3	50.5	31.8	22.5	30.3	26.5
28.06.2019	227	158	77	55	65	59	73.5	49.7	31.2	22.3	26.8	23.9
06.07.2019	192	134	68	49	57	52	58.5	40.8	26.8	22.2	23.1	26.8

JVRO C	PM ₁₀ (µg/m ³)						PM _{2.5} (µg/m ³)					
	Date	CHP	WS	Kista ram	Pallewada	Sathu pally	Venkatapuram	CHP	WS	Kista ram	Palle wada	Sathu pally
18.07.2019	181	126	64	46	54	49	54.6	38.0	32.0	23.0	27.0	24.5
02.08.2019	198	132	66	47	51	48	64.2	41.4	26.6	24.3	21.1	26.5
17.08.2019	205	144	70	51	58	55	66.4	45.2	28.2	20.6	24.0	22.2
04.09.2019	191	102	68	49	53	52	61.9	32.0	27.4	22.5	21.9	21.0
18.09.2019	185	110	65	48	51	50	59.9	41.3	26.6	24.6	21.2	20.7
03.10.2019	211	133	69	50	56	53	68.4	41.8	27.8	20.2	23.1	21.4
17.10.2019	217	137	72	52	58	55	70.3	42.9	29.4	21.2	23.9	22.7
02.11.2019	223	142	75	55	62	60	72.3	44.6	30.6	22.7	25.6	24.8
18.11.2019	229	146	73	58	65	63	74.1	45.7	29.9	23.7	27.1	26.1
03.12.2019	230	150	70	56	60	57	74.5	47.1	28.6	23.1	24.8	23.5
17.12.2019	236	154	74	59	63	60	77.3	48.7	30.2	24.1	26.3	24.8
02.01.2020	225	155	76	58	67	63	72.9	48.7	31.0	24.0	27.6	26.2
20.01.2020	231	159	80	61	70	67	75.6	50.4	32.8	25.0	29.2	27.6
03.02.2020	236	163	78	56	62	60	76.5	51.2	32.1	23.1	25.7	25.0
18.02.2020	228	151	76	53	60	63	74.8	47.9	31.1	21.6	24.9	26.0
03.03.2020	220	145	71	55	64	59	72.2	46.0	29.0	22.4	26.6	24.4
18.03.2020	201	140	60	49	52	50	65.9	44.4	24.5	20.0	21.6	20.7
03.04.2020	188	116	54	44	50	47	57.9	36.8	22.0	17.9	20.3	19.4
17.04.2020	186	110	52	42	47	45	57.3	34.9	21.3	17.0	19.2	18.6
04.05.2020	195	120	59	48	53	50	64.0	38.0	24.2	19.4	22.1	20.8
18.05.2020	200	125	61	49	55	52	66.2	39.6	24.8	19.9	22.7	21.3
02.06.2020	204	131	63	50	56	53	67.5	41.6	25.7	20.6	23.4	22.0
17.06.2020	206	135	60	52	54	55	68.2	42.8	24.5	21.2	22.4	22.7
02.07.2020	210	140	64	50	57	53	69.5	44.4	26.2	20.4	23.7	21.9
17.07.2020	212	144	68	52	55	56	70.2	45.6	28.5	21.2	22.8	23.1
03.08.2020	181	102	61	47	49	50	59.9	32.3	25.5	19.9	20.4	20.7
18.08.2020	180	107	59	49	51	52	59.6	33.9	24.7	21.0	21.2	21.5
07.09.2020	94	97.5	62	51	54	55	30.2	31.3	26.0	22.0	22.2	22.5
22.09.2020	99	107.6	65	54	56	57	31.7	34.5	27.3	23.1	23.3	23.7
08.10.2020	95	128	70	55	58	55	30.5	43.6	29.3	23.5	24.1	22.7
22.10.2020	97	126	68	55	57	56	31.1	42.8	28.3	23.3	23.7	23.1
07.11.2020	102	135	71	57	60	59	32.7	46.0	29.7	24.5	24.9	24.3
20.11.2020	112	141	69	54	62	60	36.0	48.1	28.9	23.1	25.7	24.8
09.12.2020	110	137	68	56	60	58	35.3	46.7	28.5	24.0	24.9	24.0
25.12.2020	108	138	69	56	61	59	34.7	46.9	29.0	23.7	25.2	24.2
10.01.2021	104	134	70	55	60	58	33.4	45.7	29.3	23.6	24.7	23.7
26.01.2021	107	136	67	52	58	57	34.3	46.2	28.1	22.3	24.1	23.5
11.02.2021	102	143	66	50	55	53	32.7	48.8	27.7	21.3	22.8	21.7
21.02.2021	105	147	68	51	56	54	33.6	50.0	28.3	21.9	23.4	22.4
10.03.2021	98	124	64	49	58	52	31.5	42.3	26.8	20.8	24.3	21.3
22.03.2021	101	134	69	52	56	55	33.4	46.6	28.9	22.4	23.2	22.2
06.04.2021	97	121	65	50	53	52	31.3	41.3	27.2	21.3	22.2	21.3
22.04.2021	105	129	67	49	55	50	34.8	45.0	27.4	21.1	23.4	20.4
05.05.2021	111	135	75	51	57	53	43.1	43.9	33.7	21.7	23.9	21.7
20.05.2021	101	130	60	53	55	51	39.2	49.5	25.1	22.8	23.5	20.8
07.06.2021	92	122	62	49	53	50	30.5	42.6	25.4	20.8	22.2	20.5
22.06.2021	97	126	61	51	54	51	31.9	44.0	25.6	21.9	22.7	20.7
07.07.2021	95	132	64	50	56	52	31.4	46.1	26.2	21.3	23.5	21.3
22.07.2021	103	127	62	49	58	50	34.1	44.2	26.1	21.0	24.3	20.5
07.08.2021	98	130	68	52	55	56	32.4	45.4	27.8	22.1	23.0	23.0
23.08.2021	106	135	65	50	56	53	35.1	47.1	27.1	21.6	23.6	21.6
07.09.2021	92	116	66	47	51	49	30.5	40.5	27.0	20.0	21.4	20.1
22.09.2021	95	120	68	49	54	53	31.4	41.9	28.6	20.9	22.6	21.7
13.10.2021	105	121	65	53	58	55	34.8	42.2	26.6	22.5	24.3	22.6
22.10.2021	112	125	63	56	56	52	37.1	43.6	26.4	24.0	23.5	21.3
06.11.2021	84	130	61	48	56	54	32.0	45.4	24.9	20.4	24.0	22.1
22.11.2021	89	128	59	50	54	55	37.5	44.7	24.7	21.5	23.2	22.7
06.12.2021	95	133	133	53	52	50	36.2	46.4	46.4	22.5	22.3	20.5
22.12.2021	111	140	140	50	59	56	46.7	48.9	48.9	21.5	25.3	23.1
07.01.2022	95	146	146	50	55	54	36.1	51.0	41.0	21.4	23.7	22.0
25.01.2022	101	134	134	53	56	51	42.5	46.6	46.6	22.7	24.0	21.1
07.02.2022	94	130	130	49	58	53	35.8	45.4	45.4	20.8	24.9	21.7
21.02.2022	99	137	137	51	61	56	41.6	47.7	47.7	22.1	26.2	23.0
10.03.2022	91	135	68	50	55	56	34.7	47.1	27.9	21.3	23.7	22.8
23.03.2022	90	142	60	50	53	54	37.9	49.5	25.1	21.5	22.7	22.3

Appendix III

Table 1. GK OC Mine parameters

GK OC	Production (Coal+OB)	Area contributing to pollution	Max. Quarry depth	Max. Dump height	Lead distance
Date	(t)	(Ha)	(m)	(m)	(km)
09.04.2012	1,30,042	340.0	182.0	70.0	5.5
24.04.2012	1,21,915	338.9	182.1	70.0	5.5
09.05.2012	1,27,306	337.8	182.2	70.1	5.5
24.05.2012	1,19,349	336.6	182.2	70.1	5.5
09.06.2012	1,19,893	335.5	182.3	70.2	5.5
23.06.2012	1,12,400	334.4	182.4	70.2	5.4
04.07.2012	96,513	333.3	182.5	70.3	5.4
19.07.2012	90,481	332.1	182.6	70.3	5.4
04.08.2012	49,967	331.0	182.6	70.3	5.4
19.08.2012	46,844	329.9	182.7	70.4	5.4
05.09.2012	28,995	328.7	182.8	70.4	5.4
20.09.2012	27,183	327.6	182.9	70.5	5.4
06.10.2012	19,814	326.5	183.0	70.5	5.4
19.10.2012	18,575	325.4	183.0	70.5	5.4
07.11.2012	13,247	324.2	183.1	70.6	5.4
20.11.2012	12,419	323.1	183.2	70.6	5.3
05.12.2012	13,323	322.0	183.3	70.7	5.3
20.12.2012	12,490	320.8	183.4	70.7	5.3
04.01.2013	1,46,485	319.7	183.4	70.8	5.3
19.01.2013	1,37,330	318.6	183.5	70.8	5.3
05.02.2013	1,38,062	317.5	183.6	70.8	5.3
20.02.2013	1,48,682	316.3	183.7	70.9	5.3
05.03.2013	1,07,039	315.2	183.8	70.9	5.3
20.03.2013	1,00,349	314.1	183.8	71.0	5.3
04.04.2013	90,430	311.8	184.0	71.0	5.3
19.04.2013	84,778	311.0	184.2	71.0	5.2
04.05.2013	1,01,267	310.3	184.3	71.1	5.2
20.05.2013	94,938	309.5	184.5	71.1	5.2
05.06.2013	87,134	308.7	184.6	71.2	5.2
20.06.2013	81,688	307.9	184.8	71.2	5.2
05.07.2013	61,531	307.1	185.0	71.3	5.2
19.07.2013	57,685	306.3	185.1	71.3	5.2
05.08.2013	80,819	305.5	185.3	71.3	5.2
20.08.2013	75,768	304.8	185.4	71.4	5.2
05.09.2013	74,096	304.0	185.6	71.4	5.2
19.09.2013	69,465	303.2	185.8	71.5	5.1
04.10.2013	74,331	302.4	185.9	71.5	5.1
19.10.2013	69,685	301.6	186.1	71.5	5.1
05.11.2013	83,805	300.8	186.2	71.6	5.1
20.11.2013	78,567	300.0	186.4	71.6	5.1
05.12.2013	89,583	299.3	186.6	71.7	5.1
19.12.2013	83,984	298.5	186.7	71.7	5.1
04.01.2014	86,732	297.7	186.9	71.8	5.1
20.01.2014	81,311	296.9	187.0	71.8	5.1
05.02.2014	79,326	296.1	187.2	71.8	5.1
20.02.2014	73,660	295.3	187.4	71.9	5.0
05.03.2014	68,623	294.6	187.5	71.9	5.0
20.03.2014	64,334	293.8	187.7	72.0	5.0

GK OC	Production (Coal+OB)	Area contributing to pollution	Max. Quarry depth	Max. Dump height	Lead distance
Date	(t)	(Ha)	(m)	(m)	(km)
04.04.2014	33,499	292.2	188.0	72.0	5.0
19.04.2014	31,405	292.2	188.2	72.0	5.0
05.05.2014	36,634	292.3	188.4	72.1	5.0
20.05.2014	34,344	292.3	188.6	72.1	5.0
05.06.2014	69,952	292.3	188.8	72.2	5.0
19.06.2014	65,580	292.3	189.0	72.2	5.0
04.07.2014	49,883	292.4	189.2	72.3	5.0
19.07.2014	46,766	292.4	189.3	72.3	5.0
05.08.2014	71,533	292.4	189.5	72.3	5.0
22.08.2014	67,062	292.5	189.7	72.4	4.9
04.09.2014	72,105	292.5	189.9	72.4	4.9
25.09.2014	67,598	292.5	190.1	72.5	4.9
08.10.2014	1,02,814	292.6	190.3	72.5	4.9
24.10.2014	96,388	292.6	190.5	72.5	4.9
06.11.2014	1,14,817	292.6	190.7	72.6	4.9
20.11.2014	1,07,641	292.6	190.9	72.6	4.9
04.12.2014	1,15,370	292.7	191.1	72.7	4.9
19.12.2014	1,08,159	292.7	191.3	72.7	4.9
05.01.2015	1,17,416	292.7	191.5	72.8	4.9
20.01.2015	1,10,078	292.8	191.7	72.8	4.9
05.02.2015	1,13,477	292.8	191.8	72.8	4.9
19.02.2015	1,05,371	292.8	192.0	72.9	4.9
05.03.2015	1,30,389	292.9	192.2	72.9	4.9
20.03.2015	1,22,240	292.9	192.4	73.0	4.9
07.04.2015	1,11,978	292.9	193.0	73.0	4.9
20.04.2015	1,04,980	292.7	193.2	73.0	4.8
05.05.2015	1,29,054	292.4	193.3	73.1	4.8
22.05.2015	1,20,988	292.2	193.5	73.1	4.7
03.06.2015	97,753	291.9	193.6	73.2	4.7
19.06.2015	91,643	291.7	193.8	73.2	4.7
06.07.2015	1,47,230	291.4	194.0	73.3	4.6
20.07.2015	1,38,028	291.2	194.1	73.3	4.6
06.08.2015	1,23,083	290.9	194.3	73.3	4.5
21.08.2015	1,15,390	290.7	194.4	73.4	4.5
05.09.2015	1,14,515	290.4	194.6	73.4	4.5
21.09.2015	1,07,358	290.2	194.8	73.5	4.4
07.10.2015	1,29,679	289.9	194.9	73.5	4.4
20.10.2015	1,21,574	289.7	195.1	73.5	4.3
06.11.2015	1,23,729	289.4	195.2	73.6	4.3
20.11.2015	1,15,996	289.2	195.4	73.6	4.3
05.12.2015	1,38,982	288.9	195.6	73.7	4.2
19.12.2015	1,30,295	288.7	195.7	73.7	4.2
07.01.2016	1,34,837	288.4	195.9	73.8	4.1
21.01.2016	1,26,410	288.2	196.0	73.8	4.1
06.02.2016	1,26,269	287.9	196.2	73.8	4.1
22.02.2016	1,17,851	287.7	196.4	73.9	4.0
05.03.2016	1,35,586	287.4	196.5	73.9	4.0
19.03.2016	1,27,112	287.2	196.7	74.0	3.9
06.04.2016	1,26,902	286.7	197.0	74.0	3.9
20.04.2016	1,18,971	286.5	197.3	74.0	3.8
06.05.2016	1,18,956	286.3	197.6	74.1	3.8

GK OC	Production (Coal+OB)	Area contributing to pollution	Max. Quarry depth	Max. Dump height	Lead distance
Date	(t)	(Ha)	(m)	(m)	(km)
19.05.2016	1,11,521	286.1	198.0	74.1	3.8
06.06.2016	1,00,912	286.0	198.3	74.2	3.8
20.06.2016	94,605	285.8	198.6	74.2	3.8
06.07.2016	1,11,040	285.6	198.9	74.3	3.8
20.07.2016	1,04,100	285.4	199.2	74.3	3.8
08.08.2016	1,08,571	285.2	199.6	74.3	3.8
22.08.2016	1,01,785	285.1	199.9	74.4	3.7
07.09.2016	82,922	284.9	200.2	74.4	3.7
21.09.2016	77,739	284.7	200.5	74.5	3.7
06.10.2016	1,12,604	284.5	200.8	74.5	3.7
20.10.2016	1,05,566	284.4	201.2	74.5	3.7
05.11.2016	1,19,355	284.2	201.5	74.6	3.7
22.11.2016	1,11,895	284.0	201.8	74.6	3.7
13.12.2016	1,21,302	283.8	202.1	74.7	3.7
21.12.2016	1,13,721	283.7	202.4	74.7	3.6
05.01.2017	1,14,088	283.5	202.8	74.8	3.6
23.01.2017	1,06,958	283.3	203.1	74.8	3.6
06.02.2017	96,536	283.1	203.4	74.8	3.6
20.02.2017	89,641	282.9	203.7	74.9	3.6
07.03.2017	71,332	282.8	204.0	74.9	3.6
21.03.2017	66,874	282.6	204.4	75.0	3.6
06.04.2017	99,277	282.2	205.0	75.0	3.5
20.04.2017	93,073	279.8	205.2	75.0	3.5
05.05.2017	91,222	277.3	205.4	75.1	3.5
19.05.2017	85,521	274.8	205.6	75.1	3.5
09.06.2017	81,797	272.4	205.8	75.2	3.5
23.06.2017	76,684	269.9	206.0	75.2	3.5
05.07.2017	91,672	267.4	206.3	75.3	3.5
19.07.2017	85,943	265.0	206.5	75.3	3.4
05.08.2017	85,423	262.5	206.7	75.3	3.4
22.08.2017	80,084	260.0	206.9	75.4	3.4
01.09.2017	1,05,571	257.6	207.1	75.4	3.4
16.09.2017	98,973	255.1	207.3	75.5	3.4
04.10.2017	1,13,611	252.7	207.5	75.5	3.4
16.10.2017	1,06,511	250.2	207.7	75.5	3.4
03.11.2017	1,25,605	247.7	207.9	75.6	3.4
16.11.2017	1,17,754	245.3	208.1	75.6	3.3
05.12.2017	1,39,859	242.8	208.3	75.7	3.3
18.12.2017	1,31,118	240.3	208.5	75.7	3.3
01.01.2018	1,31,231	237.9	208.8	75.8	3.3
17.01.2018	1,23,029	235.4	209.0	75.8	3.3
02.02.2018	1,32,979	232.9	209.2	75.8	3.3
16.02.2018	1,24,113	230.5	209.4	75.9	3.3
01.03.2018	1,29,133	228.0	209.6	75.9	3.2
24.03.2018	1,21,062	225.5	209.8	76.0	3.2
09.04.2018	1,19,421	220.6	210.0	76.0	3.2
25.04.2018	1,11,957	218.5	211.0	76.0	3.2
09.05.2018	1,34,591	216.4	212.0	76.1	3.2
24.05.2018	1,26,179	214.2	213.0	76.1	3.1
09.06.2018	1,09,982	212.1	214.0	76.2	3.1
19.06.2018	1,03,108	210.0	215.0	76.2	3.1

GK OC	Production (Coal+OB)	Area contributing to pollution	Max. Quarry depth	Max. Dump height	Lead distance
Date	(t)	(Ha)	(m)	(m)	(km)
02.07.2018	81,376	207.9	216.0	76.3	3.1
16.07.2018	76,290	205.7	217.0	76.3	3.0
02.08.2018	78,656	203.6	218.0	76.3	3.0
16.08.2018	73,740	201.5	219.0	76.4	3.0
03.09.2018	1,30,720	199.4	220.0	76.4	3.0
17.09.2018	1,22,550	197.2	221.0	76.5	2.9
03.10.2018	1,24,820	195.1	222.0	76.5	2.9
26.10.2018	1,17,317	193.0	223.0	76.5	2.9
03.11.2018	1,19,369	190.8	224.0	76.6	2.8
21.11.2018	1,11,909	188.7	225.0	76.6	2.8
06.12.2018	1,24,363	186.6	226.0	76.7	2.8
18.12.2018	1,16,590	184.5	227.0	76.7	2.8
01.01.2019	1,23,432	182.3	228.0	76.8	2.7
21.01.2019	1,15,718	180.2	229.0	76.8	2.7
01.02.2019	1,29,284	178.1	230.0	76.8	2.7
16.02.2019	1,20,049	176.0	231.0	76.9	2.7
07.03.2019	1,23,124	173.8	232.0	76.9	2.6
23.03.2019	1,15,429	171.7	233.0	77.0	2.6
08.04.2019	1,04,837	167.5	235.0	77.0	2.6
18.04.2019	98,285	166.2	235.0	77.0	2.5
04.05.2019	1,01,624	165.0	235.0	77.1	2.5
22.05.2019	95,272	163.8	235.0	77.1	2.5
07.06.2019	95,065	162.6	235.0	77.2	2.5
27.06.2019	89,124	161.3	235.0	77.2	2.4
05.07.2019	82,163	160.1	235.0	77.3	2.4
17.07.2019	77,028	158.9	235.0	77.3	2.4
01.08.2019	76,900	157.6	235.0	77.3	2.4
16.08.2019	72,094	156.4	235.0	77.4	2.4
03.09.2019	76,527	155.2	235.0	77.4	2.3
16.09.2019	71,745	154.0	235.0	77.5	2.3
01.10.2019	80,370	152.7	235.0	77.5	2.3
16.10.2019	75,347	151.5	235.0	77.5	2.3
01.11.2019	92,731	150.3	235.0	77.6	2.2
16.11.2019	86,936	149.1	235.0	77.6	2.2
02.12.2019	91,090	147.8	235.0	77.7	2.2
16.12.2019	85,396	146.6	235.0	77.7	2.2
01.01.2020	90,665	145.4	235.0	77.8	2.2
18.01.2020	84,999	144.1	235.0	77.8	2.1
01.02.2020	92,355	142.9	235.0	77.8	2.1
17.02.2020	86,198	141.7	235.0	77.9	2.1
02.03.2020	60,709	140.5	235.0	77.9	2.1
17.03.2020	56,915	139.2	235.0	78.0	2.0
01.04.2020	37,568	136.8	235.0	78.0	2.0
16.04.2020	35,220	136.2	235.0	78.0	2.0
02.05.2020	45,100	135.6	235.0	78.1	2.0
16.05.2020	42,281	135.0	235.0	78.1	1.9
01.06.2020	35,708	134.4	235.0	78.2	1.9
16.06.2020	33,476	133.8	235.0	78.2	1.9
01.07.2020	23,128	133.2	235.0	78.3	1.9
16.07.2020	21,683	132.6	235.0	78.3	1.9
01.08.2020	18,952	132.0	235.0	78.3	1.8

GK OC	Production (Coal+OB)	Area contributing to pollution	Max. Quarry depth	Max. Dump height	Lead distance
Date	(t)	(Ha)	(m)	(m)	(km)
17.08.2020	17,768	131.4	235.0	78.4	1.8
01.09.2020	26,116	130.8	235.0	78.4	1.8
16.09.2020	27,035	130.2	235.0	78.5	1.8
01.10.2020	17,594	129.6	235.0	78.5	1.8
16.10.2020	16,495	129.0	235.0	78.5	1.7
02.11.2020	20,249	128.4	235.0	78.6	1.7
16.11.2020	18,983	127.8	235.0	78.6	1.7
02.12.2020	23,622	127.2	235.0	78.7	1.7
17.12.2020	22,146	126.6	235.0	78.7	1.7
02.01.2021	19,542	126.0	235.0	78.8	1.6
18.01.2021	18,321	125.4	235.0	78.8	1.6
03.02.2021	22,526	124.8	235.0	78.8	1.6
19.02.2021	20,917	124.2	235.0	78.9	1.6
01.03.2021	22,745	123.6	235.0	78.9	1.6
16.03.2021	21,323	123.0	235.0	79.0	1.5
01.04.2021	17,686	121.8	235.0	79.0	1.5
16.04.2021	16,581	121.8	235.0	79.0	1.4
03.05.2021	15,889	121.8	235.0	79.1	1.4
19.05.2021	14,896	121.8	235.0	79.1	1.3
01.06.2021	16,651	121.8	235.0	79.2	1.3
16.06.2021	15,611	121.8	235.0	79.2	1.2
01.07.2021	10,956	121.8	235.0	79.3	1.1
16.07.2021	10,271	121.8	235.0	79.3	1.1
02.08.2021	12,837	121.8	235.0	79.3	1.0
17.08.2021	12,035	121.8	235.0	79.4	1.0
01.09.2021	17,374	121.8	235.0	79.4	0.9
16.09.2021	16,288	121.8	235.0	79.5	0.8
05.10.2021	18,407	121.8	235.0	79.5	0.8
21.10.2021	17,257	121.8	235.0	79.5	0.7
05.11.2021	11,123	121.8	235.0	79.6	0.7
16.11.2021	10,428	121.8	235.0	79.6	0.6
05.12.2021	8,949	121.8	235.0	79.7	0.5
16.12.2021	8,390	121.8	235.0	79.7	0.5
01.01.2022	9,073	121.8	235.0	79.8	0.4
21.01.2022	8,506	121.8	235.0	79.8	0.4
01.02.2022	9,653	121.8	235.0	79.8	0.3
16.02.2022	8,963	121.8	235.0	79.9	0.2
01.03.2022	17,859	121.8	235.0	79.9	0.2
16.03.2022	16,743	121.8	235.0	80.0	0.2

Table 2. GK OC Meteorological data

GK OC	Predominant wind direction	Avg. Temp	Avg. Humidity	Avg. Rainfall	Avg. Wind speed
Date	(degrees)	(°c)	(%)	(mm)	(m/s)
09.04.2012	225	38.2	61.0	0.0	6.3
24.04.2012	215	40.1	57.8	0.0	4.5
09.05.2012	67	42.6	59.4	0.0	0.7
24.05.2012	35	41.2	25.4	0.0	3.8
09.06.2012	78	40.0	76.5	0.1	0.6
23.06.2012	156	39.8	64.8	0.1	0.6
04.07.2012	98	38.0	78.1	0.9	1.5
19.07.2012	243	36.6	92.3	1.1	0.4

GK OC	Predominant wind direction	Avg. Temp	Avg. Humidity	Avg. Rainfall	Avg. Wind speed
Date	(degrees)	(°c)	(%)	(mm)	(m/s)
04.08.2012	55	35.5	88.3	0.2	1.6
19.08.2012	74	35.0	55.4	0.0	1.2
05.09.2012	145	33.2	91.3	0.2	0.1
20.09.2012	108	33.4	88.1	4.0	0.2
06.10.2012	50	32.8	88.6	0.4	0.4
19.10.2012	76	32.1	75.4	0.0	0.2
07.11.2012	212	30.5	65.1	0.0	0.2
20.11.2012	167	31.2	75.5	0.0	0.3
05.12.2012	225	29.8	71.6	0.0	0.0
20.12.2012	275	28.5	56.8	0.0	0.0
04.01.2013	336	27.9	73.0	0.0	1.5
19.01.2013	351	25.3	66.0	0.0	6.5
05.02.2013	48	25.0	71.8	0.0	6.9
20.02.2013	15	25.1	55.4	0.0	4.0
05.03.2013	2	26.5	71.9	0.0	4.8
20.03.2013	130	29.4	66.8	0.0	5.3
04.04.2013	124	33.5	66.5	0.0	4.6
19.04.2013	64	38.8	65.5	0.1	9.8
04.05.2013	148	41.7	61.1	0.1	5.4
20.05.2013	26	38.6	54.5	0.2	5.4
05.06.2013	23	28.5	86.0	45.8	6.4
20.06.2013	1	33.2	58.8	0.0	6.9
05.07.2013	221	34.8	92.6	28.2	3.2
19.07.2013	250	24.7	92.1	10.0	5.0
05.08.2013	304	35.1	89.6	0.0	4.4
20.08.2013	226	35.1	90.6	4.8	8.3
05.09.2013	306	35.6	91.8	0.0	7.0
19.09.2013	277	34.4	91.9	22.0	5.1
04.10.2013	221	25.6	94.0	5.0	6.4
19.10.2013	49	36.0	91.5	0.0	2.5
05.11.2013	90	34.6	91.6	0.0	8.7
20.11.2013	354	32.7	88.3	0.0	7.7
05.12.2013	75	30.6	88.4	0.0	6.8
19.12.2013	45	29.7	89.8	0.0	3.7
04.01.2014	128	31.5	91.5	0.0	8.5
20.01.2014	300	32.3	92.5	0.0	14.3
05.02.2014	166	34.8	92.9	2.4	6.7
20.02.2014	311	33.0	89.4	0.0	18.5
05.03.2014	289	31.9	88.4	0.0	12.4
20.03.2014	328	38.3	90.7	0.0	12.9
04.04.2014	257	38.2	91.4	0.0	13.4
19.04.2014	357	39.5	88.3	0.0	10.0
05.05.2014	131	40.8	86.9	0.0	7.1
20.05.2014	352	37.3	80.2	0.0	5.7
05.06.2014	177	38.1	88.1	0.0	4.7
19.06.2014	242	34.9	83.3	1.8	9.0
04.07.2014	228	41.0	56.4	0.0	7.6
19.07.2014	295	33.2	86.1	0.0	8.6
05.08.2014	33	33.0	92.9	46.2	18.7
22.08.2014	355	36.9	87.6	0.0	10.1
04.09.2014	356	34.8	88.1	0.0	14.6
25.09.2014	202	35.5	90.1	0.0	3.0
08.10.2014	47	35.5	89.1	0.0	2.6
24.10.2014	259	32.8	88.6	0.0	3.3
06.11.2014	282	30.7	88.1	0.0	4.0
20.11.2014	301	31.4	89.6	0.0	0.0
04.12.2014	312	30.7	89.1	0.0	0.0
19.12.2014	281	29.3	84.8	0.0	0.0
05.01.2015	241	34.1	87.2	0.0	0.0
20.01.2015	291	31.4	87.6	0.0	0.0
05.02.2015	353	33.4	88.6	0.0	0.0
19.02.2015	13	36.2	90.1	0.0	4.6
05.03.2015	339	35.5	89.1	0.0	1.8
20.03.2015	57	37.6	89.1	0.0	3.8
07.04.2015	108	38.9	87.6	0.0	6.6

GK OC	Predominant wind direction	Avg. Temp	Avg. Humidity	Avg. Rainfall	Avg. Wind speed
Date	(degrees)	(°c)	(%)	(mm)	(m/s)
20.04.2015	19	38.9	88.6	0.0	5.2
05.05.2015	113	38.9	87.2	0.0	5.1
22.05.2015	90	45.8	72.1	0.0	5.8
03.06.2015	6	38.3	71.1	0.0	6.5
19.06.2015	24	29.3	90.1	50.2	0.0
06.07.2015	360	36.9	79.2	0.0	7.9
20.07.2015	1	36.4	93.2	0.0	4.9
06.08.2015	143	36.3	88.6	2.2	6.0
21.08.2015	1	34.6	88.8	0.0	4.0
05.09.2015	357	35.6	92.8	0.0	2.3
21.09.2015	360	25.9	94.7	74.2	5.3
07.10.2015	5	36.0	92.6	0.0	2.2
20.10.2015	1	36.6	93.0	0.0	1.1
06.11.2015	1	34.6	92.1	0.0	2.8
20.11.2015	1	28.5	79.9	0.0	5.9
05.12.2015	1	33.7	89.9	0.0	1.8
19.12.2015	1	33.9	92.5	0.0	1.5
07.01.2016	40	32.1	92.6	0.5	1.8
21.01.2016	40	29.5	86.9	0.0	2.1
06.02.2016	40	33.6	92.0	0.0	3.1
22.02.2016	40	37.2	90.5	0.0	2.8
05.03.2016	40	35.7	87.5	0.0	2.4
19.03.2016	40	39.2	91.0	0.0	3.5
06.04.2016	114	31.5	58.0	0.2	3.8
20.04.2016	208	32.6	56.0	0.0	7.1
06.05.2016	181	29.2	61.0	0.2	1.1
19.05.2016	66	27.6	76.0	0.1	1.1
06.06.2016	202	27.7	83.8	0.4	0.3
20.06.2016	245	27.5	86.3	0.1	0.4
06.07.2016	264	29.6	65.6	0.0	2.0
20.07.2016	193	27.3	82.4	0.0	0.5
08.08.2016	286	30.4	61.3	0.0	1.6
22.08.2016	193	29.7	69.2	0.0	0.2
07.09.2016	193	27.2	88.3	0.0	0.1
21.09.2016	166	25.5	93.7	0.9	0.0
06.10.2016	178	26.9	88.6	0.4	0.4
20.10.2016	163	24.8	69.3	0.0	0.1
05.11.2016	166	27.1	72.4	0.0	0.2
22.11.2016	180	21.5	73.3	0.0	0.0
13.12.2016	219	26.1	64.5	0.0	0.0
21.12.2016	220	21.8	52.6	0.0	0.3
05.01.2017	168	21.0	71.3	0.0	0.0
23.01.2017	162	24.2	65.0	0.0	0.4
06.02.2017	176	24.5	65.8	0.0	0.2
20.02.2017	197	26.3	55.4	0.0	0.0
07.03.2017	315	29.3	69.7	0.0	0.7
21.03.2017	194	29.2	63.3	0.0	0.1
06.04.2017	305	31.7	69.6	0.1	0.2
20.04.2017	289	33.1	61.7	0.1	0.7
05.05.2017	262	32.7	60.1	0.2	0.4
19.05.2017	148	36.8	38.3	0.1	0.4
09.06.2017	185	27.6	82.2	0.2	0.3
23.06.2017	161	28.1	73.1	0.0	0.8
05.07.2017	136	29.0	78.2	0.1	0.3
19.07.2017	134	26.7	84.0	0.0	1.3
05.08.2017	122	26.7	84.2	0.0	0.5
22.08.2017	180	28.9	80.7	0.0	0.1
01.09.2017	134	28.2	88.0	0.0	0.2
16.09.2017	112	29.6	77.1	0.0	0.1
04.10.2017	203	28.4	73.6	0.0	1.2
16.10.2017	222	26.7	57.4	0.0	0.3
03.11.2017	88	24.7	73.2	0.0	0.0
16.11.2017	183	26.3	79.7	0.0	0.3
05.12.2017	156	22.3	77.3	0.0	0.0
18.12.2017	269	21.2	75.9	0.0	0.0

GK OC	Predominant wind direction	Avg. Temp	Avg. Humidity	Avg. Rainfall	Avg. Wind speed
Date	(degrees)	(°c)	(%)	(mm)	(m/s)
01.01.2018	167	24.4	62.9	0.0	0.2
17.01.2018	213	23.7	72.1	0.0	0.2
02.02.2018	261	23.9	52.6	0.0	0.0
16.02.2018	209	26.1	60.4	0.0	0.0
01.03.2018	161	27.4	59.0	0.0	0.0
24.03.2018	318	30.4	73.3	0.0	0.1
09.04.2018	307	29.7	67.7	0.0	0.1
25.04.2018	214	31.6	59.9	0.0	0.1
09.05.2018	180	32.5	64.9	0.0	0.2
24.05.2018	162	31.0	73.9	0.0	0.0
09.06.2018	241	27.9	87.0	0.2	0.1
19.06.2018	203	31.5	66.2	0.0	0.1
02.07.2018	188	29.3	83.9	0.0	0.0
16.07.2018	217	26.0	94.8	0.2	1.0
02.08.2018	201	26.6	91.4	0.7	0.0
16.08.2018	174	25.7	93.7	0.2	0.0
03.09.2018	232	28.1	83.4	0.0	0.0
17.09.2018	246	27.4	83.8	0.1	0.0
03.10.2018	209	28.3	86.1	0.0	0.0
26.10.2018	300	25.2	73.5	0.0	0.0
03.11.2018	194	28.0	80.6	0.1	0.0
21.11.2018	193	25.4	75.5	0.0	0.0
06.12.2018	213	25.0	85.4	0.0	0.0
18.12.2018	217	19.3	92.7	0.1	0.0
01.01.2019	67	17.2	76.3	0.0	0.0
21.01.2019	149	22.3	82.9	0.0	0.0
01.02.2019	139	22.1	82.2	0.0	0.0
16.02.2019	187	25.9	81.0	0.0	0.0
07.03.2019	115	29.1	78.2	0.0	0.0
23.03.2019	200	28.3	77.8	0.0	0.0
08.04.2019	187	30.5	74.4	0.0	0.0
18.04.2019	180	31.5	71.3	0.0	0.0
04.05.2019	233	33.6	49.6	0.0	0.0
22.05.2019	192	33.2	69.0	0.0	0.0
07.06.2019	174	33.8	65.9	0.0	0.0
27.06.2019	182	32.1	71.6	0.0	0.0
05.07.2019	112	28.5	81.3	0.1	0.0
17.07.2019	148	32.1	72.6	0.0	0.0
01.08.2019	138	26.0	92.2	1.5	0.0
16.08.2019	113	27.2	92.1	0.1	0.0
03.09.2019	149	25.3	93.5	0.2	0.0
16.09.2019	138	27.3	92.1	0.0	0.0
01.10.2019	230	27.0	91.0	0.0	0.0
16.10.2019	146	27.2	88.8	0.0	0.0
01.11.2019	81	26.7	90.3	0.0	0.0
16.11.2019	71	24.8	86.6	0.0	0.0
02.12.2019	225	24.2	92.5	0.1	0.0
16.12.2019	189	22.7	85.9	0.0	0.0
01.01.2020	195	23.6	84.9	0.0	0.0
18.01.2020	172	24.2	82.4	0.0	0.0
01.02.2020	182	25.5	80.4	0.0	0.0
17.02.2020	184	25.5	73.9	0.0	0.0
02.03.2020	134	26.3	78.1	0.0	0.0
17.03.2020	100	28.9	66.9	0.0	0.3
01.04.2020	163	31.5	53.0	0.0	0.2
16.04.2020	135	30.5	66.7	0.0	0.2
02.05.2020	117	31.6	66.8	0.1	0.2
16.05.2020	134	32.7	59.0	0.0	0.0
01.06.2020	179	30.9	63.7	1.6	0.3
16.06.2020	172	29.5	76.6	1.3	0.3
01.07.2020	228	27.9	87.9	0.3	0.1
16.07.2020	181	25.7	92.4	0.3	0.1
01.08.2020	155	29.0	82.9	0.0	0.0
17.08.2020	229	26.6	86.6	1.0	0.5
01.09.2020	80	30.1	73.5	0.0	0.3

GK OC	Predominant wind direction	Avg. Temp	Avg. Humidity	Avg. Rainfall	Avg. Wind speed
Date	(degrees)	(°c)	(%)	(mm)	(m/s)
16.09.2020	213	27.3	96.0	0.2	0.0
01.10.2020	176	26.1	92.6	0.0	0.0
16.10.2020	210	26.6	94.9	0.0	0.0
02.11.2020	293	26.5	84.1	0.0	0.0
16.11.2020	304	25.9	78.2	0.1	0.0
02.12.2020	161	22.1	86.6	0.0	0.0
17.12.2020	151	23.2	86.6	0.0	0.0
02.01.2021	154	21.1	85.7	0.0	0.0
18.01.2021	189	22.7	84.5	0.0	0.0
03.02.2021	175	22.9	71.9	0.0	0.0
19.02.2021	108	23.7	73.1	0.0	0.0
01.03.2021	172	27.8	75.1	0.2	0.0
16.03.2021	182	28.9	77.6	0.0	0.0
01.04.2021	169	31.8	45.2	0.0	31.8
16.04.2021	153	28.9	77.9	0.0	0.0
03.05.2021	160	30.2	73.0	0.0	0.0
19.05.2021	176	31.7	79.0	0.0	0.0
01.06.2021	121	32.7	69.1	0.0	0.6
16.06.2021	108	29.4	81.7	0.0	0.8
01.07.2021	204	25.8	95.8	0.7	1.2
16.07.2021	167	26.3	96.0	0.1	0.0
02.08.2021	175	29.2	80.7	0.0	1.9
17.08.2021	179	25.2	99.0	0.0	2.5
01.09.2021	122	25.7	96.8	0.0	0.0
16.09.2021	160	28.3	88.5	0.0	0.0
05.10.2021	148	28.2	90.4	0.0	0.4
21.10.2021	36	27.7	87.3	0.0	0.1
05.11.2021	171	25.8	89.6	0.0	0.2
16.11.2021	166	26.4	92.0	0.0	0.0
05.12.2021	38	24.3	86.7	0.0	0.0
16.12.2021	59	20.7	85.6	0.0	0.0
01.01.2022	182	22.3	86.3	0.0	0.0
21.01.2022	190	22.7	84.5	0.0	0.1
01.02.2022	235	23.1	84.4	0.0	0.2
16.02.2022	145	24.7	78.2	0.0	0.1
01.03.2022	174	26.4	62.1	0.0	0.0
16.03.2022	243	28.5	62.5	0.0	0.3

Table 3. PM₁₀ and PM_{2.5} in core and buffer zones of GK OC

GK OC	PM ₁₀ (µg/m ³)						PM _{2.5} (µg/m ³)					
	Date	CHP	WS	Penagadapa	Rudrampur	Sitammeta	Tippanapalli	CHP	WS	Penagadapa	Rudrampur	Sitammeta
09.04.2012	179	124	77	79	68	67	80	52.1	36.0	30.0	33.0	32.6
24.04.2012	181	141	74	80	71	68	78.1	49.8	37.4	29.1	35.1	36.7
09.05.2012	173	154	73	76	66	53	79.2	47.6	38.1	28.7	36.3	37.1
24.05.2012	178	168	79	78	73	58	78.6	48.1	36.8	27.6	35.2	32.5
09.06.2012	183	157	83	81	78	50	79.7	46.8	37.0	27.4	34.9	31.9
23.06.2012	171	117	68	70	72	78	71.8	42.8	34.0	30.5	36.9	35.1
04.07.2012	160	140	70	60	76	82	45.0	47.4	31.0	30.8	32.0	37.0
19.07.2012	180	150	74	69	78	83	54.0	49.1	39.2	36.5	36.5	28.0
04.08.2012	160	125	79	66	62	70	47.8	39.0	34.0	32.0	30.5	27.0
19.08.2012	194	151	76	71	64	68	54.0	52.0	36.0	34.0	30.0	32.0
05.09.2012	163	114	62	84	66	66	62.2	52.9	35.2	37.1	36.6	40.4
20.09.2012	154	111	79	89	89	72	60.3	56.8	36.3	37.3	36.5	37.0
06.10.2012	219	183	86	97	78	91	70.8	54.2	45.4	46.7	37.7	38.0
19.10.2012	161	134	96	87	93	89	50.0	45.8	54.0	45.8	46.0	45.1
07.11.2012	171	148	86	74	77	85	45.8	41.7	41.9	35.2	39.6	34.3
20.11.2012	169	148	69	65	75	76	50.0	45.8	44.4	39.6	41.2	40.3
05.12.2012	184	164	70	74	85	83	54.2	51.1	40.7	39.3	35.8	39.8
20.12.2012	200	182	79	81	86	93	54.2	46.8	43.9	47.9	38.0	46.1
04.01.2013	177	159	88	80	79	89	72.7	68.1	51.7	40.1	38.7	41.0

GK OC	PM ₁₀ (µg/m ³)						PM _{2.5} (µg/m ³)					
	Date	CHP	WS	Penagadapa	Rudrampur	Sitampeta	Tippanapalli	CHP	WS	Penagadapa	Rudrampur	Sitampeta
19.01.2013	199	163	88	83	79	81	72.0	59.6	47.1	57.4	47.9	40.4
05.02.2013	203	171	86	91	89	93	66.2	56.5	54.9	46.3	49.5	49.9
20.02.2013	205	171	91	83	86	83	69.2	51.1	50.0	50.0	46.1	57.1
05.03.2013	202	186	86	86	89	78	70.6	56.5	53.2	44.4	51.8	51.3
20.03.2013	229	212	84	91	95	94	69.6	66.7	53.3	46.1	59.2	50.0
04.04.2013	260	230	102	91	86	92	81.8	72.7	76.9	58.3	71.4	59.2
19.04.2013	266	235	98	87	94	83	70.6	69.6	53.8	46.1	59.2	50.0
04.05.2013	237	213	94	89	96	93	66.2	61.8	45.2	51.5	55.8	60.0
20.05.2013	254	225	85	81	82	94	60.4	56.1	37.5	37.9	53.3	49.4
05.06.2013	198	171	81	71	72	75	58.3	54.2	34.8	38.3	33.3	31.8
20.06.2013	212	168	71	56	67	69	71.6	69.6	48.0	36.4	43.9	43.2
05.07.2013	182	174	76	57	65	66	73.9	71.1	45.0	41.9	33.6	37.2
19.07.2013	191	183	88	67	77	77	76.9	74.2	49.0	45.6	37.6	41.1
05.08.2013	180	172	74	54	62	63	78.2	75.5	50.0	46.5	38.4	41.9
20.08.2013	187	179	83	62	72	72	69.0	66.0	39.0	37.0	28.0	32.0
05.09.2013	202	195	98	75	86	86	65.7	62.7	45.4	42.2	33.9	37.5
19.09.2013	196	188	90	68	78	78	62.0	59.0	41.0	38.0	34.0	33.0
04.10.2013	144	138	77	64	72	69	56.0	53.0	34.0	37.0	33.0	32.0
19.10.2013	149	143	84	70	78	76	59.0	56.0	39.0	41.0	37.0	36.0
05.11.2013	153	148	89	74	83	80	59.0	56.0	39.0	41.0	37.0	36.0
20.11.2013	166	160	96	80	90	87	64.0	61.0	44.0	45.0	42.0	41.0
05.12.2013	189	181	93	71	82	81	64.0	61.0	44.0	41.0	33.0	37.0
19.12.2013	167	161	92	77	86	83	55.0	51.0	34.0	36.0	37.0	40.0
04.01.2014	176	171	96	80	90	87	60.0	57.0	39.0	41.0	42.0	45.0
20.01.2014	195	190	93	85	95	83	65.0	62.0	45.0	47.0	48.0	51.0
05.02.2014	191	186	86	79	89	77	62.0	59.0	41.0	43.0	44.0	48.0
20.02.2014	195	189	87	80	90	78	59.0	56.0	37.0	39.0	40.0	44.0
05.03.2014	188	182	82	76	85	73	53.0	50.0	36.0	38.0	39.0	43.0
20.03.2014	195	190	87	80	90	78	62.0	58.0	47.0	48.0	50.0	53.0
04.04.2014	244	222	105	87	98	85	72.7	69.0	64.7	54.5	56.4	59.5
19.04.2014	265	262	104	83	94	81	69.0	65.1	65.7	45.2	46.7	50.2
05.05.2014	233	230	90	73	82	70	58.4	54.5	58.0	39.2	40.5	44.1
20.05.2014	241	239	94	77	85	73	61.4	57.4	59.8	42.5	43.5	48.5
05.06.2014	257	249	98	79	89	77	68.2	64.4	58.8	44.6	46.1	49.6
19.06.2014	260	246	94	76	85	66	64.4	60.5	47.8	35.1	36.4	40.2
04.07.2014	231	197	82	75	73	64	54.3	50.4	52.7	39.5	40.8	44.4
19.07.2014	202	190	77	71	69	60	49.2	45.3	40.4	34.1	35.3	39.0
05.08.2014	199	187	75	73	71	79	57.3	53.5	45.7	38.7	40.0	43.5
22.08.2014	224	214	77	68	79	80	52.7	49.4	35.4	32.9	34.0	37.6
04.09.2014	229	219	81	71	82	83	61.0	57.9	40.3	37.4	38.7	42.2
25.09.2014	267	239	103	93	91	97	61.8	59.0	62.8	44.5	43.4	48.1
08.10.2014	275	266	106	84	93	86	65.6	63.0	62.0	44.0	42.9	47.5
24.10.2014	265	233	89	81	78	88	61.8	59.0	56.5	39.0	38.0	42.7
06.11.2014	245	229	95	82	83	85	52.4	49.4	37.1	38.4	37.5	36.9
20.11.2014	118	205	82	76	70	79	39.6	44.6	36.7	43.4	42.4	36.5
04.12.2014	236	210	77	75	72	74	51.5	48.4	42.3	48.5	47.0	41.1
19.12.2014	248	216	81	79	75	77	55.3	52.3	47.7	53.5	51.7	45.9
05.01.2015	251	220	85	82	78	81	59.1	56.1	48.1	48.5	46.9	41.1
20.01.2015	254	220	89	86	82	84	66.7	56.1	47.5	42.6	41.2	40.7
05.02.2015	252	220	85	82	78	81	63.9	56.5	42.5	38.1	36.8	36.3
19.02.2015	224	212	85	82	79	81	54.5	51.6	35.6	42.4	41.2	35.4
05.03.2015	255	223	90	86	82	85	62.5	59.4	47.8	48.2	46.6	45.9
20.03.2015	261	228	89	86	81	84	60.4	52.8	37.1	38.7	37.4	36.9
07.04.2015	254	236	86	82	78	81	62.6	55.2	40.2	36.2	38.4	39.8
20.04.2015	257	243	88	84	80	83	64.1	60.8	47.9	42.6	46.3	45.9
05.05.2015	248	227	83	78	74	77	60.4	57.0	42.5	37.7	41.6	41.3
22.05.2015	254	242	87	82	78	81	64.1	60.9	41.7	42.4	41.0	40.6
03.06.2015	243	231	78	77	71	75	59.2	55.9	41.4	42.1	40.7	40.3
19.06.2015	196	190	64	65	67	63	55.3	51.9	35.7	37.1	35.8	35.5
06.07.2015	206	194	74	70	72	68	58.6	55.3	40.8	41.6	40.2	39.8
20.07.2015	189	175	68	65	63	71	54.2	50.1	40.3	36.0	34.8	34.5
06.08.2015	202	187	76	72	69	77	59.5	55.4	46.7	41.7	35.2	39.9
21.08.2015	190	176	71	68	65	74	63.2	59.1	46.2	36.1	39.9	44.5
05.09.2015	184	169	64	65	59	67	58.5	54.5	34.2	30.6	34.5	39.1
21.09.2015	199	173	74	70	62	71	60.9	57.8	38.9	32.6	37.8	35.9
07.10.2015	257	194	79	75	72	69	65.2	63.6	50	40.9	45.0	42.1

GK OC	PM ₁₀ (µg/m ³)						PM _{2.5} (µg/m ³)					
	Date	CHP	WS	Penagadapa	Rudrampur	Sitampeta	Tippanapalli	CHP	WS	Penagadapa	Rudrampur	Sitampeta
20.10.2015	254	184	78	74	69	82	65.2	57.8	51.2	45.4	42.8	48.8
06.11.2015	245	206	82	69	74	76	71.1	54.5	47.6	40.0	45.4	42.8
20.11.2015	261	196	79	67	53	79	68.2	56.5	38.9	40.9	25.0	45.0
05.12.2015	256	201	73	61	61	69	65.6	52.3	36.4	35.5	33.8	35.9
19.12.2015	248	205	70	55	59	66	66.1	53.3	36.7	32.1	31.1	31.9
07.01.2016	252	208	69	54	58	65	67.4	54.4	36.4	31.8	30.9	31.6
21.01.2016	212	201	71	55	55	61	60.5	51.2	35.7	30.2	31.1	32.2
06.02.2016	215	198	71	56	58	65	61.8	50.2	36.3	32.4	31.7	32.9
22.02.2016	220	202	70	55	57	64	62.2	51.8	36.8	31.6	31.2	32.2
05.03.2016	218	199	71	57	56	66	63.9	52.2	36.4	32.3	31.6	32.8
19.03.2016	216	195	70	54	54	60	60.9	51.1	36.2	35.3	33.6	35.7
06.04.2016	212	190	69	53	52	59	60.0	50.3	35.7	34.8	33.1	35.2
20.04.2016	215	198	70	55	55	63	63.1	51.9	36.2	32.9	32.1	33.5
06.05.2016	202	185	67	58	53	60	60.8	52.4	34.4	33.1	31.9	33.3
19.05.2016	198	169	65	55	51	59	58.1	50.5	35.6	34.0	32.7	34.4
06.06.2016	185	154	57	50	49	53	50.3	42.9	31.5	29.1	30.1	29.9
20.06.2016	166	138	50	45	44	48	43.5	37.1	25.4	23.5	24.3	24.2
06.07.2016	174	145	45	41	47	43	45.6	42.8	24.8	19.9	25.2	22.2
20.07.2016	171	141	51	45	43	48	44.7	39.8	27.2	24.2	26.5	25.4
08.08.2016	180	149	49	49	45	53	47.8	40.5	28.4	25.8	27.2	29.1
22.08.2016	189	155	44	40	49	42	51.1	43.2	24.6	20.5	29.2	21.6
07.09.2016	202	163	54	49	41	50	67.4	55.6	25.4	22.2	19.8	22.7
21.09.2016	173	157	46	42	48	45	55.7	52.3	21.7	20.2	23.6	20.9
06.10.2016	188	167	43	45	54	48	68.4	64.3	19.9	20.8	24.9	22.2
20.10.2016	205	181	49	47	51	53	75.2	68.6	22.8	21.9	23.7	24.6
05.11.2016	209	172	52	54	55	50	79.0	65.0	24.3	25.3	25.7	23.4
22.11.2016	219	181	54	56	56	53	78.8	68.8	25.8	26.7	26.9	25.3
13.12.2016	211	179	56	52	58	55	80.2	67.3	26.6	24.7	27.6	26.1
21.12.2016	215	185	59	56	60	58	81.7	71.4	28.1	26.7	28.6	27.7
05.01.2017	205	171	57	53	55	61	79.5	66.3	27.1	25.2	26.2	29.0
23.01.2017	192	164	60	55	57	64	74.1	63.3	28.4	26.4	27.4	30.4
06.02.2017	217	174	58	58	53	60	80.5	67.3	27.5	27.5	25.1	28.4
20.02.2017	212	170	56	56	51	58	82.1	65.8	25.8	25.8	23.5	26.7
07.03.2017	209	176	58	54	54	56	80.5	67.8	26.8	24.9	24.9	25.9
21.03.2017	216	167	55	58	57	52	83.2	64.3	24.9	26.2	25.8	23.5
06.04.2017	220	175	57	60	55	59	84.0	66.9	25.8	27.1	24.9	26.7
20.04.2017	224	179	60	57	58	62	85.6	68.4	27.5	26.2	26.6	28.5
05.05.2017	221	184	59	58	56	60	84.4	70.3	27.4	27.0	26.0	27.9
19.05.2017	217	176	62	60	53	58	78.8	64.0	27.8	26.9	23.7	26.0
09.06.2017	183	57	83	81	78	50	59.2	55.9	41.4	42.1	40.7	40.3
23.06.2017	171	117	68	70	72	78	55.3	51.9	35.7	37.1	35.8	35.5
05.07.2017	182	174	76	57	65	66	50.3	42.9	31.5	29.1	30.1	29.9
19.07.2017	191	183	88	67	77	77	43.5	37.1	25.4	23.5	24.3	24.2
05.08.2017	199	187	75	73	71	79	58.3	54.2	34.8	38.3	33.3	31.8
22.08.2017	224	214	77	68	79	80	71.6	69.6	48.0	36.4	43.9	43.2
01.09.2017	210	145	57	52	61	54	68.1	51.0	23.4	21.9	25.6	23.0
16.09.2017	212	159	55	50	58	51	68.8	56.0	22.6	21.1	24.3	21.8
04.10.2017	189	170	58	55	53	49	62.5	64.9	24.1	23.2	21.7	20.8
16.10.2017	173	183	61	58	57	53	66.3	64.4	25.0	24.4	23.9	22.5
03.11.2017	185	164	58	54	52	52	72.3	58.2	24.3	22.6	21.8	21.8
16.11.2017	190	186	63	58	55	55	71.2	66.0	26.4	24.3	23.3	23.0
05.12.2017	186	190	65	60	50	57	73.1	67.5	27.2	25.1	21.2	23.9
18.12.2017	178	179	61	57	53	51	71.8	63.4	26.1	24.4	22.9	21.8
01.01.2018	181	185	54	53	55	56	72.0	65.7	23.2	22.7	23.6	24.0
17.01.2018	192	190	58	62	51	53	71.7	67.5	24.3	26.0	21.4	22.2
02.02.2018	173	181	60	55	57	50	69.0	65.0	24.4	22.7	23.4	20.5
16.02.2018	189	195	64	58	55	56	68.7	70.0	26.2	23.8	22.6	23.0
01.03.2018	193	177	72	65	53	60	69.1	59.3	30.2	27.3	22.3	25.2
24.03.2018	196	185	75	128	50	62	69.2	66.4	31.1	28.2	20.8	25.7
09.04.2018	181	156	70	83	51	60	68.1	53.7	30.2	26.7	22.0	25.9
25.04.2018	190	162	108	116	54	63	67.7	57.0	32.6	29.0	23.8	27.7
09.05.2018	195	171	69	64	50	61	70.1	58.8	29.7	27.6	21.6	26.3
24.05.2018	201	169	72	67	51	62	71.2	59.3	31.7	29.5	22.6	27.1
09.06.2018	198	165	59	55	48	53	66.5	56.8	25.4	23.7	20.7	22.8
19.06.2018	177	152	68	61	51	59	65.4	53.5	29.8	26.8	22.4	25.8
02.07.2018	161	116	49	46	45	44	62.8	37.6	19.7	18.5	18.1	17.7

GK OC	PM ₁₀ (µg/m ³)						PM _{2.5} (µg/m ³)					
	Date	CHP	WS	Penagadapa	Rudrampur	Sitampeta	Tippanapalli	CHP	WS	Penagadapa	Rudrampur	Sitampeta
16.07.2018	172	121	47	48	40	45	62.8	39.2	18.9	18.9	16.1	18.1
02.08.2018	177	133	52	50	46	40	56.5	43.1	21.0	20.2	18.5	16.1
16.08.2018	170	140	49	44	42	46	54.2	45.2	19.1	17.3	16.9	18.5
03.09.2018	183	154	54	49	48	51	58.4	49.9	21.8	19.7	19.3	20.6
17.09.2018	177	137	51	48	47	46	56.4	44.4	19.6	18.8	18.9	18.3
03.10.2018	192	177	60	54	52	56	61.2	57.3	24.2	21.8	21.0	22.6
26.10.2018	180	148	53	56	50	50	57.3	48.0	21.8	22.9	20.5	20.3
03.11.2018	207	155	62	52	56	54	66.0	50.2	25.0	21.1	22.6	21.9
21.11.2018	190	144	58	55	53	56	60.6	46.6	23.6	22.3	21.2	22.7
06.12.2018	211	160	65	55	55	60	67.3	51.8	26.3	22.3	22.2	24.3
18.12.2018	170	115	60	54	53	58	54.2	37.3	24.1	22.0	21.5	23.5
01.01.2019	197	165	58	56	50	62	62.9	53.3	23.4	22.7	20.0	25.1
21.01.2019	213	180	64	54	55	60	68.0	58.3	26.0	21.9	22.0	24.5
01.02.2019	209	157	59	49	53	51	66.7	50.8	24.1	19.9	21.1	20.6
16.02.2019	221	170	62	52	50	55	70.4	55.0	24.3	20.4	20.1	22
07.03.2019	202	160	60	54	53	57	64.5	51.9	23.3	21.0	21.2	23.1
23.03.2019	213	169	64	56	55	60	68.1	54.8	26.1	22.2	22.9	24.3
08.04.2019	219	181	61	63	59	59	69.8	65.0	28.2	28.5	23.1	27
18.04.2019	216	185	55	58	59	51	77.9	59.1	25.7	26.6	23.3	23.6
04.05.2019	220	172	59	54	64	56	70.2	55.7	27.8	24.9	25.7	26.1
22.05.2019	232	181	60	56	60	54	74.0	58.8	28.5	26.0	24.2	25.4
07.06.2019	225	185	70	61	53	59	71.8	59.9	32.0	28.5	21.4	27.8
27.06.2019	217	171	61	55	58	57	69.2	55.3	23.6	21.6	23.4	22.9
05.07.2019	183	144	53	48	51	50	55.9	44.0	20.3	20.3	20.1	22.2
17.07.2019	173	136	51	46	48	49	52.1	41.0	25.9	23.0	24.0	24.5
01.08.2019	185	151	55	53	49	43	59.0	48.9	21.4	20.8	22.2	20.2
16.08.2019	191	158	57	50	50	48	60.9	51.2	22.2	24.6	20.2	23.8
03.09.2019	189	135	57	51	52	50	60.3	43.7	22.2	20.0	21.0	21.2
16.09.2019	198	155	54	50	48	51	63.2	50.2	21.5	20.2	22.3	21.1
01.10.2019	206	162	58	54	55	60	65.7	52.5	22.6	21.2	22.2	25.4
16.10.2019	212	167	63	56	57	57	67.6	54.0	25.1	22.4	23.4	23.5
01.11.2019	218	172	60	55	53	59	69.5	55.7	25.1	22.7	21.9	24.4
16.11.2019	223	176	63	58	56	62	71.3	57.1	25.3	23.4	23.1	25.7
02.12.2019	220	178	61	57	54	61	70.2	57.7	25.6	23.5	22.3	25.6
16.12.2019	226	182	64	60	57	64	73.3	60.0	25.7	24.2	23.5	25.7
01.01.2020	217	177	68	58	60	68	69.2	57.3	28.4	24.0	24.8	28.4
18.01.2020	222	181	72	61	63	72	72.3	59.7	28.6	24.7	26.2	28.6
01.02.2020	230	170	65	55	58	65	73.4	55.1	27.2	22.8	24.0	27.2
17.02.2020	216	167	61	58	56	61	70.2	54.9	24.3	23.4	23.1	24.3
02.03.2020	184	160	63	62	53	58	59.8	52.6	25.1	25.0	21.9	24.5
17.03.2020	190	149	55	54	51	52	61.8	49.0	21.9	21.8	21.1	22.0
01.04.2020	183	135	49	48	46	47	55.8	44.4	19.6	19.5	18.9	19.7
16.04.2020	180	127	48	46	44	45	54.9	41.8	19.2	18.4	18.0	18.9
02.05.2020	188	140	52	50	48	51	61.1	46.1	20.7	20.2	19.8	21.4
16.05.2020	193	145	55	52	49	54	63.2	47.7	22.0	21.0	20.3	22.8
01.06.2020	197	152	57	54	51	55	64.6	50.1	22.8	21.7	21.0	23.3
16.06.2020	195	155	55	51	50	53	64.0	51.0	21.9	20.6	20.7	22.4
01.07.2020	190	150	58	50	52	55	62.3	49.4	23.1	20.2	21.5	23.3
16.07.2020	196	153	60	52	48	57	64.3	50.3	23.9	21.2	20.3	24.1
01.08.2020	192	130	54	47	45	51	63.0	42.8	21.4	19.5	19.0	21.6
17.08.2020	188	125	52	49	47	50	59.8	41.1	20.7	20.5	19.9	21.2
01.09.2020	197	131	55	51	49	53	62.8	43.2	21.8	21.5	20.9	22.2
16.09.2020	207	138	57	54	52	55	65.9	45.3	22.9	22.6	21.9	23.3
01.10.2020	212	143	61	57	54	58	67.4	47.0	24.3	23.8	22.8	24.5
16.10.2020	210	140	60	55	55	57	66.6	46.1	23.9	23.0	23.3	23.9
02.11.2020	223	148	63	58	51	59	70.9	48.7	25.2	24.2	21.6	25.1
16.11.2020	218	152	65	56	50	61	69.3	50.0	25.9	23.4	21.2	25.8
02.12.2020	225	163	68	59	55	65	71.6	53.6	27.1	24.7	23.3	27.5
17.12.2020	222	154	65	58	52	62	70.6	50.8	26.1	24.1	22.0	26.1
02.01.2021	218	150	64	57	53	60	69.4	49.4	25.4	23.9	22.3	25.5
18.01.2021	221	152	67	60	56	61	70.2	49.9	26.7	25.1	23.7	25.8
03.02.2021	216	161	89	59	51	63	68.7	53.0	27.5	24.7	21.6	26.6
19.02.2021	221	165	68	60	52	65	70.6	54.3	27.1	25.3	22.1	27.3
01.03.2021	215	158	65	59	55	61	68.4	52.0	25.9	24.7	23.3	25.8
16.03.2021	216	160	62	57	50	60	68.7	54.1	24.7	23.8	21.2	25.4
01.04.2021	210	186	64	55	49	58	66.8	56.6	25.5	23.0	20.7	24.5

GK OC	PM ₁₀ (µg/m ³)						PM _{2.5} (µg/m ³)					
	Date	CHP	WS	Penagadapa	Rudrampur	Sitampeta	Tippanapalli	CHP	WS	Penagadapa	Rudrampur	Sitampeta
16.04.2021	218	168	65	86	51	57	69.5	57.0	25.3	23.7	22.1	24.1
03.05.2021	201	156	59	61	49	65	63.9	51.3	24.5	25.4	20.2	27.2
19.05.2021	211	164	51	49	50	55	67.3	55.6	20.8	20.0	21.5	22.4
01.06.2021	197	159	55	50	48	53	62.6	52.3	21.4	20.4	19.8	22.4
16.06.2021	204	161	58	55	53	54	65.1	54.7	23.1	23.0	22.4	22.8
01.07.2021	202	168	56	51	50	52	64.2	55.3	21.8	20.8	20.7	22.0
16.07.2021	205	163	57	52	48	53	65.4	55.2	22.7	21.7	20.3	22.4
02.08.2021	196	153	60	50	51	55	62.3	50.3	23.3	20.4	21.1	23.3
17.08.2021	201	161	58	51	50	53	64.1	54.7	23.0	21.3	21.0	22.6
01.09.2021	192	132	55	48	49	53	43.4	61.1	21.4	19.6	20.2	22.4
16.09.2021	197	138	59	52	51	55	46.8	62.8	23.5	21.7	21.5	23.2
05.10.2021	193	152	57	53	48	50	50.0	61.4	22.2	21.6	19.8	21.2
21.10.2021	198	144	60	51	55	55	48.8	63.2	23.9	21.3	22.7	23.3
05.11.2021	190	136	51	47	50	51	44.7	60.4	21.6	19.2	20.7	21.6
16.11.2021	204	140	56	49	49	53	47.5	65.1	22.3	20.5	20.2	22.4
05.12.2021	191	145	66	48	55	64	60.7	49.2	26.7	21.1	23.1	26.9
16.12.2021	202	129	69	53	51	68	64.4	42.4	29.3	22.7	21.8	29.1
01.01.2022	197	138	62	49	51	59	62.6	45.2	23.5	20.1	21.2	25.0
21.01.2022	187	160	58	57	50	60	59.7	54.1	23.1	23.8	20.7	25.4
01.02.2022	185	167	55	48	48	56	58.8	54.9	20.8	19.6	19.8	23.7
16.02.2022	191	176	58	50	50	59	60.9	59.5	23.0	21.1	20.8	24.9
01.03.2022	95	158	60	51	51	55	29.4	52	22.7	20.6	21.2	23.4
16.03.2022	97	166	57	50	49	53	30.8	56.3	22.7	20.9	20.5	22.4

Appendix IV

Table 1. RG OC-I Mine parameters

RG OC-I	Production (Coal+OB)	Area contributing to pollution	Max. Quarry depth	Max. Dump height	Lead distance
Date	(t)	(Ha)	(m)	(m)	(km)
07.04.2012	155,612	421.7	105.0	60.0	5.0
22.04.2012	145,886	426.3	105.3	60.8	5.0
06.05.2012	151,178	430.8	105.6	61.6	5.0
21.05.2012	141,729	435.4	105.8	62.4	5.0
06.06.2012	120,725	439.9	106.1	63.2	5.0
21.06.2012	113,180	444.5	106.4	64.0	5.0
05.07.2012	95,465	449.0	106.7	64.8	5.0
19.07.2012	89,498	453.6	107.0	65.6	4.9
06.08.2012	108,860	458.1	107.2	66.4	4.9
21.08.2012	102,056	462.7	107.5	67.2	4.9
06.09.2012	117,619	467.3	107.8	68.0	4.9
20.09.2012	110,268	471.8	108.1	68.8	4.9
05.10.2012	135,890	476.4	108.4	69.6	4.9
17.10.2012	135,890	480.9	108.6	70.4	4.9
07.11.2012	144,403	485.5	108.9	71.2	4.9
22.11.2012	154,030	490.0	109.2	72.0	4.9
06.12.2012	188,329	494.6	109.5	72.8	4.9
21.12.2012	200,885	499.2	109.8	73.6	4.9
04.01.2013	184,873	503.7	110.0	74.4	4.8
21.01.2013	197,198	508.3	110.3	75.2	4.8
05.02.2013	140,214	512.8	110.6	76.0	4.8
21.02.2013	149,562	517.4	110.9	76.8	4.8
07.03.2013	160,361	521.9	111.2	77.6	4.8
21.03.2013	171,052	526.5	111.4	78.4	4.8
05.04.2013	154,825	535.6	112.0	80.0	4.8
20.04.2013	165,146	535.5	112.1	80.0	4.8
06.05.2013	143,034	535.4	112.2	80.0	4.8
20.05.2013	152,570	535.3	112.4	80.0	4.8
06.06.2013	105,004	535.2	112.5	80.0	4.8
20.06.2013	112,004	535.1	112.6	80.0	4.8
05.07.2013	99,514	535.0	112.7	80.0	4.8
23.07.2013	106,148	534.8	112.8	80.0	4.8
06.08.2013	87,012	534.7	113.0	80.0	4.8
23.08.2013	92,813	534.6	113.1	80.0	4.8
06.09.2013	124,886	534.5	113.2	80.0	4.8
20.09.2013	133,212	534.4	113.3	80.0	4.8
05.10.2013	103,403	534.3	113.4	80.0	4.8
21.10.2013	110,296	534.2	113.6	80.0	4.7
07.11.2013	147,962	534.1	113.7	80.0	4.7
22.11.2013	138,715	534.0	113.8	80.0	4.7
06.12.2013	175,818	533.9	113.9	80.0	4.7
20.12.2013	164,829	533.8	114.0	80.0	4.7
04.01.2014	185,779	533.7	114.2	80.0	4.7
20.01.2014	174,167	533.5	114.3	80.0	4.7
06.02.2014	162,161	533.4	114.4	80.0	4.7
20.02.2014	152,026	533.3	114.5	80.0	4.7
06.03.2014	162,463	533.2	114.6	80.0	4.7

RG OC-I	Production (Coal+OB)	Area contributing to pollution	Max. Quarry depth	Max. Dump height	Lead distance
Date	(t)	(Ha)	(m)	(m)	(km)
20.03.2014	152,309	533.1	114.8	80.0	4.7
05.04.2014	147,681	532.9	115.0	80.0	4.7
21.04.2014	138,451	533.2	115.2	80.0	4.7
06.05.2014	154,945	533.4	115.4	80.0	4.7
22.05.2014	145,261	533.7	115.6	80.0	4.7
04.06.2014	159,369	533.9	115.8	80.0	4.7
18.06.2014	149,408	534.2	116.0	80.0	4.7
04.07.2014	126,756	534.5	116.2	80.0	4.7
20.07.2014	118,834	534.7	116.3	80.0	4.7
06.08.2014	141,534	535.0	116.5	80.0	4.7
21.08.2014	132,688	535.2	116.7	80.0	4.7
03.09.2014	146,056	535.5	116.9	80.0	4.7
24.09.2014	136,928	535.8	117.1	80.0	4.7
04.10.2014	151,364	536.0	117.3	80.0	4.7
20.10.2014	141,903	536.3	117.5	80.0	4.6
05.11.2014	151,870	536.5	117.7	80.0	4.6
20.11.2014	151,870	536.8	117.9	80.0	4.6
04.12.2014	144,360	537.1	118.1	80.0	4.6
20.12.2014	153,984	537.3	118.3	80.0	4.6
03.01.2015	148,439	537.6	118.5	80.0	4.6
19.01.2015	158,335	537.8	118.7	80.0	4.6
04.02.2015	119,142	538.1	118.8	80.0	4.6
19.02.2015	127,084	538.4	119.0	80.0	4.6
06.03.2015	177,320	538.6	119.2	80.0	4.6
19.03.2015	189,141	538.9	119.4	80.0	4.6
07.04.2015	134,701	539.4	120.0	80.0	4.6
20.04.2015	143,681	541.3	120.3	80.4	4.6
05.05.2015	121,816	543.2	120.6	80.8	4.5
20.05.2015	129,937	545.0	121.0	81.2	4.5
05.06.2015	114,646	546.9	121.3	81.6	4.5
19.06.2015	122,289	548.8	121.6	82.0	4.5
05.07.2015	114,289	550.7	121.9	82.4	4.4
20.07.2015	121,909	552.5	122.2	82.8	4.4
05.08.2015	131,029	554.4	122.6	83.2	4.4
20.08.2015	139,765	556.3	122.9	83.6	4.3
05.09.2015	112,430	558.2	123.2	84.0	4.3
19.09.2015	119,925	560.0	123.5	84.4	4.3
05.10.2015	133,732	561.9	123.8	84.8	4.2
26.10.2015	142,648	563.8	124.2	85.2	4.2
10.11.2015	130,177	565.7	124.5	85.6	4.2
23.11.2015	138,855	567.5	124.8	86.0	4.2
09.12.2015	126,949	569.4	125.1	86.4	4.1
18.12.2015	119,015	571.3	125.4	86.8	4.1
05.01.2016	115,691	573.2	125.8	87.2	4.1
17.01.2016	108,460	575.0	126.1	87.6	4.0
03.02.2016	128,628	576.9	126.4	88.0	4.0
17.02.2016	120,588	578.8	126.7	88.4	4.0
05.03.2016	130,404	580.7	127.0	88.8	3.9
21.03.2016	122,254	582.5	127.4	89.2	3.9
04.04.2016	114,102	586.3	128.0	90.0	3.9

RG OC-I	Production (Coal+OB)	Area contributing to pollution	Max. Quarry depth	Max. Dump height	Lead distance
Date	(t)	(Ha)	(m)	(m)	(km)
19.04.2016	106,970	588.1	128.5	90.0	3.8
05.05.2016	100,823	589.8	129.0	90.0	3.8
21.05.2016	94,522	591.6	129.4	90.0	3.8
02.06.2016	85,130	593.4	129.9	90.0	3.8
16.06.2016	79,810	595.1	130.4	90.0	3.8
01.07.2016	80,723	596.9	130.9	90.0	3.8
16.07.2016	75,678	598.6	131.4	90.0	3.8
04.08.2016	90,787	600.4	131.8	90.0	3.8
16.08.2016	85,112	602.2	132.3	90.0	3.7
01.09.2016	85,105	603.9	132.8	90.0	3.7
16.09.2016	79,786	605.7	133.3	90.0	3.7
01.10.2016	83,608	607.5	133.8	90.0	3.7
17.10.2016	78,382	609.2	134.2	90.0	3.7
02.11.2016	99,145	611.0	134.7	90.0	3.7
17.11.2016	92,949	612.8	135.2	90.0	3.7
02.12.2016	117,200	614.5	135.7	90.0	3.7
17.12.2016	117,200	616.3	136.2	90.0	3.6
02.01.2017	118,656	618.0	136.6	90.0	3.6
16.01.2017	126,566	619.8	137.1	90.0	3.6
01.02.2017	132,640	621.6	137.6	90.0	3.6
16.02.2017	141,482	623.3	138.1	90.0	3.6
01.03.2017	145,547	625.1	138.6	90.0	3.6
17.03.2017	155,251	626.9	139.0	90.0	3.6
03.04.2017	109,720	630.4	140.0	90.0	3.5
17.04.2017	117,034	628.4	140.8	90.0	3.5
02.05.2017	94,846	626.4	141.7	90.0	3.5
17.05.2017	101,169	624.4	142.5	90.0	3.5
03.06.2017	89,659	622.4	143.3	90.0	3.5
18.06.2017	95,636	620.4	144.2	90.0	3.5
04.07.2017	89,335	618.3	145.0	90.0	3.5
19.07.2017	95,290	616.3	145.8	90.0	3.4
04.08.2017	101,329	614.3	146.7	90.0	3.4
18.08.2017	108,085	612.3	147.5	90.0	3.4
04.09.2017	87,264	610.3	148.3	90.0	3.4
18.09.2017	93,082	608.3	149.2	90.0	3.4
04.10.2017	88,942	606.3	150.0	90.0	3.4
17.10.2017	94,872	604.3	150.8	90.0	3.4
01.11.2017	86,540	602.3	151.7	90.0	3.4
17.11.2017	92,310	600.3	152.5	90.0	3.3
01.12.2017	98,462	598.3	153.3	90.0	3.3
18.12.2017	105,026	596.3	154.2	90.0	3.3
02.01.2018	124,798	594.3	155.0	90.0	3.3
16.01.2018	116,998	592.2	155.8	90.0	3.3
01.02.2018	122,817	590.2	156.7	90.0	3.3
16.02.2018	115,141	588.2	157.5	90.0	3.3
02.03.2018	165,286	586.2	158.3	90.0	3.2
17.03.2018	154,956	584.2	159.2	90.0	3.2
02.04.2018	108,018	580.2	160.0	90.0	3.2
17.04.2018	101,267	580.2	160.4	90.0	3.3
02.05.2018	96,777	580.2	160.8	90.0	3.4

RG OC-I	Production (Coal+OB)	Area contributing to pollution	Max. Quarry depth	Max. Dump height	Lead distance
Date	(t)	(Ha)	(m)	(m)	(km)
17.05.2018	90,729	580.2	161.2	90.0	3.5
01.06.2018	76,570	580.2	161.6	90.0	3.6
21.06.2018	71,784	580.2	162.0	90.0	3.7
04.07.2018	53,104	580.2	162.4	90.0	3.7
22.07.2018	49,785	580.2	162.8	90.0	3.8
03.08.2018	78,546	580.2	163.2	90.0	3.9
23.08.2018	73,637	580.2	163.6	90.0	4.0
01.09.2018	83,956	580.2	164.0	90.0	4.1
16.09.2018	78,709	580.2	164.4	90.0	4.2
05.10.2018	84,209	580.2	164.8	90.0	4.3
22.10.2018	78,946	580.2	165.2	90.0	4.4
08.11.2018	99,316	580.2	165.6	90.0	4.4
21.11.2018	93,109	580.2	166.0	90.0	4.5
06.12.2018	103,151	580.2	166.4	90.0	4.6
20.12.2018	96,704	580.2	166.8	90.0	4.7
07.01.2019	87,538	580.2	167.2	90.0	4.8
21.01.2019	87,538	580.2	167.6	90.0	4.9
07.02.2019	84,299	580.2	168.0	90.0	5.0
20.02.2019	89,919	580.2	168.4	90.0	5.1
06.03.2019	93,651	580.2	168.8	90.0	5.1
21.03.2019	99,895	580.2	169.2	90.0	5.2
04.04.2019	75,549	580.2	170.0	90.0	5.4
20.04.2019	80,585	580.2	170.2	91.2	5.3
06.05.2019	84,071	580.2	170.4	92.4	5.3
22.05.2019	89,676	580.2	170.6	93.6	5.2
06.06.2019	83,270	580.3	170.8	94.8	5.2
20.06.2019	88,821	580.3	171.0	96.0	5.1
01.07.2019	77,370	580.3	171.2	97.2	5.1
22.07.2019	82,528	580.3	171.4	98.4	5.0
05.08.2019	68,069	580.3	171.6	99.6	4.9
22.08.2019	72,606	580.3	171.8	100.8	4.9
05.09.2019	82,386	580.4	172.0	102.0	4.8
20.09.2019	87,879	580.4	172.2	103.2	4.8
06.10.2019	77,942	580.4	172.4	104.4	4.7
21.10.2019	83,138	580.4	172.6	105.6	4.6
07.11.2019	87,244	580.4	172.8	106.8	4.6
21.11.2019	93,061	580.4	173.0	108.0	4.5
07.12.2019	90,925	580.5	173.2	109.2	4.5
24.12.2019	96,987	580.5	173.4	110.4	4.4
06.01.2020	132,431	580.5	173.6	111.6	4.4
22.01.2020	141,260	580.5	173.8	112.8	4.3
06.02.2020	145,012	580.5	174.0	114.0	4.2
22.02.2020	135,949	580.5	174.2	115.2	4.2
05.03.2020	160,925	580.6	174.4	116.4	4.1
20.03.2020	150,867	580.6	174.6	117.6	4.1
06.04.2020	114,681	580.6	175.0	120.0	4.0
16.04.2020	107,514	580.0	175.2	120.0	4.0
04.05.2020	97,526	579.4	175.4	120.0	4.0
21.05.2020	91,431	578.7	175.6	120.0	4.0
04.06.2020	65,142	578.1	175.8	120.0	4.0

RG OC-I	Production (Coal+OB)	Area contributing to pollution	Max. Quarry depth	Max. Dump height	Lead distance
Date	(t)	(Ha)	(m)	(m)	(km)
16.06.2020	61,070	577.5	176.0	120.0	4.0
08.07.2020	80,452	576.9	176.2	120.0	4.0
23.07.2020	75,424	576.3	176.4	120.0	4.0
08.08.2020	60,193	575.6	176.6	120.0	4.0
20.08.2020	56,431	575.0	176.8	120.0	4.0
08.09.2020	85,478	574.4	177.0	120.0	4.0
19.09.2020	80,136	573.8	177.2	120.0	4.0
08.10.2020	90,049	573.2	177.4	120.0	4.0
22.10.2020	84,421	572.5	177.6	120.0	4.0
07.11.2020	105,487	571.9	177.8	120.0	4.0
21.11.2020	98,894	571.3	178.0	120.0	4.0
08.12.2020	120,006	570.7	178.2	120.0	4.0
21.12.2020	112,506	570.1	178.4	120.0	4.0
07.01.2021	129,105	569.4	178.6	120.0	4.0
21.01.2021	121,036	568.8	178.8	120.0	4.0
06.02.2021	122,298	568.2	179.0	120.0	4.0
16.02.2021	122,298	567.6	179.2	120.0	4.0
06.03.2021	117,224	567.0	179.4	120.0	4.0
16.03.2021	125,039	566.3	179.6	120.0	4.0
07.04.2021	102,442	565.1	180.0	120.0	4.0
23.04.2021	109,271	565.1	180.0	120.0	4.0
08.05.2021	89,005	565.1	180.0	120.0	4.0
22.05.2021	94,939	565.1	180.0	120.0	4.0
03.06.2021	69,927	565.1	180.0	120.0	4.0
19.06.2021	74,589	565.1	180.0	120.0	4.0
03.07.2021	68,196	565.1	180.0	120.0	4.0
19.07.2021	72,742	565.1	180.0	120.0	4.0
04.08.2021	66,821	565.1	180.0	120.0	4.0
18.08.2021	71,276	565.1	180.0	120.0	4.0
04.09.2021	53,412	565.1	180.0	120.0	4.0
18.09.2021	56,972	565.1	180.0	120.0	4.0
01.10.2021	75,937	565.1	180.0	120.0	4.0
18.10.2021	80,999	565.1	180.0	120.0	4.0
01.11.2021	82,019	565.1	180.0	120.0	4.0
18.11.2021	87,487	565.1	180.0	120.0	4.0
13.12.2021	89,350	565.1	180.0	120.0	4.0
28.12.2021	95,306	565.1	180.0	120.0	4.0
03.01.2022	91,646	565.1	180.0	120.0	4.0
16.01.2022	97,756	565.1	180.0	120.0	4.0
03.02.2022	75,364	565.1	180.0	120.0	4.0
17.02.2022	80,388	565.1	180.0	120.0	4.0
11.03.2022	76,520	565.1	180.0	120.0	4.0
26.03.2022	71,737	565.1	180.0	120.0	4.0

Table 2. RG OC-I Meteorological data

RG OC-I	Predominant wind direction	Avg. Temp	Avg. Humidity	Avg. Rainfall	Avg. Wind speed
Date	(degrees)	(°c)	(%)	(mm)	(m/s)
07.04.2012	89	35.1	60.1	0.0	1.2
22.04.2012	120	36.2	55.6	0.0	2.3
06.05.2012	140	37.0	57.8	0.0	0.5
21.05.2012	112	37.8	24.5	0.0	1.5
06.06.2012	123	38.9	75.6	0.0	0.2
21.06.2012	135	39.2	63.2	0.1	0.4
05.07.2012	240	38.5	48.9	0.7	1.5
19.07.2012	120	37.7	83.9	1.0	0.5
06.08.2012	180	35.6	78.9	0.0	1.2
21.08.2012	195	33.2	55.4	0.0	1.5
06.09.2012	110	32.7	91.3	0.0	1.0
20.09.2012	223	32.4	88.1	2.0	0.2
05.10.2012	312	31.4	88.6	0.1	0.5
17.10.2012	269	30.6	75.4	0.0	0.1
07.11.2012	215	28.7	65.1	0.0	1.6
22.11.2012	35	26.5	75.5	0.0	0.3
06.12.2012	12	25.8	71.6	0.0	0.0
21.12.2012	100	24.1	56.8	0.0	0.4
04.01.2013	89	23.6	73.0	0.0	1.2
21.01.2013	30	22.1	66.0	0.0	3.5
05.02.2013	151	22.8	71.8	0.0	5.2
21.02.2013	68	23.5	55.4	0.0	3.3
07.03.2013	340	24.5	71.9	0.0	2.3
21.03.2013	322	26.7	66.8	0.0	2.8
05.04.2013	26	29.1	66.5	0.0	3.8
20.04.2013	133	29.4	65.5	0.1	6.8
06.05.2013	135	30.1	61.1	0.1	5.4
20.05.2013	211	29.9	54.5	0.2	6.8
06.06.2013	59	28.2	86.0	14	4.6
20.06.2013	305	31.6	72.6	0.0	4.1
05.07.2013	126	28.1	78.8	0.0	4.3
23.07.2013	243	24.7	75.0	60.0	2.9
06.08.2013	308	27.3	81.8	6.0	4.6
23.08.2013	285	27.2	77.3	0.0	4.7
06.09.2013	309	29.5	74.9	0.0	2.6
20.09.2013	281	30.0	75.3	0.0	3.1
05.10.2013	190	29.0	77.4	5.0	3.3
21.10.2013	32	29.2	67.8	0.0	3.3
07.11.2013	260	25.3	68.5	0.0	1.9
22.11.2013	57	25.1	67.3	0.0	3.3
06.12.2013	333	22.3	67.5	0.0	3.1
20.12.2013	195	22.5	59.2	0.0	4.1
04.01.2014	138	22.9	66.8	0.0	6.3
20.01.2014	333	22.7	67.9	0.0	6.6
06.02.2014	173	25.2	67.3	2.4	6.9
20.02.2014	258	25.0	60.5	0.0	9.6
06.03.2014	73	23.5	75.6	0.0	15.3
20.03.2014	28	30.5	60.3	0.0	6.2
05.04.2014	34	31.8	43.4	0.0	9.0
21.04.2014	179	31.8	59.0	0.0	7.3
06.05.2014	243	33.9	58.3	0.0	5.9
22.05.2014	343	34.8	51.1	0.0	5.0
04.06.2014	293	33.8	62.5	0.0	3.3
18.06.2014	33	31.4	74.5	6.1	1.5
04.07.2014	351	34.9	57.2	0.0	3.3
20.07.2014	49	28.6	84.6	23.2	2.8
06.08.2014	224	28.3	89.2	2.0	9.2
21.08.2014	65	32.4	76.0	0.0	12.7
03.09.2014	36	29.2	83.5	0.0	5.9
24.09.2014	27	30.1	84.2	0.0	2.2
04.10.2014	296	31.1	73.7	0.0	1.0
20.10.2014	202	28.6	74.6	0.0	1.9
05.11.2014	120	26.1	64.3	0.0	2.5

RG OC-I	Predominant wind direction	Avg. Temp	Avg. Humidity	Avg. Rainfall	Avg. Wind speed
Date	(degrees)	(°c)	(%)	(mm)	(m/s)
20.11.2014	124	23.4	66.5	0.0	2.0
04.12.2014	159	23.1	64.5	0.0	3.1
20.12.2014	141	19.1	66.8	0.0	2.0
03.01.2015	218	27.6	80.0	0.0	2.4
19.01.2015	155	20.7	66.8	0.0	1.2
04.02.2015	194	24.4	76.9	0.0	1.1
19.02.2015	282	29.0	64.1	0.0	4.1
06.03.2015	147	28.8	62.4	0.0	4.2
19.03.2015	102	29.7	61.2	0.0	5.5
07.04.2015	282	34.5	67.1	0.0	4.6
20.04.2015	216	35.2	59.9	0.0	2.8
05.05.2015	188	32.7	58.6	0.0	3.0
20.05.2015	129	37.3	40.8	0.0	4.7
05.06.2015	25	36.0	57.2	0.0	2.2
19.06.2015	16	29.7	87.3	11.5	1.0
05.07.2015	234	34.7	86.6	0.0	2.5
20.07.2015	12	30.8	87.3	8.4	0.0
05.08.2015	235	30.9	69.8	0.0	3.5
20.08.2015	270	30.3	75.8	0.0	0.0
05.09.2015	351	30.7	68.7	0.0	0.0
19.09.2015	238	29.0	73.8	13.4	0.0
05.10.2015	296	28.7	70.8	0.0	0.0
26.10.2015	59	28.8	63.0	0.0	0.0
10.11.2015	63	26.0	59.2	0.0	0.0
23.11.2015	41	27.5	59.0	0.0	0.0
09.12.2015	344	23.7	55.3	0.0	0.0
18.12.2015	307	29.6	54.7	0.0	0.0
05.01.2016	122	23.8	58.1	0.0	1.0
17.01.2016	210	27.1	50.6	0.0	0.6
03.02.2016	149	28.9	49.3	0.0	0.3
17.02.2016	88	26.7	50.0	0.0	0.2
05.03.2016	219	29.4	57.9	0.0	0.1
21.03.2016	256	32.2	39.0	0.0	0.3
04.04.2016	98	35.0	45.2	0.2	0.2
19.04.2016	176	36.4	48.8	0.0	0.1
05.05.2016	123	36.5	58.6	0.2	1.1
21.05.2016	344	37.5	38.8	0.1	1.3
02.06.2016	267	39.1	34.6	0.0	2.4
16.06.2016	326	36.1	38.1	0.0	3.1
01.07.2016	221	26.7	76.3	3.6	2.2
16.07.2016	180	31.8	63.9	0.4	1.2
04.08.2016	264	24.9	85.4	25.2	1.8
16.08.2016	129	29.6	66.0	0.0	2.5
01.09.2016	184	29.3	72.1	0.0	2.2
16.09.2016	195	29.7	72.6	7.6	3.2
01.10.2016	132	27.5	75.6	0.0	1.8
17.10.2016	168	27.2	57.5	0.0	3.5
02.11.2016	166	25.8	61.1	0.0	2.4
17.11.2016	118	24.3	64.9	0.0	1.4
02.12.2016	290	24.4	58.5	0.0	1.0
17.12.2016	125	25.7	55.9	0.0	3.5
02.01.2017	91	23.6	73.0	0.0	1.2
16.01.2017	28	22.1	66.0	0.0	3.5
01.02.2017	152	22.8	71.8	0.0	5.2
16.02.2017	70	23.5	55.4	0.0	3.3
01.03.2017	323	24.5	71.9	0.0	2.3
17.03.2017	320	26.7	66.8	0.0	2.8
03.04.2017	28	29.1	66.5	0.0	3.8
17.04.2017	135	29.4	65.5	0.1	6.8
02.05.2017	139	30.1	61.1	0.1	5.4
17.05.2017	205	29.9	54.5	0.2	6.8
03.06.2017	60	28.2	86.0	2.0	4.6
18.06.2017	320	31.6	72.6	0.0	4.1
04.07.2017	125	28.1	78.8	6.0	4.3
19.07.2017	233	24.7	75.0	1.2	2.9

RG OC-I	Predominant wind direction	Avg. Temp	Avg. Humidity	Avg. Rainfall	Avg. Wind speed
Date	(degrees)	(°c)	(%)	(mm)	(m/s)
04.08.2017	312	27.3	81.8	3.0	4.6
18.08.2017	290	27.2	77.3	0.0	4.7
04.09.2017	283	29.6	73.4	0.0	1.0
18.09.2017	284	29.6	68.0	0.0	0.8
04.10.2017	192	28.4	77.5	0.0	0.5
17.10.2017	129	29.2	68.4	0.0	0.8
01.11.2017	59	28.1	61.9	0.0	1.5
17.11.2017	78	24.8	61.1	0.0	0.8
01.12.2017	112	26.7	60.9	0.0	3.3
18.12.2017	58	23.5	52.7	0.0	0.8
02.01.2018	50	24.3	54.1	0.0	1.4
16.01.2018	70	22.3	48.0	0.0	1.0
01.02.2018	139	26.0	48.7	0.0	0.8
16.02.2018	171	26.5	45.2	0.0	1.9
02.03.2018	196	29.6	32.5	0.0	1.8
17.03.2018	173	27.3	55.9	0.0	2.3
02.04.2018	171	34.4	39.0	0.2	1.4
17.04.2018	187	35.9	39.1	0.0	2.5
02.05.2018	150	37.8	21.1	0.0	1.4
17.05.2018	190	36.1	38.4	0.0	2.7
01.06.2018	118	34.4	26.7	0.0	1.4
21.06.2018	144	31.1	59.1	0.0	0.5
04.07.2018	207	29.8	65.2	0.0	1.1
22.07.2018	211	31.5	58.0	0.0	1.2
03.08.2018	199	30.8	60.6	0.0	1.6
23.08.2018	46	27.0	86.9	0.5	1.2
01.09.2018	243	30.5	62.3	0.0	1.0
16.09.2018	284	28.9	66.4	0.2	1.1
05.10.2018	172	29.7	63.9	0.0	2.6
22.10.2018	138	29.1	60.8	0.0	1.9
08.11.2018	207	27.8	65.2	0.0	1.8
21.11.2018	100	24.9	73.5	0.1	2.2
06.12.2018	104	22.3	48.1	0.0	1.2
20.12.2018	121	25	63	0	1
07.01.2019	109	26.6	49.7	0.0	2.1
21.01.2019	208	29.8	47.3	0.0	3.3
07.02.2019	223	23.0	53.4	0.0	2.2
20.02.2019	185	20.9	62.2	0.0	0.4
06.03.2019	99	28.2	28.4	0.0	2.0
21.03.2019	248	32.9	36.9	0.0	0.9
04.04.2019	217	31.5	40.0	0.0	1.5
20.04.2019	222	31.0	38.4	0.0	1.5
06.05.2019	126	35.3	32.9	0.0	1.5
22.05.2019	90	37.0	46.2	0.0	2.6
06.06.2019	206	37.7	27.2	0.0	3.2
20.06.2019	144	31.3	71.8	0.1	3.9
01.07.2019	126	27.8	66.9	0.1	1.4
22.07.2019	241	32.2	54.0	0.0	1.4
05.08.2019	98	28.3	65.2	0.1	2.5
22.08.2019	221	26.6	78.1	0.4	1.4
05.09.2019	237	29.5	60.8	0.0	2.0
20.09.2019	149	28.8	76.9	0.1	1.0
06.10.2019	121	28.0	70.7	0.5	2.0
21.10.2019	144	26.7	75.8	0.0	3.0
07.11.2019	19	25.6	62.0	0.0	0.0
21.11.2019	89	23.8	62.0	0.0	2.0
07.12.2019	90	24.9	65.1	0.0	2.5
24.12.2019	96	23.6	70.1	0.0	1.3
06.01.2020	186	22.4	56.9	0.0	2.2
22.01.2020	142	25.5	62.0	0.0	2.4
06.02.2020	114	26.1	53.5	0.0	2.3
22.02.2020	160	26.8	48.1	0.0	1.6
05.03.2020	194	27.8	53.3	0.0	1.2
20.03.2020	217	30.8	39.5	0.1	1.5
06.04.2020	159	32.3	43.6	0.0	2.0

RG OC-I	Predominant wind direction	Avg. Temp	Avg. Humidity	Avg. Rainfall	Avg. Wind speed
Date	(degrees)	(°c)	(%)	(mm)	(m/s)
16.04.2020	176	34.3	38.7	0.0	1.0
04.05.2020	291	31.3	15.4	0.3	2.0
21.05.2020	187	28.7	31.7	0.0	2.0
04.06.2020	232	34.2	41.5	0.0	1.7
16.06.2020	295	36.9	28.7	0.1	2.8
08.07.2020	299	33.0	45.3	0.0	1.2
23.07.2020	151	29.0	76.8	0.0	1.7
08.08.2020	271	25.7	88.7	0.0	1.4
20.08.2020	309	29.1	74.7	0.0	1.9
08.09.2020	210	32.1	46.6	0.0	1.0
19.09.2020	212	28.4	63.8	2.8	1.0
08.10.2020	138	25.5	79.4	0.3	2.0
22.10.2020	85	27.3	64.9	0.0	1.0
07.11.2020	71	25.6	68.3	0.0	2.0
21.11.2020	119	26.9	81.5	0.0	2.0
08.12.2020	275	22.6	44.3	0.0	1.4
21.12.2020	229	19.8	32.4	0.0	1.7
07.01.2021	259	25.0	51.2	0.0	2.7
21.01.2021	157	25.5	71.3	0.0	1.8
06.02.2021	144	23.7	73.6	0.0	2.5
16.02.2021	128	26.4	66.4	0.0	1.7
06.03.2021	87	28.6	55.2	0.0	1.4
16.03.2021	144	29.5	24.4	0.0	1.3
07.04.2021	146	31.9	27.6	0.0	1.7
23.04.2021	166	33.7	22.2	0.0	1.2
08.05.2021	145	34.1	22.6	0.0	1.5
22.05.2021	195	33.8	57.7	0.0	1.8
03.06.2021	132	27.4	87.8	2.0	2.0
19.06.2021	151	29.0	58.9	0.0	1.0
03.07.2021	221	30.0	42.3	0.0	1.0
19.07.2021	141	30.2	73.0	0.0	1.0
04.08.2021	112	30.2	82.6	0.0	2.0
18.08.2021	178	26.9	64.3	0.0	2.0
04.09.2021	178	27.6	55.6	0.9	1.0
18.09.2021	257	26.8	58.7	1.8	1.0
01.10.2021	212	26.1	52.3	0.0	1.2
18.10.2021	184	27.4	87.1	0.0	1.5
01.11.2021	113	30.2	87.8	0.0	1.0
18.11.2021	67	25.9	67.2	0.9	0.9
13.12.2021	122	21.4	78.8	0.0	1.3
28.12.2021	222	23.2	82.3	0.0	1.2
03.01.2022	230	21.6	79.6	0.0	1.2
16.01.2022	125	21.2	91.9	0.0	1.6
03.02.2022	226	24.2	82.7	0.0	1.6
17.02.2022	152	25.0	77.0	0.0	1.3
11.03.2022	192	29.0	65.0	0.0	3.0
26.03.2022	229	30.3	80.7	0.0	1.0

Table 3. PM₁₀ and PM_{2.5} in core and buffer zones of RG OC-I

RG OC-I Date	PM ₁₀ (µg/m ³)						PM _{2.5} (µg/m ³)					
	CHP	WS	Junjapadug	ector-II	ulapally	ulkalapally	CHP	WS	Junjapadug	ector-II	ulapally	ulkalapally
07.04.2012	169	156	80	82	92	87	80.3	75.6	55.4	60	58.2	40.3
22.04.2012	172	148	78	81	93	84	81.2	75.8	52.8	59.8	59.1	39.8
06.05.2012	170	145	77	79	89	80	79.8	61.7	51.6	57.1	57.9	37.9
21.05.2012	176	141	71	75	86	82	76.1	62.9	50.9	56.9	58	38.1
06.06.2012	178	167	60	110	95	80	68.3	62.4	43.7	56.8	57.4	37.6
21.06.2012	174	129	81	50	97	81	77.8	63.7	41.6	27.1	44.1	35.5
05.07.2012	159	113	77	67	81	71	81.7	56.4	46.5	40.4	47.0	34.4
19.07.2012	116	102	70	62	93	77	61.9	57.1	43.3	33.3	44.5	39.2
06.08.2012	130	93	77	66	97	66	66.2	48.0	41.4	30.5	46.3	26.8
21.08.2012	148	110	70	74	93	62	74.4	53.8	38.9	34.9	36.9	32.3
06.09.2012	172	106	63	81	87	58	79.1	48.2	34.9	39.3	42.8	27.1
20.09.2012	168	115	60	85	84	64	76.1	53.5	30.6	42.2	38.2	31.6
05.10.2012	150	105	57	79	75	60	73.3	49.1	36.2	39.6	37.5	30.8
17.10.2012	152	110	52	74	72	57	76.2	53.6	40.0	37.5	33.1	26.2
07.11.2012	138	102	56	66	64	52	70.8	51.1	44.4	33.8	32.1	29.1
22.11.2012	135	97	74	69	62	50	67.6	48.2	47.4	34.8	31.3	25.6
06.12.2012	142	102	71	72	64	53	70.8	51.1	42.3	36.1	30.6	27.8
21.12.2012	159	117	82	79	58	68	72.8	54.2	45.4	38.0	28.7	31.6
04.01.2013	171	129	81	82	77	64	75.0	58.9	49.8	40.9	33.8	32.7
21.01.2013	179	137	77	85	82	70	72.3	62.5	41.8	41.7	39.4	36.0
05.02.2013	175	142	84	81	85	78	68.6	58.3	45.6	42.8	42.7	39.1
21.02.2013	178	138	77	90	89	86	70.8	54.2	47.8	46.5	43.3	42.8
07.03.2013	193	151	70	94	85	81	72.8	59.1	43.5	41.7	39.6	38.5
21.03.2013	235	163	83	112	98	92	81.4	64.3	45.3	51.1	49.2	42.8
05.04.2013	275	195	93	120	109	97	83.3	69.1	51.0	58.3	53.6	49.4
20.04.2013	286	162	84	128	102	81	87.5	66.7	43.9	61.1	57.5	41.1
06.05.2013	267	143	79	119	109	91	92.9	54.2	44.2	67.1	61.5	43.4
20.05.2013	241	130	84	107	102	78	75.8	63.4	36.4	53.7	53.3	35.5
06.06.2013	209	145	70	86	91	64	61.3	49.1	42.5	43.6	47.5	33.6
20.06.2013	232	153	72	90	85	71	66.2	55.0	27.6	46.9	42.0	31.7
05.07.2013	194	141	82	96	98	83	59.2	41.9	36.2	55.1	51.6	46.4
23.07.2013	167	130	54	73	72	91	54.2	46.7	22.2	39.1	40.0	52.9
06.08.2013	152	119	59	64	66	79	61.2	39.4	25.5	35.9	30.8	42.1
23.08.2013	136	123	71	49	71	64	48.4	43.4	27.3	23.9	33.7	35.6
06.09.2013	152	130	77	58	83	71	54.7	44.9	37.7	27.4	43.7	31.3
20.09.2013	146	148	85	66	85	79	44.1	53.6	32.8	30.3	51.3	34.5
05.10.2013	155	151	69	63	81	70	40.2	60.8	30.5	33.4	54.3	30.0
21.10.2013	146	135	78	70	76	72	45.2	51.1	35.1	39.9	42.1	35.4
07.11.2013	178	138	74	76	85	75	58.6	54.2	32.4	42.7	47.9	42.1
22.11.2013	197	156	77	81	92	71	69.6	60.8	29.8	48.1	55.1	48.1
06.12.2013	235	169	86	89	96	81	73.7	64.6	33.4	52.1	58.7	51.9
20.12.2013	259	178	89	95	100	86	76.8	68.4	35.7	56.1	56.4	52.7
04.01.2014	268	185	93	102	98	82	80.1	67.2	37.4	59.4	54.7	50.7
20.01.2014	279	199	90	108	91	72	81.2	70.8	36.8	60.5	49.2	39.4
06.02.2014	284	210	79	100	93	68	79.2	67.4	39.2	52.7	47.6	34.5
20.02.2014	255	185	94	79	79	61	72.6	59.7	41.6	36.8	32.4	30.9
06.03.2014	179	138	75	65	64	57	54.2	51.4	27.6	37.5	47.9	30.1
20.03.2014	261	203	71	98	87	78	62.5	60.0	25.9	39.4	35.3	34.2
05.04.2014	274	252	80	100	102	78	79.2	62.5	36.2	53.7	53.3	35.5
21.04.2014	242	193	84	98	101	92	81.4	72.8	40.5	51.1	49.2	42.8
06.05.2014	278	201	95	105	104	78	86.2	67.1	41.7	56.4	57.4	32.5
22.05.2014	290	240	85	84	86	75	83.2	69.8	38.7	54.0	44.9	43.1
04.06.2014	275	233	90	85	80	76	76.7	61.6	44.3	54.2	53.4	56.0
18.06.2014	219	203	72	66	71	68	61.2	56.3	36.4	45.3	57.1	50.0
04.07.2014	218	205	75	62	64	63	61.2	56.2	42.8	47.5	57.0	50.0
20.07.2014	211	202	70	63	61	60	67.1	60.4	26.8	47.4	47.1	43.3
06.08.2014	240	179	79	65	60	62	90.8	68.2	32.5	52.9	47.1	51.4
21.08.2014	226	186	88	57	57	68	93.7	70.4	37.2	42.0	39.6	45.7
03.09.2014	248	187	84	69	58	55	94.1	70.0	33.8	50.5	39.1	43.7
24.09.2014	239	196	91	68	61	59	97.1	73.7	40.5	51.3	37.7	43.2
04.10.2014	241	195	83	73	64	58	93.3	75.3	38.2	51.0	41.2	44.4
20.10.2014	244	190	80	78	67	66	89.0	70.4	35.7	53.0	43.2	40.4
05.11.2014	232	191	87	75	69	60	90.0	72.5	47.1	47.5	44.6	41.0
20.11.2014	240	186	77	72	60	64	92.5	74.6	36.9	45.0	42.5	38.1

RG OC-I	PM ₁₀ (µg/m ³)						PM _{2.5} (µg/m ³)					
	Date	CHP	WS	Junjapadug	ector-II	ulapally	tulkalapally	CHP	WS	Junjapadug	ector-II	ulapally
04.12.2014	227	192	92	74	63	69	90.4	72.5	43.7	51.5	40.8	45.0
20.12.2014	233	207	88	78	65	72	86.6	70.4	38.7	48.0	39.8	47.4
03.01.2015	211	180	85	72	59	66	78.7	74.2	38.7	47.5	34.2	42.6
19.01.2015	193	168	78	67	63	65	80.0	68.7	37.9	43.5	36.6	40.4
04.02.2015	233	182	86	74	69	71	87.9	71.7	37.5	45.0	42.0	43.6
19.02.2015	228	174	90	78	73	76	79.6	70.4	45.2	44.5	46.2	47.4
06.03.2015	235	184	81	80	75	73	81.2	65.8	33.8	46.5	43.2	48.1
19.03.2015	224	172	84	76	77	75	78.7	68.3	34.8	49.5	43.9	42.5
07.04.2015	230	167	79	86	79	72	82.9	70.0	33.8	52.0	41.5	44.4
20.04.2015	241	175	92	82	77	74	79.6	67.5	49.3	54.0	48.8	40.0
05.05.2015	229	188	71	86	79	77	82.5	72.5	33.6	51.7	46.8	44.4
20.05.2015	231	179	88	73	74	75	72.1	70.4	38.0	47.0	41.9	45.6
05.06.2015	240	174	82	76	76	74	80.4	75.0	41.7	49.8	46.0	48.5
19.06.2015	189	155	58	67	66	65	67.5	66.0	34.3	41.1	39.3	41.2
05.07.2015	198	159	64	73	71	69	70.5	65.1	32.4	44.5	40.2	41.4
20.07.2015	200	163	66	75	67	70	74.6	61.3	37.5	45.0	40.8	42.6
05.08.2015	171	146	62	66	65	66	64.8	60.0	30.7	41.3	40.5	39.7
20.08.2015	203	160	68	71	69	68	74.5	65.0	32.9	44.5	45.6	42.0
05.09.2015	198	165	66	77	70	69	78.5	67.5	33.9	47.5	48.0	41.4
19.09.2015	236	152	66	79	85	71	68.1	55.0	30.8	36.8	42.0	31.7
05.10.2015	206	133	59	79	78	71	49.0	45.4	27.4	35.7	34.6	36.1
26.10.2015	171	131	86	82	77	64	75.0	60.9	41.2	40.9	33.8	32.7
10.11.2015	158	188	85	76	88	80	66.0	72.8	37.8	51.1	49.2	42.8
23.11.2015	187	156	74	96	75	71	72.8	66.9	41.8	58.3	39.6	38.5
09.12.2015	179	181	64	91	82	70	72.3	80.0	37.6	57.2	39.4	36.0
18.12.2015	200	234	64	93	100	65	78.4	74.5	42.6	51.1	59.1	31.4
05.01.2016	155	191	74	85	98	73	62.8	68.2	45.1	47.2	58.0	35.5
17.01.2016	160	174	79	82	91	70	60.5	61.5	41.4	46.8	49.8	31.4
03.02.2016	199	180	71	88	85	68	68.9	62.3	37.6	56.9	44.1	30.2
17.02.2016	197	192	69	74	63	69	75.8	72.5	38.3	51.5	40.8	45.0
05.03.2016	194	180	86	96	98	83	59.2	54.5	41.2	55.1	51.6	46.4
21.03.2016	242	211	81	97	85	86	79.8	79.1	39.7	59.1	50.8	44.4
04.04.2016	244	179	74	98	100	89	75.3	55.3	41.2	60.0	55.8	48.3
19.04.2016	200	189	76	95	86	84	70.1	56.3	41.2	46.9	56.3	42.1
05.05.2016	236	225	69	93	89	88	75.8	62.3	39.8	52.3	59.1	49.3
21.05.2016	224	191	79	90	69	71	73.7	83.7	49.6	50.0	31.1	36.4
02.06.2016	153	160	84	69	70	68	54.1	65.2	47.6	39.1	32.5	31.4
16.06.2016	147	155	66	62	68	61	50.9	56.4	39.8	32.9	33.6	29.8
01.07.2016	151	163	78	59	76	63	48.6	58.9	45.2	29.9	38.9	32.5
16.07.2016	159	179	76.1	65	68	58	55.7	61.5	43.0	35.6	33.7	29.7
04.08.2016	150	170	72	68	66	55	51.2	56.9	42.4	36.1	31.4	26.4
16.08.2016	141	151	74	62	62	51	48.3	51.4	41.0	32.4	25.6	27.8
01.09.2016	139	147	78	57	55	48	38.6	50.3	45.1	30.2	24.3	24.1
16.09.2016	130	150	78	68	65	60	40.3	56.7	43.7	45.8	46.2	34.4
01.10.2016	163	171	73	75	75	67	54.3	64.3	46.8	34.3	52.3	38.1
17.10.2016	176	180	76	81	86	69	52.3	66.0	43.7	51.9	55.3	41.6
02.11.2016	180	196	76	95	95	76	58.1	70.2	41.7	58.7	56.1	48.4
17.11.2016	198	215	74	104	98	94	65.9	76.8	43.8	55.8	61.3	53.6
02.12.2016	215	220	75	97	90	88	68.9	71.1	42.3	44.6	50.1	47.6
17.12.2016	176	227	82	104	97	71	54.3	68.6	47.5	57.1	54.9	35.1
02.01.2017	198	218	85	92	95	73	69.1	72.3	48.7	54.6	57.3	36.1
16.01.2017	230	229	76	97	93	84	82.1	78.1	49.4	58.7	54.1	46.6
01.02.2017	241	236	74	106	86	92	88.6	70.3	40.8	62.3	47.5	53.0
16.02.2017	185	195	76	92	93	66	71.4	51.2	46.1	51.2	53.4	31.2
01.03.2017	176	210	76	94	90	70	68.3	62.3	42.3	55.3	50.8	35.9
17.03.2017	190	215	82	97	95	78	70.2	68.8	48.7	58.4	48.3	45.1
03.04.2017	205	220	82	95	97	85	72.3	75.0	52.4	55.6	54.8	52.3
17.04.2017	210	208	82	97	92	90	76.9	72.6	41.2	58.3	50.6	56.6
02.05.2017	215	215	93	92	94	81	78.3	73.5	55.6	53.4	52.2	51.7
17.05.2017	182	220	76	95	92	85	55.7	69.0	42.1	55.7	48.1	42.4
03.06.2017	189	178	77	89	90	83	54.8	68.1	51.7	55	47.8	42
18.06.2017	180	169	75	91	89	82	54.6	67.5	48.9	54.6	47	41.7
04.07.2017	177	153	73	90	87	80	54.7	66.8	47.3	54.7	46.4	41.1
19.07.2017	175	142	74	87	84	81	54.1	64.2	46.7	53.4	45.7	41.3
04.08.2017	176	138	75	86	89	75	54.9	65.4	46	52.6	45.1	40
18.08.2017	165	132	76	91	78	72	55	59.3	45.5	52.7	43.8	44.1

RG OC-I	PM ₁₀ (µg/m ³)						PM _{2.5} (µg/m ³)					
	Date	CHP	WS	Gunjapadug	ector-II	ulapally	tulkalapally	CHP	WS	Gunjapadug	ector-II	ulapally
04.09.2017	158	129	79	93	64	69	55.3	50.0	44.6	49.0	40.8	43.6
18.09.2017	223	185	76	85	86	81	78.9	64.3	41.9	42.3	48.9	40.4
04.10.2017	229	196	76	96	88	96	82.3	69.4	44.5	55.1	51.3	56.3
17.10.2017	220	203	74	97	93	92	78.4	72.4	42.8	58.3	55.4	57.4
01.11.2017	225	229	79	95	96	95	83.4	76.4	43.2	56.1	58.1	55.2
17.11.2017	230	237	78	110	102	98	86.1	80.0	41.3	57.8	61.3	57.3
01.12.2017	246	224	97	106	91	89	84.1	73.7	54.1	62.5	53.0	38.4
18.12.2017	195	200	83	96	95	75	70.8	54.2	46.9	41.5	47.1	36.9
02.01.2018	235	187	78	55	53	68	79.2	70.8	42.1	24.0	28.6	30.0
16.01.2018	194	193	84	56	76	84	62.5	70.8	44.6	28.8	33.3	45.0
01.02.2018	197	240	94	99	98	91	68.7	76.7	36.9	57.6	57.1	50.0
16.02.2018	247	239	86	90	90	101	87.5	80.8	41.2	58.4	56.4	55.0
02.03.2018	216	227	82	95	94	86	66.7	87.5	47.6	56.1	57.5	47.1
17.03.2018	231	240	71	98	98	90	78.1	96.6	46.1	59.2	59.1	50.8
02.04.2018	240	196	86	96	95	84	89.5	69.3	46.8	55.4	55.1	45.3
17.04.2018	245	205	91	93	90	89	93.6	73.8	46.6	51.7	51.2	48.7
02.05.2018	241	201	89	91	92	93	91.5	65.3	46.4	45.9	54.7	51.5
17.05.2018	237	215	89	86	86	89	85.1	69.4	42.8	40.1	49.4	47.1
01.06.2018	220	189	91	81	90	70	74.3	55.1	42.1	37.2	55.4	40.1
21.06.2018	186	155	74	96	81	65	65.9	51.2	36.8	55.7	47.3	38.1
04.07.2018	150	140	41	75	65	55	51.2	40.8	12.8	51.6	41.1	32.7
22.07.2018	141	126	46	61	69	51	48.9	35.4	23.3	44.2	43.7	30.1
03.08.2018	136	115	91	54	61	48	41.9	31.6	58.1	35.2	35.3	25.9
23.08.2018	162	138	89	65	68	52	55.8	41.7	39.4	41.2	41.3	27.8
01.09.2018	151	175	89	71	72	58	55.3	62.5	42.3	48.3	45.6	29.3
16.09.2018	158	180	91	74	75	61	59.4	65.3	48.1	51.9	48.2	32.7
05.10.2018	156	173	89	76	64	57	51.8	62.7	46.8	43.5	30.5	35.0
22.10.2018	168	185	92	79	68	65	58.4	66.3	52.1	47.6	41.4	38.9
08.11.2018	176	194	83	90	76	71	59.0	75.4	43.9	50.2	47.7	42.2
21.11.2018	152	174	88	82	59	65	56.2	70.8	41.5	45.8	41.2	38.9
06.12.2018	163	181	82	79	63	71	58.9	76.5	49.1	49.6	45.4	42.8
20.12.2018	169	187	89	82	71	78	62.5	72.8	45.9	49.9	38.2	42.9
07.01.2019	184	176	81	76	66	59	71.2	77.1	43.2	44.4	38.0	36.2
21.01.2019	186	178	69	78	68	62	71.4	77.0	42.1	44.3	38.2	36.4
07.02.2019	189	181	73	84	71	64	70.5	77.3	40.6	45.0	37.8	36.9
20.02.2019	190	184	86	85	74	66	70.8	77.6	38.7	45.2	37.9	37.2
06.03.2019	203	212	84	89	87	73	79.7	81.7	43.1	51.7	46.8	41.7
21.03.2019	194	203	76	86	89	82	73.4	84.9	39.1	49.6	51.4	43.2
04.04.2019	192	201	79	91	73	84	87.5	86.6	36.8	48.3	39.4	46.9
20.04.2019	201	216	81	86	92	79	76.5	86.1	42.6	52.5	42.4	51.3
06.05.2019	226	201	82	96	85	94	82.2	86.0	39.4	53.4	49.7	52.3
22.05.2019	203	213	74	74	89	71	74.6	62.2	40.9	47.3	46.3	41.2
06.06.2019	172	206	81	87	67	79	62.6	70.5	41.7	51.2	39.7	42.3
20.06.2019	182	189	87	64	59	62	69.4	82.5	38.2	46.5	35.2	39.8
01.07.2019	142	174	45	79	75	69	57.2	75.8	22.9	43.8	44.2	39.5
22.07.2019	127	136	89	61	66	86	61.9	64.3	41.3	37.2	40.0	48.5
05.08.2019	115	123	53	65	57	64	53.1	61.3	25.7	39.4	33.4	36.2
22.08.2019	132	109	73	71	52	69	58.5	49.8	31.8	42.4	33.2	41.3
05.09.2019	136	129	83	59	72	60	57.3	52.8	40.1	34.8	41.5	36.1
20.09.2019	125	133	66	61	60	57	52.6	57.3	22.6	40.2	38.3	32.7
06.10.2019	145	120	71	73	67	63	61.5	53.1	34.2	43.5	36.2	36.4
21.10.2019	169	176	89	78	62	71	69.4	58.3	39.5	39.7	34.5	42.2
07.11.2019	178	167	81	82	78	64	74.5	52.6	41.8	47.5	42.6	37.5
21.11.2019	172	182	84	79	75	64	74.8	79.9	39.7	42.5	48.9	41.5
07.12.2019	193	178	84	73	84	79	70.2	56.4	41.9	43.4	47.9	43.8
24.12.2019	192	168	88	68	67	79	70.2	51.6	45.4	39.4	41.8	46.5
06.01.2020	172	152	79	87	79	76	64.3	56.1	34.6	51.4	40.8	37.5
22.01.2020	195	203	85	86	85	76	64.2	62.3	36.4	47.6	49.9	45.5
06.02.2020	178	186	87	79	74	59	58.4	63.8	45.6	39.8	42.7	35.8
22.02.2020	206	194	85	92	69	82	66.8	57.6	46.5	49.9	38.2	44.7
05.03.2020	216	223	82	84	82	79	61.8	66.5	47.6	46.9	48.6	43.1
20.03.2020	210	208	81	67	78	80	62.4	67	38.9	32.6	42.1	41.8
06.04.2020	202	199	67	57	59	65	57.1	49.5	32.9	32.6	35.8	39.7
16.04.2020	175	184	63	79	58	61	63.7	58.1	23.7	42.2	40.4	42.6
04.05.2020	194	206	76	76	87	74	56.5	51.3	33.9	46.4	51.2	47.3
21.05.2020	216	199	73	57	86	84	58.6	61.9	39.6	32.4	52.5	48.3

RG OC-I	PM ₁₀ (µg/m ³)						PM _{2.5} (µg/m ³)					
	Date	CHP	WS	Gunjapadug	ector-II	ulapally	tulkalapally	CHP	WS	Gunjapadug	ector-II	ulapally
04.06.2020	142	152	81	74	71	66	49.2	51.4	42.8	41.2	39.5	35.8
16.06.2020	129	147	78	73	62	68	41.5	46.9	41.5	44.2	35.2	39.5
08.07.2020	124	137	63	59	64	59	42.6	46.8	32.4	34.5	36.4	34.5
23.07.2020	130	138	82	59	59	63	45.7	43.4	43.8	34.9	38.8	36.5
08.08.2020	126	152	74	61	67	59	45.6	51.6	32.1	36.7	39.6	35.1
20.08.2020	113	138	58	57	59	63	41.6	45.4	23.6	32.4	39.6	35.1
08.09.2020	120	136	72	68	73	52	41.3	44.8	35.8	39.1	38.9	29.8
19.09.2020	124	136	83	73	65	70	43.4	47.6	45.3	41.5	39.8	39.1
08.10.2020	139	121	84	61	70	63	42.1	35.6	42.5	35.1	39.9	33.4
22.10.2020	162	176	76	59	73	68	51.6	54.2	42.1	39.2	38.6	38.6
07.11.2020	170	166	83	63	78	69	62.2	59.3	40.9	39.4	47.4	44.4
21.11.2020	164	172	81	76	85	75	55.5	50	41.2	35.4	51.6	41.1
08.12.2020	187	208	86	89	76	87	59.7	62.8	44.2	47.3	48.1	34.6
21.12.2020	142	168	81	89	86	82	46.8	54.3	42.7	51.6	43.8	35.4
07.01.2021	175	192	89	78	86	65	47.5	59.6	41.2	43.5	47.4	38
21.01.2021	179	183	88	76	79	74	47.5	51.4	43.7	43.4	43.4	39.8
06.02.2021	162	178	81	80	65	72	54.5	62.2	46.7	42.9	37.6	40.2
16.02.2021	171	186	89	85	71	84	59.6	62.8	43.7	47.2	40.5	47.2
06.03.2021	179	188	82	72	76	71	57.2	58.2	51.6	37.8	44.5	39.7
16.03.2021	153	176	91	85	62	76	46.5	57.3	50.5	47.2	44.8	41.6
07.04.2021	173	162	84	84	75	86	49.2	51.6	43.2	48.6	42.8	47.2
23.04.2021	184	197	79	84	73	66	59.6	62.4	39.7	42.6	42.2	41.5
08.05.2021	176	185	79	81	79	82	47.5	49.9	36.5	43.5	41.2	44.5
22.05.2021	176	189	82	79	80	88	47.3	50.7	42.1	45.6	42.2	47.2
03.06.2021	124	136	87	63	59	61	41.8	43.6	46.8	35.8	35.4	33.8
19.06.2021	138	152	71	66	63	71	46.3	49.2	32.9	38.4	38.1	39.7
03.07.2021	106	124	66	58	58	56	36.8	41.2	34.5	33.5	35.4	33.5
19.07.2021	112	136	81	61	61	59	44.6	43.8	42.5	32	40.5	33.9
04.08.2021	92	113	88	57	59	61	42.6	44.2	42.2	32.4	33.5	35.4
18.08.2021	106	126	81	62	51	62	39.6	46.8	41.2	33.5	29.4	35.6
04.09.2021	112	125	86	62	69	72	42.6	45.8	42.8	35.6	37.5	39.2
18.09.2021	103	119	79	65	58	62	42.5	43.4	40.1	38.4	32.5	35.3
01.10.2021	157	162	73	72	67	59	45.4	51.9	38.4	34.3	39.6	36.2
18.10.2021	157	162	74	80	71	68	47.4	56.6	35.1	39.4	29.2	33.6
01.11.2021	168	182	81	69	69	61	42.6	47.4	41.2	41.7	32.4	33.2
18.11.2021	179	195	82	85	69	86	46.2	52.8	45.7	40.5	36.6	41.2
13.12.2021	184	192	88	89	79	72	44.6	48.6	41.5	42.2	36.1	35.1
28.12.2021	188	204	79	82	74	81	45.4	56.2	38.7	41.4	35.8	41.1
03.01.2022	181	209	74	86	82	76	45.6	54.5	36.4	41.6	39.4	36.6
16.01.2022	185	196	85	84	83	79	46.2	50.8	38.9	42.9	41.8	36.8
03.02.2022	188	211	84	82	84	71	48.7	55.6	46.7	42.7	41.6	35.4
17.02.2022	174	204	61	88	88	76	46.7	53.9	32.4	43.4	42.3	37.3
11.03.2022	173	195	81	79	84	72	48.5	54.7	40.5	44.4	47.8	38.6
26.03.2022	176	188	88	83	89	79	56.4	59.3	47.3	46.6	49.6	41.2

Appendix V

Table 1. SRP OC Mine parameters

SRP OC	Production (Coal+OB)	Area contributing to pollution	Max. Quarry depth	Max. Dump height	Lead distance
Date	(t)	(Ha)	(m)	(m)	(km)
07.04.2012	81,727	258.9	80.0	30.0	5.5
22.04.2012	76,619	261.1	80.2	30.6	5.4
06.05.2012	80,259	263.3	80.4	31.2	5.4
21.05.2012	75,243	265.5	80.6	31.8	4.5
07.06.2012	55,870	267.7	80.8	32.4	4.4
22.06.2012	52,378	269.9	81.0	33.0	4.4
07.07.2012	38,422	272.1	81.2	33.6	4.3
22.07.2012	36,021	274.3	81.4	34.2	4.3
07.08.2012	50,027	276.5	81.6	34.8	4.2
22.08.2012	46,900	278.7	81.8	35.4	4.2
07.09.2012	58,251	280.9	82.0	36.0	4.1
22.09.2012	54,610	283.1	82.2	36.6	4.1
06.10.2012	63,760	285.3	82.4	37.2	4.0
22.10.2012	59,775	287.5	82.6	37.8	4.0
07.11.2012	23,220	289.7	82.8	38.4	3.9
22.11.2012	21,769	291.9	83.0	39.0	3.9
08.12.2012	44,833	294.1	83.2	39.6	3.8
24.12.2012	42,031	296.3	83.4	40.2	3.7
07.01.2013	40,590	298.5	83.6	40.8	3.7
22.01.2013	38,053	300.7	83.8	41.4	3.6
07.02.2013	11,848	302.9	84.0	42.0	3.6
21.02.2013	11,108	305.1	84.2	42.6	3.5
08.03.2013	10,158	307.3	84.4	43.2	3.5
23.03.2013	9,524	309.5	84.6	43.8	3.4
08.04.2013	13,183	313.9	85.0	45.0	4.2
22.04.2013	12,359	312.1	85.6	45.8	4.2
08.05.2013	13,984	310.3	86.2	46.6	4.2
20.05.2013	13,110	308.5	86.8	47.4	4.2
08.06.2013	59,233	306.7	87.4	48.2	4.2
22.06.2013	55,531	304.9	88.0	49.0	4.2
08.07.2013	55,207	303.1	88.6	49.8	4.2
25.07.2013	51,756	301.3	89.2	50.6	4.2
08.08.2013	56,151	299.4	89.8	51.4	4.2
23.08.2013	52,642	297.6	90.4	52.2	4.2
07.09.2013	66,287	295.8	91.0	53.0	4.2
22.09.2013	62,144	294.0	91.6	53.8	4.2
07.10.2013	58,525	292.2	92.2	54.6	4.2
22.10.2013	54,867	290.4	92.8	55.4	4.2
09.11.2013	82,571	288.6	93.4	56.2	4.2
22.11.2013	77,410	286.8	94.0	57.0	4.2
09.12.2013	105,172	285.0	94.6	57.8	4.2
23.12.2013	98,598	283.2	95.2	58.6	4.2
06.01.2014	114,937	281.4	95.8	59.4	4.2
22.01.2014	107,753	279.6	96.4	60.2	4.2
07.02.2014	85,940	277.8	97.0	61.0	4.2
22.02.2014	80,569	276.0	97.6	61.8	4.2
07.03.2014	114,590	274.2	98.2	62.6	4.2
29.03.2014	107,429	272.4	98.8	63.4	4.2
13.04.2014	118,315	268.7	100.0	65.0	4.2

SRP OC	Production (Coal+OB)	Area contributing to pollution	Max. Quarry depth	Max. Dump height	Lead distance
Date	(t)	(Ha)	(m)	(m)	(km)
28.04.2014	110,920	270.1	100.5	65.1	4.2
15.05.2014	105,431	271.4	100.9	65.2	4.2
30.05.2014	98,841	272.8	101.4	65.4	4.2
15.06.2014	105,420	274.1	101.8	65.5	4.2
30.06.2014	98,831	275.4	102.3	65.6	4.2
14.07.2014	90,746	276.8	102.8	65.7	4.2
30.07.2014	85,075	278.1	103.2	65.8	4.2
14.08.2014	98,741	279.5	103.7	66.0	4.2
30.08.2014	92,570	280.8	104.2	66.1	4.2
15.09.2014	91,252	282.1	104.6	66.2	4.2
30.09.2014	85,549	283.5	105.1	66.3	4.2
15.10.2014	102,931	284.8	105.5	66.4	4.2
31.10.2014	96,498	286.2	106.0	66.6	4.1
14.11.2014	106,031	287.5	106.5	66.7	4.1
30.11.2014	99,404	288.9	106.9	66.8	4.1
14.12.2014	117,209	290.2	107.4	66.9	4.1
22.12.2014	109,883	291.5	107.8	67.0	4.1
08.01.2015	116,378	292.9	108.3	67.2	4.1
22.01.2015	109,105	294.2	108.8	67.3	4.1
09.02.2015	80,077	295.6	109.2	67.4	4.1
27.02.2015	75,072	296.9	109.7	67.5	4.1
13.03.2015	119,628	298.2	110.2	67.6	4.1
30.03.2015	112,151	299.6	110.6	67.8	4.1
13.04.2015	130,946	302.3	112.0	68.0	4.1
28.04.2015	122,762	303.6	112.6	68.3	4.1
14.05.2015	144,292	304.9	113.2	68.6	4.1
29.05.2015	135,273	306.2	113.8	68.8	4.1
14.06.2015	103,535	307.6	114.4	69.1	4.1
28.06.2015	97,064	308.9	115.0	69.4	4.1
14.07.2015	107,962	310.2	115.6	69.7	4.1
29.07.2015	101,215	311.5	116.2	70.0	4.1
14.08.2015	111,755	312.9	116.8	70.2	4.1
30.08.2015	104,770	314.2	117.4	70.5	4.1
14.09.2015	113,958	315.5	118.0	70.8	4.1
24.09.2015	106,835	316.8	118.6	71.1	4.1
09.10.2015	110,295	318.1	119.2	71.4	4.1
23.10.2015	103,402	319.5	119.8	71.6	4.1
07.11.2015	116,730	320.8	120.4	71.9	4.1
24.11.2015	109,435	322.1	121.0	72.2	4.1
08.12.2015	110,874	323.4	121.6	72.5	4.1
23.12.2015	103,944	324.8	122.2	72.8	4.1
09.01.2016	114,683	326.1	122.8	73.0	4.1
23.01.2016	107,516	327.4	123.4	73.3	4.1
08.02.2016	103,114	328.7	124.0	73.6	4.1
23.02.2016	96,670	330.1	124.6	73.9	4.1
14.03.2016	106,306	331.4	125.2	74.2	4.1
30.03.2016	99,661	332.7	125.8	74.4	4.1
14.04.2016	440,712	335.4	127.0	75.0	4.1
28.04.2016	413,167	332.9	127.1	75.1	4.1
13.05.2016	366,153	330.5	127.2	75.2	4.1
28.05.2016	343,268	328.0	127.4	75.4	4.0
13.06.2016	44,998	325.5	127.5	75.5	4.0

SRP OC	Production (Coal+OB)	Area contributing to pollution	Max. Quarry depth	Max. Dump height	Lead distance
Date	(t)	(Ha)	(m)	(m)	(km)
29.06.2016	42,186	323.1	127.6	75.6	4.0
13.07.2016	63,050	320.6	127.7	75.7	4.0
29.07.2016	59,110	318.2	127.8	75.8	4.0
13.08.2016	79,144	315.7	128.0	76.0	3.9
29.08.2016	74,198	313.3	128.1	76.1	3.9
14.09.2016	82,862	310.8	128.2	76.2	3.9
29.09.2016	77,683	308.4	128.3	76.3	3.9
08.10.2016	105,978	305.9	128.4	76.4	3.8
24.10.2016	99,354	303.5	128.6	76.6	3.8
08.11.2016	186,889	301.0	128.7	76.7	3.8
23.11.2016	175,208	298.6	128.8	76.8	3.8
07.12.2016	222,407	296.1	128.9	76.9	3.7
24.12.2016	208,506	293.7	129.0	77.0	3.7
08.01.2017	224,084	291.2	129.2	77.2	3.7
24.01.2017	210,079	288.8	129.3	77.3	3.7
08.02.2017	228,515	286.3	129.4	77.4	3.7
23.02.2017	214,233	283.9	129.5	77.5	3.6
08.03.2017	215,331	281.4	129.6	77.6	3.6
23.03.2017	201,873	278.9	129.8	77.8	3.6
14.04.2017	207,149	274.0	130.0	78.0	3.5
28.04.2017	194,202	276.7	130.4	78.2	3.5
13.05.2017	196,438	279.4	130.8	78.5	3.5
29.05.2017	184,161	282.1	131.3	78.7	3.5
14.06.2017	171,008	284.8	131.7	79.0	3.5
28.06.2017	160,320	287.5	132.1	79.2	3.4
13.07.2017	194,808	290.2	132.5	79.4	3.4
20.07.2017	182,632	292.9	132.9	79.7	3.4
14.08.2017	158,389	295.5	133.3	79.9	3.4
28.08.2017	148,490	298.2	133.8	80.2	3.4
12.09.2017	213,938	300.9	134.2	80.4	3.3
27.09.2017	200,567	303.6	134.6	80.6	3.3
12.10.2017	216,133	306.3	135.0	80.9	3.3
26.10.2017	202,625	309.0	135.4	81.1	3.3
13.11.2017	212,491	311.7	135.8	81.4	3.3
27.11.2017	199,210	314.4	136.3	81.6	3.2
12.12.2017	250,468	317.0	136.7	81.8	3.2
27.12.2017	234,814	319.7	137.1	82.1	3.2
11.01.2018	192,807	322.4	137.5	82.3	3.2
25.01.2018	180,756	325.1	137.9	82.6	3.2
12.02.2018	211,990	327.8	138.3	82.8	3.1
26.02.2018	198,741	330.5	138.8	83.0	3.1
13.03.2018	203,761	333.2	139.2	83.3	3.1
27.03.2018	191,026	335.9	139.6	83.5	3.1
12.04.2018	212,697	341.2	140.0	84.0	3.1
26.04.2018	199,404	341.0	140.3	84.1	3.1
11.05.2018	193,965	340.8	140.6	84.2	3.1
26.05.2018	181,843	340.6	141.0	84.4	3.2
11.06.2018	158,509	340.4	141.3	84.5	3.2
27.06.2018	148,602	340.1	141.6	84.6	3.2
12.07.2018	126,967	339.9	141.9	84.7	3.3
26.07.2018	119,031	339.7	142.2	84.8	3.3
11.08.2018	153,603	339.5	142.6	85.0	3.4

SRP OC	Production (Coal+OB)	Area contributing to pollution	Max. Quarry depth	Max. Dump height	Lead distance
Date	(t)	(Ha)	(m)	(m)	(km)
27.08.2018	144,002	339.3	142.9	85.1	3.4
12.09.2018	191,851	339.0	143.2	85.2	3.4
27.09.2018	179,860	338.8	143.5	85.3	3.5
11.10.2018	211,940	338.6	143.8	85.4	3.5
27.10.2018	198,693	338.4	144.2	85.6	3.5
13.11.2018	188,185	338.2	144.5	85.7	3.6
28.11.2018	176,423	337.9	144.8	85.8	3.6
12.12.2018	177,761	337.7	145.1	85.9	3.7
27.12.2018	166,651	337.5	145.4	86.0	3.7
10.01.2019	189,853	337.3	145.8	86.2	3.7
28.01.2019	177,987	337.1	146.1	86.3	3.8
12.02.2019	181,798	336.8	146.4	86.4	3.8
26.02.2019	170,436	336.6	146.7	86.5	3.8
12.03.2019	187,518	336.4	147.0	86.6	3.9
28.03.2019	175,798	336.2	147.4	86.8	3.9
11.04.2019	171,180	335.7	148.0	87.0	4.0
25.04.2019	160,481	336.3	149.1	87.1	4.0
11.05.2019	173,462	337.0	150.2	87.2	4.1
27.05.2019	162,621	337.6	151.2	87.4	4.1
11.06.2019	162,636	338.2	152.3	87.5	4.2
27.06.2019	152,471	338.8	153.4	87.6	4.2
11.07.2019	115,385	339.4	154.5	87.7	4.2
25.07.2019	108,174	340.0	155.6	87.8	4.3
12.08.2019	108,207	340.6	156.6	88.0	4.3
27.08.2019	101,444	341.2	157.7	88.1	4.4
12.09.2019	92,088	341.8	158.8	88.2	4.4
26.09.2019	86,333	342.4	159.9	88.3	4.4
14.10.2019	136,171	343.0	161.0	88.4	4.5
27.10.2019	127,661	343.6	162.0	88.6	4.5
12.11.2019	150,716	344.2	163.1	88.7	4.6
27.11.2019	141,296	344.8	164.2	88.8	4.6
12.12.2019	163,318	345.4	165.3	88.9	4.6
26.12.2019	153,111	346.0	166.4	89.0	4.7
11.01.2020	170,958	346.6	167.4	89.2	4.7
27.01.2020	160,273	347.3	168.5	89.3	4.8
11.02.2020	157,285	347.9	169.6	89.4	4.8
26.02.2020	147,455	348.5	170.7	89.5	4.8
12.03.2020	159,462	349.1	171.8	89.6	4.9
27.03.2020	149,496	349.7	172.8	89.8	4.9
11.04.2020	158,747	350.9	175.0	90.0	5.0
25.04.2020	148,825	350.2	175.2	90.0	5.1
13.05.2020	191,108	349.5	175.4	90.0	5.1
27.05.2020	179,164	348.9	175.6	90.0	5.2
14.06.2020	165,087	348.2	175.8	90.0	5.2
25.06.2020	154,769	347.5	176.0	90.0	5.3
11.07.2020	155,327	346.8	176.2	90.0	5.4
27.07.2020	145,619	346.2	176.4	90.0	5.4
13.08.2020	97,236	345.5	176.6	90.0	5.5
27.08.2020	91,159	344.8	176.8	90.0	5.5
10.09.2020	143,164	344.1	177.0	90.0	5.6
28.09.2020	134,216	343.5	177.2	90.0	5.7
12.10.2020	176,021	342.8	177.4	90.0	5.7

SRP OC	Production (Coal+OB)	Area contributing to pollution	Max. Quarry depth	Max. Dump height	Lead distance
Date	(t)	(Ha)	(m)	(m)	(km)
27.10.2020	165,020	342.1	177.6	90.0	5.8
11.11.2020	181,149	341.4	177.8	90.0	5.8
26.11.2020	169,827	340.8	178.0	90.0	5.9
09.12.2020	183,339	340.1	178.2	90.0	6.0
29.12.2020	171,881	339.4	178.4	90.0	6.0
12.01.2021	186,221	338.8	178.6	90.0	6.1
28.01.2021	174,582	338.1	178.8	90.0	6.1
11.02.2021	150,206	337.4	179.0	90.0	6.2
25.02.2021	140,818	336.7	179.2	90.0	6.3
11.03.2021	140,717	336.1	179.4	90.0	6.3
25.03.2021	131,922	335.4	179.6	90.0	6.4
12.04.2021	124,489	334.0	180.0	90.0	6.5
27.04.2021	116,708	334.0	180.0	90.0	6.4
13.05.2021	157,840	334.0	180.0	90.0	6.2
27.05.2021	147,975	334.0	180.0	90.0	6.1
10.06.2021	128,431	334.0	180.0	90.0	5.9
26.06.2021	120,404	334.0	180.0	90.0	5.8
12.07.2021	128,268	334.0	180.0	90.0	5.6
28.07.2021	120,251	334.0	180.0	90.0	5.5
12.08.2021	151,731	334.0	180.0	90.0	5.3
26.08.2021	142,247	334.0	180.0	90.0	5.2
13.09.2021	142,298	334.0	180.0	90.0	5.0
25.09.2021	133,405	334.0	180.0	90.0	4.9
12.10.2021	183,875	334.0	180.0	90.0	4.7
27.10.2021	172,382	334.0	180.0	90.0	4.6
11.11.2021	190,079	334.0	180.0	90.0	4.4
25.11.2021	178,199	334.0	180.0	90.0	4.3
11.12.2021	205,202	334.0	180.0	90.0	4.1
28.12.2021	192,377	334.0	180.0	90.0	4.0
11.01.2022	193,236	334.0	180.0	90.0	3.8
27.01.2022	181,159	334.0	180.0	90.0	3.7
10.02.2022	139,086	334.0	180.0	90.0	3.5
25.02.2022	130,393	334.0	180.0	90.0	3.4
11.03.2022	146,791	334.0	180.0	90.0	3.2
25.03.2022	137,617	334.0	180.0	90.0	2.8

Table 2. SRP OC Meteorological data

SRP OC	Predominant wind direction	Avg. Temp	Avg. Humidity	Avg. Rainfall	Avg. Wind speed
Date	(degrees)	(°c)	(%)	(mm)	(m/s)
07.04.2012	120	35.1	60.1	0.0	1.2
22.04.2012	132	36.2	55.6	0.0	2.3
06.05.2012	79	37.0	57.8	0.0	0.5
21.05.2012	34	37.8	24.5	0.0	1.5
07.06.2012	170	38.9	75.6	0.0	0.2
22.06.2012	143	39.2	63.2	0.1	0.4
07.07.2012	120	38.5	48.9	0.7	1.5
22.07.2012	124	37.7	83.9	1.0	0.5
07.08.2012	169	35.6	78.9	0.0	1.2
22.08.2012	192	33.2	55.4	0.0	1.5

SRP OC	Predominant wind direction	Avg. Temp	Avg. Humidity	Avg. Rainfall	Avg. Wind speed
Date	(degrees)	(°c)	(%)	(mm)	(m/s)
07.09.2012	90	32.7	91.3	0.0	1.0
22.09.2012	210	32.4	88.1	2.0	0.2
06.10.2012	324	31.4	88.6	0.1	0.5
22.10.2012	240	30.6	75.4	0.0	0.1
07.11.2012	215	28.7	65.1	0.0	1.6
22.11.2012	28	26.5	75.5	0.0	0.3
08.12.2012	10	25.8	71.6	0.0	0.0
24.12.2012	109	24.1	56.8	0.0	0.4
07.01.2013	270	23.6	73.0	0.0	5.6
22.01.2013	267	22.1	66.0	0.0	4.5
07.02.2013	306	22.8	71.8	0.0	3.7
21.02.2013	272	23.5	55.4	0.0	4.2
08.03.2013	10	24.5	71.9	0.0	5.4
23.03.2013	345	26.7	66.8	0.0	8.1
08.04.2013	111	29.1	66.5	0.0	5.5
22.04.2013	21	29.4	65.5	0.1	8.7
08.05.2013	78	30.1	61.1	0.1	5.4
20.05.2013	91	29.9	54.5	0.2	12.0
08.06.2013	75	28.2	86.0	0.0	5.6
22.06.2013	180	30.6	65.1	0.0	8.2
08.07.2013	139	29.2	73.5	35.6	6.8
25.07.2013	120	27.7	75.8	8.2	5.5
08.08.2013	207	28.4	76.7	0.0	8.1
23.08.2013	152	26.3	75.5	0.0	4.9
07.09.2013	190	28.8	68.3	0.0	4.6
22.09.2013	93	24.9	83.8	9.8	4.7
07.10.2013	173	27.1	79.2	5.0	0.0
22.10.2013	281	27.3	71.3	0.0	4.5
09.11.2013	42	24.4	69.2	0.0	1.6
22.11.2013	246	24.9	63.7	0.0	4.2
09.12.2013	313	26.0	46.6	0.0	3.4
23.12.2013	186	26.0	50.7	0.0	0.1
06.01.2014	20	24.5	62.8	0.0	6.1
22.01.2014	31	24.2	62.9	0.0	9.4
07.02.2014	55	25.1	47.8	2.4	4.3
22.02.2014	192	26.8	58.1	0.0	8.0
07.03.2014	222	22.2	74.6	0.0	3.7
29.03.2014	218	31.9	47.1	0.0	4.8
13.04.2014	190	32.3	45.7	0.0	12.7
28.04.2014	153	34.4	46.7	0.0	8.2
15.05.2014	77	34.8	38.9	0.0	2.1
30.05.2014	314	36.2	38.2	0.0	5.0
15.06.2014	64	32.5	58.4	0.0	5.3
30.06.2014	61	31.1	57.9	0.0	0.0
14.07.2014	45	26.2	79.9	6.0	0.0
30.07.2014	7	26.8	77.8	7.0	0.0
14.08.2014	162	30.8	62.1	0.0	0.0
30.08.2014	288	28.1	76.3	9.0	0.0
15.09.2014	218	27.2	77.8	28.6	0.0

SRP OC	Predominant wind direction	Avg. Temp	Avg. Humidity	Avg. Rainfall	Avg. Wind speed
Date	(degrees)	(°c)	(%)	(mm)	(m/s)
30.09.2014	210	27.2	67.4	0.0	0.0
15.10.2014	309	29.9	65.0	0.0	0.0
31.10.2014	148	24.7	58.2	0.0	0.0
14.11.2014	182	27.0	67.9	0.0	0.0
30.11.2014	163	22.8	54.7	0.0	0.0
14.12.2014	198	22.4	78.6	0.0	0.0
22.12.2014	196	18.2	56.7	0.0	0.0
08.01.2015	199	20.4	58.1	0.0	0.0
22.01.2015	300	22.4	62.8	0.0	0.0
09.02.2015	258	23.7	56.9	0.0	0.0
27.02.2015	306	26.8	51.1	0.0	0.0
13.03.2015	56	26.8	51.1	0.0	0.0
30.03.2015	187	26.8	51.1	0.0	0.0
13.04.2015	96	26.8	51.1	0.0	0.0
28.04.2015	297	26.8	51.1	0.0	0.0
14.05.2015	44	26.8	51.1	0.0	0.0
29.05.2015	157	38.6	51.1	0.0	0.0
14.06.2015	348	39.6	51.1	7.6	0.0
28.06.2015	83	30.9	61.8	2.4	0.0
14.07.2015	93	30.6	66.3	17.8	0.0
29.07.2015	45	31.5	56.4	0.0	0.0
14.08.2015	182	25.9	67.2	2.8	5.3
30.08.2015	112	27.1	77.5	19.4	4.1
14.09.2015	95	29.0	71.0	26.4	4.0
24.09.2015	98	31.2	64.4	0.0	2.8
09.10.2015	169	28.3	59.7	0.0	2.4
23.10.2015	179	28.4	62.6	0.0	2.2
07.11.2015	273	26.2	58.4	0.0	4.2
24.11.2015	253	26.8	63.3	0.0	3.6
08.12.2015	270	23.0	57.5	0.0	2.7
23.12.2015	103	27.0	61.9	0.0	3.6
09.01.2016	90	23.0	53.0	0.0	1.2
23.01.2016	180	19.7	41.2	0.0	0.6
08.02.2016	267	27.2	56.7	0.0	2.3
23.02.2016	92	30.4	52.0	0.0	1.0
14.03.2016	270	31.9	53.6	0.2	0.1
30.03.2016	324	32.8	46.4	0.0	1.3
14.04.2016	116	34.3	37.3	0.2	2.5
28.04.2016	209	36.3	42.0	0.0	2.0
13.05.2016	192	37.4	39.3	0.2	1.1
28.05.2016	65	37.0	48.5	0.1	1.3
13.06.2016	200	32.8	59.5	5.4	0.1
29.06.2016	187	25.4	82.8	38.8	0.0
13.07.2016	223	28.0	73.8	5.8	2.2
29.07.2016	198	29.7	70.1	2.8	0.5
13.08.2016	277	30.2	72.2	0	1.6
29.08.2016	189	30.5	76.3	8.6	0.2
14.09.2016	105	28.0	83.1	2.4	4.1
29.09.2016	178	28.8	80.6	5.2	3.8

SRP OC	Predominant wind direction	Avg. Temp	Avg. Humidity	Avg. Rainfall	Avg. Wind speed
Date	(degrees)	(°c)	(%)	(mm)	(m/s)
08.10.2016	193	27.7	81.8	0.0	0.3
24.10.2016	160	27.6	64.0	0.0	0.2
08.11.2016	167	23.7	63.0	0.0	0.4
23.11.2016	129	22.2	63.3	0.0	0.3
07.12.2016	220	22.1	68.3	0.0	0.0
24.12.2016	189	20.3	58.6	0.0	0.3
08.01.2017	170	22.7	67.4	0.0	0.1
24.01.2017	198	24.5	58.2	0.0	0.1
08.02.2017	123	25.1	61.6	0.0	0.3
23.02.2017	197	26.8	60.4	0.0	0.0
08.03.2017	321	28.9	69.9	0.0	0.4
23.03.2017	180	30.2	63.1	0.0	0.0
14.04.2017	284	31.7	67.3	0.0	0.2
28.04.2017	202	32.6	64.0	0.0	0.0
13.05.2017	266	33.0	59.3	0.0	0.5
29.05.2017	153	36.8	39.5	0.0	0.1
14.06.2017	178	30.5	72.5	0.6	0.4
28.06.2017	149	27.0	87.1	0.4	0.0
13.07.2017	120	28.0	78.5	0.0	0.4
20.07.2017	145	24.0	99.1	0.1	2.5
14.08.2017	120	27.2	89.0	0.0	0.5
28.08.2017	90	27.8	83.6	0.0	0.3
12.09.2017	227	29.9	74.2	0.0	3.9
27.09.2017	112	29.8	70.5	0.0	4.4
12.10.2017	138	29.6	67.9	0.7	1.8
26.10.2017	355	27.3	65.2	0.0	0.3
13.11.2017	154	25.3	48.5	0.0	0.7
27.11.2017	165	33.9	42.8	0.0	0.7
12.12.2017	226	28.2	78.7	0.0	2.5
27.12.2017	61	26.8	54.2	0.0	2.4
11.01.2018	120	26.8	55.9	0.0	2.1
25.01.2018	95	36.5	32.7	0.0	2.3
12.02.2018	129	28.7	52.9	0.0	3.2
26.02.2018	143	28.3	56.2	0.0	3.0
13.03.2018	159	30.8	29.9	0.0	1.2
27.03.2018	138	32.8	40.3	0.0	1.1
12.04.2018	169	32.8	34.6	0.0	1.2
26.04.2018	179	34.9	33.8	0.0	1.2
11.05.2018	137	36.5	34.7	0.0	2.5
26.05.2018	152	35.2	37.1	0.0	1.2
11.06.2018	256	31.8	58.3	3.3	0.8
27.06.2018	200	32.4	59.8	1.2	1.5
12.07.2018	145	28.1	71.7	1.5	0.3
26.07.2018	208	27.7	77.1	0.0	1.4
11.08.2018	155	26.4	84.6	10.6	0.6
27.08.2018	237	30.6	65.5	0.0	0.1
12.09.2018	282	26.1	88.2	3.2	6.4
27.09.2018	215	26.5	87.7	0.0	0.1
11.10.2018	64	27.5	54.5	0.0	2.9

SRP OC	Predominant wind direction	Avg. Temp	Avg. Humidity	Avg. Rainfall	Avg. Wind speed
Date	(degrees)	(°c)	(%)	(mm)	(m/s)
27.10.2018	99	25.7	56.5	0.0	2.1
13.11.2018	137	23.6	65.0	0.0	1.5
28.11.2018	92	22.2	72.9	0.0	1.7
12.12.2018	140	24.9	48.1	0.0	2.2
27.12.2018	75	18.4	78.8	0.0	1.0
10.01.2019	160	23.4	42.0	0.0	2.4
28.01.2019	80	30.7	33.8	0.0	1.5
12.02.2019	145	20.9	72.1	0.0	1.0
26.02.2019	223	22.9	69.0	0.0	2.4
12.03.2019	187	29.7	32.3	0.0	1.0
28.03.2019	217	31.4	39.3	0.0	1.0
11.04.2019	263	35.2	30.5	0.0	1.0
25.04.2019	238	35.0	29.1	0.0	1.0
11.05.2019	233	36.5	26.5	1.0	2.0
27.05.2019	151	39.7	23.8	0.0	1.0
11.06.2019	235	37.4	32.5	0.0	2.0
27.06.2019	274	34.3	45.5	0.0	1.0
11.07.2019	250	28.1	75.2	0.5	2.0
25.07.2019	285	30.9	52.4	0.0	2.0
12.08.2019	138	24.8	83.2	1.2	2.0
27.08.2019	154	29.1	73.5	1.3	1.0
12.09.2019	224	26.2	83.9	0.0	1.0
26.09.2019	216	25.2	95.2	0.2	1.0
14.10.2019	165	28.9	63.6	0.0	2.0
27.10.2019	100	28.5	66.4	0.0	2.0
12.11.2019	123	24.4	62.8	0.0	2.0
27.11.2019	217	25.3	63.5	0.0	1.0
12.12.2019	107	23.6	66.2	0.0	2.3
26.12.2019	122	23.9	74.7	0.0	1.0
11.01.2020	235	21.3	48.8	0.0	2.1
27.01.2020	112	25.4	46.5	0.0	2.4
11.02.2020	95	24.4	66.6	0.0	1.9
26.02.2020	141	25.9	33.9	0.0	1.5
12.03.2020	161	28.2	58.0	0.0	2.0
27.03.2020	220	31.9	33.1	0.0	1.6
11.04.2020	177	31.5	37.6	0.0	1.0
25.04.2020	162	35.2	36.1	0.0	1.0
13.05.2020	187	31.2	34.9	0.0	2.0
27.05.2020	201	26.2	27.5	0.0	2.0
14.06.2020	292	36.3	34.3	0.0	1.4
25.06.2020	164	31.9	66.6	0.1	1.2
11.07.2020	219	37.5	34.9	0.0	3.3
27.07.2020	244	33.9	49.1	0.0	1.8
13.08.2020	262	27.1	87.3	0.3	3.0
27.08.2020	275	28.5	70.6	0.1	1.8
10.09.2020	196	29.5	56.8	0.0	1.0
28.09.2020	222	30.1	51.6	0.0	3.0
12.10.2020	60	27.8	71.2	0.0	1.0
27.10.2020	73	25.8	83.0	0.0	3.0

SRP OC	Predominant wind direction	Avg. Temp	Avg. Humidity	Avg. Rainfall	Avg. Wind speed
Date	(degrees)	(°c)	(%)	(mm)	(m/s)
11.11.2020	148	23.1	74.9	0.0	2.0
26.11.2020	146	23.8	72.9	0.0	2.0
09.12.2020	250	22.6	43.2	0.0	1.8
29.12.2020	178	22.8	45.1	0.0	1.9
12.01.2021	101	24.0	49.3	0.0	1.8
28.01.2021	191	25.2	82.7	0.0	2.0
11.02.2021	141	23.8	68.5	0.0	1.7
25.02.2021	62	26.9	62.4	0.0	1.7
11.03.2021	140	29.0	26.8	0.0	1.8
25.03.2021	161	30.8	23.5	0.0	1.5
12.04.2021	166	31.5	24.9	0.0	1.5
27.04.2021	174	33.9	12.2	0.0	1.4
13.05.2021	160	35.4	20.0	0.0	1.7
27.05.2021	85	33.9	54.3	0.0	1.0
10.06.2021	251	28.7	47.7	0.8	2.0
26.06.2021	207	28.5	55.8	2.0	2.0
12.07.2021	121	27.1	82.2	0.0	3.0
28.07.2021	165	30.3	65.5	0.0	1.0
12.08.2021	115	30.4	82.7	0.0	1.0
26.08.2021	233	28.1	54.4	1.0	1.0
13.09.2021	207	29.8	36.1	0.0	1.0
25.09.2021	226	26.5	59.4	3.7	2.0
12.10.2021	143	28.0	91.3	0.0	1.3
27.10.2021	181	25.4	71.6	0.0	1.5
11.11.2021	86	29.1	87.0	0.0	1.3
25.11.2021	160	29.3	80.8	0.0	1.5
11.12.2021	170	24.7	62.5	0.0	3.0
28.12.2021	216	23.8	68.8	0.0	3.0
11.01.2022	262	23.9	72.5	0.0	3.0
27.01.2022	202	21.2	43.7	0.0	4.0
10.02.2022	277	25.7	56.3	0.0	2.0
25.02.2022	193	25.1	80.2	0.0	2.0
11.03.2022	279	29.7	42.0	0.0	2.0
25.03.2022	233	31.1	50.8	0.0	2.0

Table 3. PM₁₀ and PM_{2.5} in core and buffer zones of SRP OC

SRP OC	PM ₁₀ (µg/m ³)						PM _{2.5} (µg/m ³)					
	Date	CHP	WS	Srirampur	Ramaraopet	Indaram	Sitarampally	CHP	WS	Srirampur	Ramaraopet	Indaram
07.04.2012	159	146	79	72	87	77	71.2	68.4	55.4	38.3	58.2	40.1
22.04.2012	151	138	78	61	83	74	69.1	69.3	52.8	39.1	59.1	39.7
06.05.2012	155	136	77	69	89	70	70.3	61.7	51.6	37.9	57.9	39.7
21.05.2012	154	141	72	65	86	72	72.1	62.9	50.9	36.8	55.8	31.8
07.06.2012	152	160	75	64	89	62	51.4	60.9	33.3	30.6	50.1	28.8
22.06.2012	151	129	85	79	96	92	71.6	72.7	47.6	49.3	64.7	43.1
07.07.2012	146	111	84	69	85	71	67.2	64.3	45.5	54.6	40.8	42.6
22.07.2012	144	108	88	64	80	69	58.9	58.9	38.7	46.8	42.7	41.2
07.08.2012	150	114	86	68	94	67	59.1	59.3	44.4	46.6	52.9	38.9
22.08.2012	129	113	87	58	91	63	54.5	59.1	44.6	37.0	43.5	35.3
07.09.2012	180	125	82	55	96	57	59.6	54.5	38.5	44.4	40.3	34.3
22.09.2012	132	121	76	49	90	51	63.6	50.2	43.7	30.9	43.7	31.2

SRP OC	PM ₁₀ (µg/m ³)						PM _{2.5} (µg/m ³)					
	Date	CHP	WS	Srirampur	Ramaraopet	Indaram	Sitarampally	CHP	WS	Srirampur	Ramaraopet	Indaram
06.10.2012	152	103	70	55	84	45	60.9	55.8	38.9	40.0	44.4	33.6
22.10.2012	111	83	47	70	68	57	56.5	50.0	30.9	46.7	53.3	35.7
07.11.2012	124	105	58	76	73	70	59.1	43.5	38.9	44.2	47.4	42.1
22.11.2012	129	98	62	66	70	71	63.6	39.1	33.3	50.0	45.0	38.2
08.12.2012	142	110	82	64	87	69	58.4	53.6	41.2	39.5	41.9	38.1
24.12.2012	159	112	95	76	92	74	66.0	51.8	47.1	39.0	48.3	38.3
07.01.2013	195	121	97	85	98	81	71.4	58.7	41.2	46.8	47.8	51.8
22.01.2013	181	123	85	78	102	85	67.7	55.1	48.5	51.3	55.9	47.6
07.02.2013	173	119	92	68	93	91	64.5	51.6	51.9	45.3	49.9	53.0
21.02.2013	181	138	93	72	97	84	68.6	56.4	58.1	52.2	58.5	51.2
08.03.2013	199	129	87	80	92	89	72.4	50.6	52.8	48.8	52.7	56.0
23.03.2013	211	187	83	84	97	94	87.2	67.8	50.6	38.8	57.5	58.3
08.04.2013	244	198	89	98	111	85	83.5	64.8	52.6	52.5	65.8	49.2
22.04.2013	231	204	93	79	119	91	87.5	68.7	49.5	57.1	62.8	50.6
08.05.2013	233	196	98	91	125	79	85.7	76.3	65.8	62.8	90.2	65.7
20.05.2013	248	212	103	83	109	87	84.6	69.6	58.3	41.1	62.1	45.1
08.06.2013	227	187	79	75	97	93	73.8	60.7	46.1	34.7	58.6	38.6
22.06.2013	196	164	67	63	88	85	67.5	63.7	25.4	29.4	47.4	40.6
08.07.2013	163	147	61	57	79	74	58.3	61.2	21.8	25.2	43.4	38.5
25.07.2013	169	124	57	65	81	79	53.1	55.2	23.7	29.4	37.5	32.1
08.08.2013	172	143	83	89	98	77	63.4	57.4	39.4	42.9	46.1	35.1
23.08.2013	184	159	89	83	94	80	67.4	60.7	44.5	35.7	39.1	37.9
07.09.2013	197	187	96	76	98	89	68.9	63.7	48.6	32.4	42.8	39.5
22.09.2013	203	195	91	83	92	95	69.5	58.2	42.1	34.9	43.6	35.1
07.10.2013	178	127	75	71	89	83	61.3	50.4	31.8	29.5	40.3	37.1
22.10.2013	196	158	79	65	82	87	63.4	52.6	35.6	32.7	37.5	41.2
09.11.2013	191	169	85	73	93	91	64.1	57.1	40.3	38.4	42.5	43.6
22.11.2013	201	173	80	77	97	82	65.3	53.4	38.4	37.9	43.7	40.7
09.12.2013	208	187	87	79	95	93	64.1	54.3	41.5	39.4	38.9	42.7
23.12.2013	221	191	93	83	98	97	66.7	56.7	43.3	41.3	44.4	47.1
06.01.2014	231	195	89	87	112	95	67.1	55.1	45.7	43.8	52.6	44.5
22.01.2014	246	198	84	81	108	90	63.8	59.2	46.1	40.5	50.1	41.9
07.02.2014	238	203	97	85	115	89	62.5	61.7	39.5	42.9	55.4	45.1
22.02.2014	241	207	95	91	104	85	68.2	63.4	37.5	35.9	49.7	39.1
07.03.2014	219	183	91	70	102	79	62.3	55.6	37.8	25.7	47.5	26.9
29.03.2014	224	185	82	93	106	87	64.1	52.1	35.5	41.7	41.3	37.3
13.04.2014	227	189	94	90	110	83	63.4	55.6	37.6	36.7	53.7	30.4
28.04.2014	235	172	90	72	105	98	65.4	53.4	34.6	28.4	45.4	40.3
15.05.2014	228	179	79	89	112	80	61.2	47.5	29.4	30.2	48.5	32.7
30.05.2014	232	190	85	78	107	97	60.5	52.7	35.1	33.9	50.6	44.3
15.06.2014	222	197	92	91	104	79	63.7	53.7	41.3	42.3	52.7	36.5
30.06.2014	230	181	89	70	97	81	64.4	50.4	43.9	36.9	47.9	37.4
14.07.2014	219	175	81	79	92	85	62.8	48.5	46.7	41.9	43.3	43.8
30.07.2014	201	159	77	85	89	83	58.9	46.8	43.1	38.8	39.1	40.3
14.08.2014	204	167	86	87	86	79	62.3	57.2	40.9	36.9	40.1	38.4
30.08.2014	208	177	80	81	94	71	63.5	56.4	37.5	34.1	46.1	35.8
15.09.2014	210	181	86	88	91	78	64.5	57.4	39.4	36.8	41.5	37.2
30.09.2014	215	195	95	75	96	92	65.3	58.6	47.3	32.4	48.7	48.1
15.10.2014	217	197	90	83	90	75	62.7	60.4	50.1	47.5	53.1	45.5
31.10.2014	206	173	84	91	98	72	61.4	55.5	41.9	49.1	55.2	34.0
14.11.2014	221	187	93	94	80	80	65.2	51.8	53.7	51.6	33.5	43.1
30.11.2014	227	194	97	80	93	89	66.7	53.7	48.2	43.7	50.4	46.1
14.12.2014	234	202	88	77	97	95	66.7	61.8	48.5	36.6	54.5	47.2
22.12.2014	239	189	91	86	104	90	69.2	59.1	42.8	39.1	57.4	47.5
08.01.2015	241	193	96	82	108	93	73.2	55.0	49.5	47.2	56.2	50.5
22.01.2015	237	198	85	93	112	97	75.0	57.3	42.8	39.1	52.7	48.0
09.02.2015	257	203	89	87	116	92	76.8	61.8	44.2	53.3	58.1	53.5
27.02.2015	259	208	92	84	119	96	73.2	66.2	50.0	43.7	56.8	54.0
13.03.2015	247	205	97	73	123	85	70.6	65.6	52.9	41.4	57.1	40.0
30.03.2015	242	195	95	81	114	89	72.4	60.5	47.4	39.3	54.5	48.4
13.04.2015	238	191	90	85	118	83	72.0	57.1	45.0	36.9	56.7	40.0
28.04.2015	233	201	84	80	111	92	69.5	62.2	48.2	40.0	52.2	55.2
14.05.2015	236	187	86	73	109	79	75.4	62.6	43.1	35.7	52.8	41.5
29.05.2015	180	195	90	84	105	93	64.3	62.4	53.3	38.7	52.7	47.2
14.06.2015	209	183	82	70	91	90	62.9	58.5	50.6	36.6	48.6	52.2

SRP OC	PM ₁₀ (µg/m ³)						PM _{2.5} (µg/m ³)					
	Date	CHP	WS	Srirampur	Ramaraopet	Indaram	Sitarampally	CHP	WS	Srirampur	Ramaraopet	Indaram
28.06.2015	191	156	73	61	79	78	57.6	52.8	39.1	29.3	37.0	36.6
14.07.2015	193	161	67	64	82	76	56.2	56.2	26.7	25.0	41.7	34.3
29.07.2015	188	168	61	61	85	79	59.0	54.5	26.7	30.0	42.8	36.5
14.08.2015	165	132	72	66	77	70	54.1	50.0	30.7	29.4	35.9	32.9
30.08.2015	169	141	68	62	81	73	57.2	47.7	32.6	34.0	37.8	28.1
14.09.2015	197	159	65	69	77	81	59.5	50.1	30.3	29.6	40.3	36.7
24.09.2015	176	150	70	65	78	68	62.5	46.0	39.1	33.3	32.6	31.9
09.10.2015	155	154	78	60	66	64	61.8	50.2	44.6	32.8	31.1	34.5
23.10.2015	154	174	74	69	69	56	52.7	43.6	43.6	36.5	31.5	31.4
07.11.2015	164	183	83	57	64	64	51.2	46.7	44.6	33.9	37.5	32.9
24.11.2015	173	204	78	64	67	73	57.8	56.3	51.2	41.2	49.8	48.4
08.12.2015	183	186	82	68	68	76	61.4	59.4	48.7	38.3	43.4	46.1
23.12.2015	172	175	72	72	66	75	72.1	64.1	42.0	43.4	44.2	38.5
09.01.2016	191	184	79	79	69	85	62.4	56.7	43.6	48.7	39.2	41.5
23.01.2016	183	178	89	84	73	78	59.6	58.6	49.6	48.7	36.6	43.5
08.02.2016	193	183	79	71	81	82	62.4	63.4	45.8	44.8	39.7	46.1
23.02.2016	189	192	92	89	86	78	60.4	59.8	47.8	45.7	42.1	49.2
14.03.2016	226	209	92	82	82	89	70.5	60.4	53.1	43.4	54.6	48.6
30.03.2016	239	212	96	76	76	87	61.2	59.1	42.3	41.4	52.3	47.6
14.04.2016	228	216	79	82	98	72	73.1	67.8	41.2	39.6	56.4	43.1
28.04.2016	236	196	86	79	96	96	62.3	49.6	41.0	39.8	56.6	52.3
13.05.2016	223	194	82	86	92	79	66.4	62.3	43.2	37.4	48.6	42.7
28.05.2016	224	212	91	82	79	86	65.2	62.4	49.5	40.8	45.5	42.2
13.06.2016	216	220	89	76	92	78	63.4	66.9	51.2	48.2	51.9	46.5
29.06.2016	206	182	72	72	86	69	61.2	61.2	42.0	42.5	48.7	39.8
13.07.2016	195	130	63	82	91	77	62.1	46.1	40.5	51.2	50.5	47.6
29.07.2016	221	206	97	85	97	82	66.1	58.4	56.8	46.8	55.4	51.0
13.08.2016	217	221	92	94	96	85	61.2	64.2	53.4	52.1	48.8	48.7
29.08.2016	225	231	92	93	94	84	63.4	66.4	46.2	50.8	52.1	41.7
14.09.2016	236	204	92	92	94	89	66.7	60.7	55.7	52.1	50.2	46.8
29.09.2016	223	176	88	82	92	91	56.9	50.1	46.8	46.9	53.6	52.7
08.10.2016	231	212	86	89	96	74	64.7	62.4	57.8	52.4	58.0	48.9
24.10.2016	234	228	89	86	94	78	64.2	62.7	50.1	46.8	56.1	43.6
08.11.2016	231	204	95	79	94	82	66.4	62.8	58.7	40.9	50.2	42.1
23.11.2016	219	232	97	92	96	82	61.4	63.5	52.5	50.8	54.6	45.9
07.12.2016	234	229	87	78	98	91	63.7	62.4	46.8	42.6	52.7	51.5
24.12.2016	244	236	94	82	97	89	68.6	66.2	57.2	45.2	56.8	46.6
08.01.2017	196	207	94	91	89	83	59.7	62.4	56.9	53.4	51.0	49.7
24.01.2017	213	228	92	89	97	81	58.4	61.7	52.3	49.7	58.7	42.8
08.02.2017	211	225	93	93	97	86	56.4	59.1	52.7	57.2	58.4	47.5
23.02.2017	225	235	92	84	98	89	63.2	66.4	51.2	46.2	57.6	54.3
08.03.2017	186	213	92	86	98	72	51.2	62.3	56.3	42.8	58.4	40.6
23.03.2017	223	217	91	82	79	95	66.4	62.5	54.8	46.4	46.2	59.1
14.04.2017	241	248	94	81	97	79	72.8	67.9	58.7	47.9	59.5	46.4
28.04.2017	232	234	83	92	94	76	58.1	63.4	41.5	55.4	56.9	46.2
13.05.2017	247	253	85	87	109	95	70.5	66.1	46.4	46.1	57.4	54.9
29.05.2017	236	238	91	88	92	72	52.7	62.4	52.1	49.0	51.9	42.8
14.06.2017	238	241	83	79	95	70	56.1	63.5	50.0	48.7	50.3	41.2
28.06.2017	235	242	81	75	98	73	61.3	64.0	49.8	49.2	48.2	40.8
13.07.2017	233	244	94	71	91	79	51.6	64.3	47.6	50.4	41.5	40.1
20.07.2017	236	245	82	72	90	71	57.8	66.0	46.7	46.2	42.8	42.1
14.08.2017	233	232	89	72	94	73	70.0	67.1	45.2	40.1	41.8	43.8
28.08.2017	234	232	81	76	86	71	54.2	68.0	43.0	41.2	40.5	40.4
12.09.2017	239	241	91	76	81	84	67.5	69.4	41.9	39.7	40.3	43.4
27.09.2017	232	252	94	91	84	82	54.2	64.7	54.1	53.8	46.7	47.1
12.10.2017	241	264	92	67	94	86	72.1	86.7	48.9	39.8	48.4	41.5
26.10.2017	242	256	91	84	93	76	81.6	76.4	47.9	46.2	49.2	35.4
13.11.2017	238	241	94	76	94	68	68.4	72.1	54.5	42.6	56.4	38.2
27.11.2017	228	233	79	96	67	84	64.2	78.2	41.7	52.1	32.7	43.3
12.12.2017	237	224	92	78	96	69	62.4	56.7	51.7	41.6	51.5	39.3
27.12.2017	243	268	69	79	86	84	81.5	74.2	36.4	38.4	45.7	42.5
11.01.2018	248	183	69	77	96	89	72.1	49.1	34.2	33.1	57.2	44.2
25.01.2018	241	214	73	88	89	91	73.6	61.2	39.4	45.1	52.8	49.7
12.02.2018	234	232	74	76	81	81	68.2	63.2	41.2	39.5	39.1	47.4
26.02.2018	256	246	89	87	91	91	71.3	68.4	42.8	39.4	42.3	50.2

SRP OC	PM ₁₀ (µg/m ³)						PM _{2.5} (µg/m ³)					
	Date	CHP	WS	Srirampur	Ramaraopet	Indaram	Sitarampally	CHP	WS	Srirampur	Ramaraopet	Indaram
13.03.2018	263	264	91	86	94	79	68.3	62.4	46.8	47.9	54.3	35.5
27.03.2018	241	243	93	71	94	82	52.3	63.6	43.2	38.4	51.3	41.8
12.04.2018	232	247	93	89	82	82	55.1	62.3	52.1	51.8	41.2	47.5
26.04.2018	262	231	95	82	97	79	82.3	64.2	54.1	50.2	52.4	43.8
11.05.2018	262	267	84	93	94	89	63.7	84.1	43.8	56.9	51.2	51.2
26.05.2018	243	263	92	84	96	63	63.1	64.2	52.3	48.2	53.4	38.4
11.06.2018	214	243	87	83	92	54	42.8	53.1	43.8	42.7	47.7	31.1
27.06.2018	223	141	97	85	96	71	56.8	42.1	52.6	35.2	52.4	43.4
12.07.2018	116	238	91	51	89	63	36.7	53.2	46.6	22.4	42.1	32.7
26.07.2018	231	256	93	73	93	87	56.9	72.3	47.1	32.6	56.6	45.5
11.08.2018	106	253	91	36	91	42	32.8	81.5	50.1	18.4	52.7	22.5
27.08.2018	187	262	69	91	67	87	45.4	67.3	36.7	49.2	36.7	43.4
12.09.2018	227	256	92	76	89	87	61.2	71.2	51.2	34.6	51.4	47.3
27.09.2018	241	234	94	87	93	69	64.6	63.2	52.2	46.8	54.1	28.4
11.10.2018	263	241	63	61	96	72	69.4	68.4	35.4	34.4	57.4	45.8
27.10.2018	242	247	92	65	96	87	63.4	62.3	53.9	32.5	54.2	50.1
13.11.2018	241	268	93	74	74	63	63.3	72.1	47.8	36.5	40.1	32.1
28.11.2018	263	267	85	91	121	86	61.2	66.4	48.1	51.2	56.4	50.6
12.12.2018	235	271	93	81	91	72	57.3	72.4	55.1	45.7	56.4	43.6
27.12.2018	239	264	82	88	114	74	58.4	71.6	42.1	51.2	57.2	46.5
10.01.2019	273	268	89	74	125	61	63.6	72.4	41.5	40.8	55.1	39.7
28.01.2019	226	281	89	91	92	71	52.7	72.1	45.7	50.1	50.3	39.8
12.02.2019	261	256	76	87	94	63	63.4	71.2	33.8	41.8	56.8	40.2
26.02.2019	272	267	92	89	95	64	72.1	64.9	56.7	48.2	56.1	36.7
12.03.2019	231	248	93	92	97	74	62.1	65.4	47.2	46.8	46.1	39.4
28.03.2019	236	251	81	88	88	76	55.9	63.6	47.2	49.6	48.8	39.7
11.04.2019	271	253	89	81	121	73	68.9	63.2	45.8	42.3	54.3	40.5
25.04.2019	271	271	86	89	124	71	64.2	66.9	48.1	42.5	56.4	39.4
11.05.2019	226	241	93	74	87	87	62.6	53.6	48.9	39.6	41.6	41.2
27.05.2019	239	243	92	85	89	74	62.1	65.4	51.2	32.7	42.1	39.4
11.06.2019	219	224	92	79	93	68	55.3	56.7	53.6	39.4	51.2	41.2
27.06.2019	221	236	89	88	91	67	56.4	63.1	46.7	32.8	49.5	26.4
11.07.2019	113	231	55	51	41	43	36.4	54.4	21.3	20.6	20.2	20.1
25.07.2019	131	81	82	45	87	41	41.6	32.1	41.0	25.2	24.1	22.5
12.08.2019	216	256	71	87	54	92	52.1	62.1	36.5	46.3	24.1	51.2
27.08.2019	138	245	91	81	93	76	43.8	55.3	45.1	41.6	47.2	39.4
12.09.2019	141	268	69	41	44	48	39.4	56.2	34.6	28.9	26.7	21.2
26.09.2019	121	128	66	51	71	48	47.9	46.7	24.9	23.4	25.1	22.1
14.10.2019	221	261	91	76	56	64	52.4	62.4	48.6	28.4	21.7	26.3
27.10.2019	211	226	58	84	91	69	47.6	53.8	25.1	41.8	46.4	36.6
12.11.2019	234	268	89	82	77	74	51.2	62.4	41.6	39.4	28.6	36.5
27.11.2019	234	261	94	88	64	76	61.5	68.4	52.4	42.7	32.1	46.5
12.12.2019	239	236	73	82	91	64	52.2	66.8	41.6	46.1	47.9	32.2
26.12.2019	267	192	92	74	86	67	68.6	55.4	47.1	41.3	43.8	32.4
11.01.2020	276	263	93	83	88	64	62.4	67.1	46.8	38.4	46.7	26.5
27.01.2020	236	242	82	68	74	71	62.3	52.4	43.7	32.5	42.2	36.8
11.02.2020	273	261	89	78	90	64	68.4	66.9	51.6	39.7	52.1	31.2
26.02.2020	268	264	84	82	89	74	63.1	71.4	48.2	41.2	46.2	32.7
12.03.2020	241	241	91	68	87	74	65.4	63.6	50.5	32.1	36.8	46.9
27.03.2020	232	268	74	87	72	63	55.2	63.8	39.5	42.6	36.7	31.8
11.04.2020	211	192	68	72	65	51	54.9	49.5	33.6	43.1	28.9	30.1
25.04.2020	231	219	52	63	51	42	56.7	52.3	26.9	32.1	36.4	20.5
13.05.2020	236	261	72	73	64	68	62.5	58.2	40.8	35.4	31.0	32.9
27.05.2020	236	243	92	88	81	72	56.8	68.4	46.7	47.1	46.5	38.4
14.06.2020	57	231	87	85	76	92	32.8	55.8	48.2	46.2	42.5	46.7
25.06.2020	238	192	89	88	64	71	62.4	52.6	42.1	46.9	31.0	36.8
11.07.2020	211	232	61	63	74	55	51.2	53.4	31.4	31.7	39.4	30.8
27.07.2020	221	211	82	72	84	66	53.7	51.2	48.7	35.8	47.1	36.4
13.08.2020	43	61	51	35	41	42	21.1	22.6	32.4	20.4	25.4	21.6
27.08.2020	218	211	46	81	72	63	41.8	51.4	21.2	34.1	36.2	36.7
10.09.2020	155	196	81	85	89	65	46.7	51.1	40.4	46.1	43.1	32.1
28.09.2020	138	125	67	43	86	43	33.6	42.5	30.2	32.1	40.9	27.2
12.10.2020	264	263	93	74	89	82	63.4	62.1	51.2	40.8	42.1	49.4
27.10.2020	232	267	88	82	74	85	55.4	61.2	41.1	42.1	33.8	42.6
11.11.2020	269	239	92	73	81	82	65.3	63.8	47.6	35.4	41.6	42.1

SRP OC	PM ₁₀ (µg/m ³)						PM _{2.5} (µg/m ³)					
	Date	CHP	WS	Srirampur	Ramaraopet	Indaram	Sitarampally	CHP	WS	Srirampur	Ramaraopet	Indaram
26.11.2020	211	241	89	82	88	61	63.4	62.4	40.1	42.2	43.8	31.0
09.12.2020	243	247	94	81	93	83	64.3	63.7	56.1	46.9	52.2	49.1
29.12.2020	231	241	91	86	81	85	55.8	62.3	51.2	48.9	41.7	45.2
12.01.2021	238	236	94	82	71	88	65.4	63.7	51.6	46.7	32.5	47.6
28.01.2021	268	263	85	91	86	92	66.7	72.1	48.2	51.3	49.2	52.8
11.02.2021	278	262	88	86	91	76	68.4	61.7	49.7	42.5	48.1	36.5
25.02.2021	271	243	93	79	85	86	63.5	56.8	51.8	44.6	48.2	51.6
11.03.2021	241	266	96	87	74	92	65.3	63.4	53.7	50.6	42.8	53.8
25.03.2021	233	232	92	83	74	93	53.7	61.2	49.5	42.5	43.8	52.7
12.04.2021	232	238	89	81	84	82	62.1	63.6	41.6	47.1	49.2	42.4
27.04.2021	233	267	91	81	68	84	62.3	66.5	49.6	38.8	32.1	46.2
13.05.2021	211	264	93	66	73	76	52.3	62.7	46.8	31.2	39.8	31.6
27.05.2021	239	258	81	69	73	88	63.8	62.7	42.9	33.8	38.4	45.7
10.06.2021	211	236	86	81	63	82	56.1	62.1	46.9	42.1	30.8	41.2
26.06.2021	219	224	91	82	88	76	53.7	61.2	50.5	41.8	42.5	41.1
12.07.2021	162	73	86	69	51	56	45.1	31.6	41.6	40.2	22.6	23.7
28.07.2021	228	236	82	92	88	86	62.4	62.7	45.1	48.8	43.2	47.6
12.08.2021	211	191	88	81	76	79	48.7	57.1	40.2	41.2	39.5	36.7
26.08.2021	149	173	81	71	68	72	43.8	49.2	40.5	36.1	30.5	35.4
13.09.2021	196	242	89	77	81	88	51.8	58.9	48.2	38.1	42.5	42.1
25.09.2021	241	242	79	76	63	79	63.5	58.7	38.4	38.4	31.5	39.8
12.10.2021	215	196	68	86	77	82	52.1	54.8	33.7	46.7	32.6	41.1
27.10.2021	231	263	93	88	74	73	56.8	65.2	42.1	38.0	32.1	31.0
11.11.2021	231	261	84	82	74	89	63.4	62.8	47.1	42.0	41.3	45.1
25.11.2021	228	236	71	73	81	84	52.6	63.8	39.4	38.4	47.1	49.1
11.12.2021	224	228	89	82	90	84	63.8	56.8	40.2	36.9	41.2	43.1
28.12.2021	227	193	92	84	89	68	53.9	55.8	46.8	41.1	43.7	33.6
11.01.2022	211	236	76	86	81	88	53.7	53.7	39.5	47.3	43.2	46.8
27.01.2022	236	258	88	71	65	83	63.2	64.2	40.8	37.1	31.5	42.8
10.02.2022	238	241	84	82	84	86	57.1	53.8	48.9	41.9	46.5	42.8
25.02.2022	241	247	88	86	79	72	63.8	63.4	51.4	40.1	47.0	39.4
11.03.2022	225	239	89	91	88	75	51.2	56.8	41.6	50.2	48.2	41.8
25.03.2022	269	251	73	84	91	81	63.4	62.8	38.4	40.5	39.4	40.6

Appendix VI

Table 1. BPA OC Mine parameters

BPAOC	Production (Coal+OB)	Area contributing to pollution	Max. Quarry depth	Max. Dump height	Lead distance
Date	(t)	(Ha)	(m)	(m)	(km)
02.04.2012	-	37.2	70.0	30.0	0.0
18.04.2012	-	37.2	70.0	30.0	0.0
03.05.2012	-	37.2	70.0	30.0	0.0
19.05.2012	-	37.2	70.0	30.0	0.0
01.06.2012	-	37.2	70.0	30.0	0.0
19.06.2012	-	37.2	70.0	30.0	0.0
12.07.2012	-	37.2	70.0	30.0	0.0
29.07.2012	-	37.2	70.0	30.0	0.0
11.08.2012	-	37.2	70.0	30.0	0.0
28.08.2012	-	37.2	70.0	30.0	0.0
11.09.2012	-	37.2	70.0	30.0	0.0
26.09.2012	-	37.2	70.0	30.0	0.0
12.10.2012	-	37.2	70.0	30.0	0.0
28.10.2012	-	37.2	70.0	30.0	0.0
10.11.2012	-	37.2	70.0	30.0	0.0
27.11.2012	-	37.2	70.0	30.0	0.0
11.12.2012	-	37.2	70.0	30.0	0.0
26.12.2012	-	37.2	70.0	30.0	0.0
10.01.2013	-	37.2	70.0	30.0	0.0
25.01.2013	-	37.2	70.0	30.0	0.0
12.02.2013	-	37.2	70.0	30.0	0.0
25.02.2013	-	37.2	70.0	30.0	0.0
12.03.2013	-	37.2	70.0	30.0	0.0
27.03.2013	-	37.2	70.0	30.0	0.0
10.04.2013	-	37.2	70.0	30.0	0.0
26.04.2013	-	37.2	70.0	30.0	0.0
11.05.2013	-	37.2	70.0	30.0	0.0
27.05.2013	-	37.2	70.0	30.0	0.0
13.06.2013	-	37.2	70.0	30.0	0.0
27.06.2013	-	37.2	70.0	30.0	0.0
10.07.2013	-	37.2	70.0	30.0	0.0
28.07.2013	-	37.2	70.0	30.0	0.0
12.08.2013	-	37.2	70.0	30.0	0.0
27.08.2013	-	37.2	70.0	30.0	0.0
11.09.2013	-	37.2	70.0	30.0	0.0
25.09.2013	-	37.2	70.0	30.0	0.0
10.10.2013	-	37.2	70.0	30.0	0.0
26.10.2013	-	37.2	70.0	30.0	0.0
13.11.2013	-	37.2	70.0	30.0	0.0
27.11.2013	-	37.2	70.0	30.0	0.0
11.12.2013	-	37.2	70.0	30.0	0.0
28.12.2013	-	37.2	70.0	30.0	0.0
10.01.2014	-	37.2	70.0	30.0	0.0
29.01.2014	-	37.2	70.0	30.0	0.0
12.02.2014	-	37.2	70.0	30.0	0.0
25.02.2014	-	37.2	70.0	30.0	0.0
12.03.2014	-	37.2	70.0	30.0	0.0
26.03.2014	-	37.2	70.0	30.0	0.0
11.04.2014	-	37.2	70.0	30.0	0.0
25.04.2014	-	37.2	70.0	30.0	0.0
13.05.2014	-	37.2	70.0	30.0	0.0
28.05.2014	-	37.2	70.0	30.0	0.0
11.06.2014	-	37.2	70.0	30.0	0.0
27.06.2014	-	37.2	70.0	30.0	0.0
12.07.2014	-	37.2	70.0	30.0	0.0
28.07.2014	-	37.2	70.0	30.0	0.0
13.08.2014	-	37.2	70.0	30.0	0.0
28.08.2014	-	37.2	70.0	30.0	0.0
11.09.2014	-	37.2	70.0	30.0	0.0
28.09.2014	-	37.2	70.0	30.0	0.0

BPAOC	Production (Coal+OB)	Area contributing to pollution	Max. Quarry depth	Max. Dump height	Lead distance
Date	(t)	(Ha)	(m)	(m)	(km)
14.10.2014	-	37.2	70.0	30.0	0.0
29.10.2014	-	37.2	70.0	30.0	0.0
11.11.2014	-	37.2	70.0	30.0	0.0
26.11.2014	-	37.2	70.0	30.0	0.0
10.12.2014	-	37.2	70.0	30.0	0.0
26.12.2014	-	37.2	70.0	30.0	0.0
10.01.2015	-	37.2	70.0	30.0	0.0
26.01.2015	-	37.2	70.0	30.0	0.0
10.02.2015	-	37.2	70.0	30.0	0.0
26.02.2015	-	37.2	70.0	30.0	0.0
11.03.2015	-	37.2	70.0	30.0	0.0
26.03.2015	-	37.2	70.0	30.0	0.0
11.04.2015	-	37.2	70.0	30.0	0.0
25.04.2015	-	36.9	69.6	30.0	0.0
11.05.2015	-	36.7	69.2	30.0	0.0
25.05.2015	-	36.5	68.8	30.0	0.0
13.06.2015	-	36.3	68.4	30.0	0.0
27.06.2015	-	36.1	68.0	30.0	0.0
13.07.2015	-	35.8	67.6	30.0	0.0
27.07.2015	-	35.6	67.2	30.0	0.0
13.08.2015	-	35.4	66.8	30.0	0.0
26.08.2015	-	35.2	66.4	30.0	0.0
10.09.2015	-	35.0	66.0	30.0	0.0
26.09.2015	-	34.8	65.6	30.0	0.0
10.10.2015	-	34.5	65.2	30.0	0.0
19.10.2015	-	34.3	64.8	30.0	0.0
11.11.2015	-	34.1	64.4	30.0	0.0
25.11.2015	-	33.9	64.0	30.0	0.0
10.12.2015	-	33.7	63.6	30.0	0.0
25.12.2015	-	33.5	63.2	30.0	0.0
12.01.2016	-	33.2	62.8	30.0	0.0
27.01.2016	-	33.0	62.4	30.0	0.0
12.02.2016	-	32.8	62.0	30.0	0.0
27.02.2016	-	32.6	61.6	30.0	0.0
12.03.2016	-	32.4	61.2	30.0	0.0
25.03.2016	-	32.2	60.8	30.0	0.0
12.04.2016	-	31.7	60.0	30.0	0.0
27.04.2016	-	33.0	61.2	30.0	0.0
12.05.2016	-	34.3	62.4	30.0	0.1
25.05.2016	-	35.5	63.6	30.0	0.1
08.06.2016	986	36.8	64.8	30.0	0.2
26.06.2016	1,127	38.1	66.0	30.0	0.2
11.07.2016	8,671	39.4	67.2	30.0	0.2
25.07.2016	9,249	40.6	68.4	30.0	0.3
13.08.2016	24,120	41.9	69.6	30.0	0.3
25.08.2016	25,728	43.2	70.8	30.0	0.4
10.09.2016	14,746	44.5	72.0	30.0	0.4
30.09.2016	16,852	45.7	73.2	30.0	0.4
14.10.2016	29,129	47.0	74.4	30.0	0.5
26.10.2016	31,071	48.3	75.6	30.0	0.5
11.11.2016	38,408	49.6	76.8	30.0	0.6
26.11.2016	43,895	50.8	78.0	30.0	0.6
12.12.2016	42,982	52.1	79.2	30.0	0.6
28.12.2016	45,847	53.4	80.4	30.0	0.7
11.01.2017	54,103	54.7	81.6	30.0	0.7
27.01.2017	57,709	55.9	82.8	30.0	0.8
10.02.2017	55,652	57.2	84.0	30.0	0.8
25.02.2017	55,652	58.5	85.2	30.0	0.8
10.03.2017	58,864	59.8	86.4	30.0	0.9
29.03.2017	62,788	61.0	87.6	30.0	0.9
13.04.2017	65,675	63.6	90.0	30.0	1.0
28.04.2017	75,057	64.6	90.4	30.0	1.0
13.05.2017	65,746	65.7	90.8	30.0	1.0
27.05.2017	70,129	66.8	91.3	30.0	1.0
12.06.2017	50,888	67.9	91.7	30.0	1.0

BPAOC	Production (Coal+OB)	Area contributing to pollution	Max. Quarry depth	Max. Dump height	Lead distance
Date	(t)	(Ha)	(m)	(m)	(km)
27.06.2017	58,158	68.9	92.1	30.0	1.0
13.07.2017	49,191	70.0	92.5	30.0	1.0
28.07.2017	52,470	71.1	92.9	30.0	1.0
13.08.2017	42,875	72.1	93.3	30.0	1.0
28.08.2017	45,734	73.2	93.8	30.0	1.0
15.09.2017	37,769	74.3	94.2	30.0	1.0
29.09.2017	43,164	75.3	94.6	30.0	1.0
14.10.2017	43,412	76.4	95.0	30.0	1.0
31.10.2017	46,306	77.5	95.4	30.0	1.0
14.11.2017	71,145	78.5	95.8	30.0	1.0
28.11.2017	81,309	79.6	96.3	30.0	1.0
13.12.2017	66,603	80.7	96.7	30.0	1.0
27.12.2017	71,043	81.7	97.1	30.0	1.0
13.01.2018	59,987	82.8	97.5	30.0	1.0
27.01.2018	63,986	83.9	97.9	30.0	1.0
12.02.2018	58,974	84.9	98.3	30.0	1.0
27.02.2018	58,974	86.0	98.8	30.0	1.0
12.03.2018	51,259	87.1	99.2	30.0	1.0
27.03.2018	54,676	88.1	99.6	30.0	1.0
12.04.2018	49,344	90.3	100.0	30.0	1.0
26.04.2018	56,393	90.6	100.0	30.0	1.0
11.05.2018	45,843	90.9	100.0	30.0	1.0
26.05.2018	48,899	91.2	100.0	30.0	1.0
12.06.2018	39,150	91.5	100.0	30.0	1.0
27.06.2018	44,743	91.8	100.0	30.0	1.0
12.07.2018	26,807	92.1	100.0	30.0	1.0
26.07.2018	28,594	92.4	100.0	30.0	1.1
13.08.2018	20,911	92.7	100.0	30.0	1.1
27.08.2018	22,305	93.0	100.0	30.0	1.1
12.09.2018	31,264	93.3	100.0	30.0	1.1
27.09.2018	35,730	93.6	100.0	30.0	1.1
12.10.2018	49,094	93.9	100.0	30.0	1.1
29.10.2018	52,367	94.2	100.0	30.0	1.1
13.11.2018	45,301	94.5	100.0	30.0	1.1
27.11.2018	51,773	94.8	100.0	30.0	1.1
13.12.2018	38,301	95.1	100.0	30.0	1.1
27.12.2018	40,855	95.3	100.0	30.0	1.1
11.01.2019	35,723	95.6	100.0	30.0	1.1
28.01.2019	38,104	95.9	100.0	30.0	1.2
12.02.2019	46,528	96.2	100.0	30.0	1.2
27.02.2019	46,528	96.5	100.0	30.0	1.2
12.03.2019	48,452	96.8	100.0	30.0	1.2
28.03.2019	51,682	97.1	100.0	30.0	1.2
12.04.2019	29,830	97.7	100.0	30.0	1.2
26.04.2019	34,091	97.7	98.8	30.0	1.2
11.05.2019	30,805	97.7	97.6	30.0	1.2
27.05.2019	32,859	97.6	96.4	30.0	1.2
12.06.2019	20,682	97.6	95.2	30.0	1.2
27.06.2019	23,637	97.5	94.0	30.0	1.3
11.07.2019	10,880	97.5	92.8	30.0	1.3
26.07.2019	11,605	97.4	91.6	30.0	1.3
12.08.2019	767	97.4	90.4	30.0	1.3
28.08.2019	818	97.3	89.2	30.0	1.3
12.09.2019	201	97.3	88.0	30.0	1.3
27.09.2019	230	97.3	86.8	30.0	1.3
12.10.2019	357	97.2	85.6	30.0	1.3
28.10.2019	381	97.2	84.4	30.0	1.4
12.11.2019	349	97.1	83.2	30.0	1.4
27.11.2019	399	97.1	82.0	30.0	1.4
12.12.2019	372	97.0	80.8	30.0	1.4
27.12.2019	397	97.0	79.6	30.0	1.4
11.01.2020	296	97.0	78.4	30.0	1.4
27.01.2020	316	96.9	77.2	30.0	1.4
12.02.2020	720	96.9	76.0	30.0	1.4
27.02.2020	771	96.8	74.8	30.0	1.5

BPAOC	Production (Coal+OB)	Area contributing to pollution	Max. Quarry depth	Max. Dump height	Lead distance
Date	(t)	(Ha)	(m)	(m)	(km)
12.03.2020	4,612	96.8	73.6	30.0	1.5
26.03.2020	4,920	96.7	72.4	30.0	1.5
11.04.2020	3,197	96.7	70.0	30.0	1.5
27.04.2020	3,654	95.0	69.9	30.0	1.5
13.05.2020	2,495	93.4	69.8	30.0	1.5
27.05.2020	2,662	91.8	69.6	30.0	1.5
11.06.2020	2,634	90.2	69.5	30.0	1.5
26.06.2020	3,010	88.6	69.4	30.0	1.5
11.07.2020	1,263	87.0	69.3	30.0	1.5
28.07.2020	1,348	85.4	69.2	30.0	1.5
12.08.2020	856	83.8	69.0	30.0	1.5
27.08.2020	913	82.2	68.9	30.0	1.5
10.09.2020	1,605	80.6	68.8	30.0	1.5
26.09.2020	1,834	79.0	68.7	30.0	1.5
12.10.2020	1,891	77.4	68.6	30.0	1.5
28.10.2020	2,017	75.8	68.4	30.0	1.5
11.11.2020	2,734	74.2	68.3	30.0	1.5
25.11.2020	3,124	72.6	68.2	30.0	1.5
10.12.2020	2,611	71.0	68.1	30.0	1.5
28.12.2020	2,785	69.4	68.0	30.0	1.5
11.01.2021	2,933	67.7	67.8	30.0	1.5
27.01.2021	3,129	66.1	67.7	30.0	1.5
10.02.2021	2,404	64.5	67.6	30.0	1.5
25.02.2021	2,404	62.9	67.5	30.0	1.5
10.03.2021	1,940	61.3	67.4	30.0	1.5
25.03.2021	2,070	59.7	67.2	30.0	1.5
10.04.2021	2,658	56.5	67.0	30.0	1.5
26.04.2021	3,037	56.5	67.0	30.0	1.5
11.05.2021	2,476	56.5	67.0	30.0	1.5
26.05.2021	2,641	56.5	67.0	30.0	1.5
11.06.2021	2,298	56.5	67.0	30.0	1.5
25.06.2021	2,626	56.5	67.0	30.0	1.5
10.07.2021	1,633	56.5	67.0	30.0	1.5
27.07.2021	1,742	56.5	67.0	30.0	1.5
11.08.2021	1,012	56.5	67.0	30.0	1.5
26.08.2021	1,079	56.5	67.0	30.0	1.5
11.09.2021	805	56.5	67.0	30.0	1.5
25.09.2021	920	56.5	67.0	30.0	1.5
11.10.2021	1,169	56.5	67.0	30.0	1.5
27.10.2021	1,247	56.5	67.0	30.0	1.5
11.11.2021	1,124	56.5	67.0	30.0	1.5
26.11.2021	1,285	56.5	67.0	30.0	1.5
10.12.2021	562	56.5	67.0	30.0	1.5
30.12.2021	600	56.5	67.0	30.0	1.5
15.01.2022	1,287	56.5	67.0	30.0	1.5
31.01.2022	1,373	56.5	67.0	30.0	1.5
10.02.2022	1,446	56.5	67.0	30.0	1.5
25.02.2022	1,446	56.5	67.0	30.0	1.5
11.03.2022	1,312	56.5	67.0	30.0	1.5
26.03.2022	1,400	56.5	67.0	30.0	1.5

Table 2. BPA OC Meteorological data

BPA OC	Predominant wind direction	Avg. Temp	Avg. Humidity	Avg. Rainfall	Avg. Wind speed
Date	(degrees)	(^o c)	(%)	(mm)	(m/s)
02.04.2012	124	38.1	64.1	1.0	5.2
18.04.2012	139	39.2	57.6	0.0	4.3
03.05.2012	83	40.0	62.8	0.0	5.5
19.05.2012	39	39.8	26.5	0.0	3.5
01.06.2012	175	41.9	79.6	1.0	2.2
19.06.2012	147	42.2	65.2	1.1	3.4

BPA OC	Predominant wind direction	Avg. Temp	Avg. Humidity	Avg. Rainfall	Avg. Wind speed
Date	(degrees)	(°c)	(%)	(mm)	(m/s)
12.07.2012	123	40.5	50.9	0.7	5.5
29.07.2012	126	39.7	86.9	2.0	3.5
11.08.2012	174	38.6	83.9	0.0	3.2
28.08.2012	198	35.2	58.4	0.0	2.5
11.09.2012	97	34.7	95.3	0.0	5.0
26.09.2012	217	35.4	91.1	2.0	4.2
12.10.2012	330	34.4	90.6	1.1	2.5
28.10.2012	242	32.6	77.4	1.0	0.1
10.11.2012	224	31.7	70.1	1.0	2.6
27.11.2012	38	28.5	80.5	1.0	3.3
11.12.2012	21	28.8	76.6	0.0	5.0
26.12.2012	113	27.1	61.8	0.0	3.4
10.01.2013	250	25.6	78.0	0.0	3.8
25.01.2013	269	23.1	69.0	1.0	2.8
12.02.2013	46	23.8	74.8	0.0	4.0
25.02.2013	274	25.5	59.4	0.0	5.3
12.03.2013	97	26.5	76.9	0.0	4.9
27.03.2013	174	29.7	67.8	0.0	3.6
10.04.2013	130	31.1	67.5	0.0	6.0
26.04.2013	168	30.4	70.5	1.1	10.3
11.05.2013	193	31.1	63.1	0.0	6.9
27.05.2013	34	32.9	57.5	0.0	7.9
13.06.2013	185	24.3	79.7	0.0	5.7
27.06.2013	26	27.5	71.6	0.0	5.3
10.07.2013	288	30.0	63.7	0.0	3.5
28.07.2013	5	29.2	67.4	0.1	5.6
12.08.2013	282	28.7	70.8	0.0	5.9
27.08.2013	77	25.7	75.8	1.0	3.0
11.09.2013	248	27.7	73.7	0.0	0.4
25.09.2013	245	28.8	67.0	0.4	3.7
10.10.2013	46	27.2	74.2	0.0	2.3
26.10.2013	102	25.0	80.8	0.0	5.1
13.11.2013	167	21.4	61.3	0.0	5.3
27.11.2013	248	25.3	68.5	0.0	5.7
11.12.2013	47	20.3	52.3	0.0	6.3
28.12.2013	130	21.0	62.4	0.0	0.6
10.01.2014	131	23.7	63.7	0.0	6.9
29.01.2014	19	20.8	51.6	0.0	0.1
12.02.2014	229	24.9	55.7	0.0	1.1
25.02.2014	113	26.1	61.2	0.0	1.8
12.03.2014	15	27.4	59.6	0.0	7.0
26.03.2014	188	29.0	57.0	0.0	7.5
11.04.2014	192	31.0	42.7	0.0	0.1
25.04.2014	20	34.2	43.0	0.0	7.0
13.05.2014	206	33.9	45.2	0.0	4.3
28.05.2014	246	36.3	36.7	0.0	6.5
11.06.2014	245	33.4	55.0	0.0	1.0
27.06.2014	262	30.5	57.8	0.0	4.1
12.07.2014	138	28.1	65.3	0.0	6.2
28.07.2014	112	26.8	73.6	3.6	23.9
13.08.2014	22	30.2	60.8	0.0	0.0
28.08.2014	149	28.2	70.7	38.6	8.7
11.09.2014	250	28.9	69.4	0.0	3.4
28.09.2014	245	28.8	63.2	0.0	0.0
14.10.2014	245	27.8	69.0	0.0	23.3
29.10.2014	245	23.4	67.8	0.0	0.0

BPA OC	Predominant wind direction	Avg. Temp	Avg. Humidity	Avg. Rainfall	Avg. Wind speed
Date	(degrees)	(°c)	(%)	(mm)	(m/s)
11.11.2014	15	27.6	66.1	0.0	0.0
26.11.2014	313	23.3	57.2	0.0	0.0
10.12.2014	59	24.6	64.8	0.0	0.0
26.12.2014	320	19.8	52.6	0.0	11.5
10.01.2015	298	17.4	57.0	0.0	2.4
26.01.2015	116	24.0	57.9	0.0	0.4
10.02.2015	245	23.4	59.7	0.0	1.2
26.02.2015	74	28.3	42.2	0.0	0.0
11.03.2015	320	27.5	60.4	0.0	0.0
26.03.2015	104	30.5	50.9	0.0	4.9
11.04.2015	19	31.5	54.7	0.0	0.0
25.04.2015	86	29.9	58.7	0.0	0.0
11.05.2015	61	35.3	41.6	0.0	9.3
25.05.2015	246	37.0	30.5	0.0	4.2
13.06.2015	25	30.9	59.0	3.2	0.0
27.06.2015	198	30.6	60.7	0.0	0.0
13.07.2015	15	32.6	59.2	0.0	3.8
27.07.2015	65	29.3	66.5	0.0	0.0
13.08.2015	227	28.5	74.6	37.4	1.0
26.08.2015	179	29.3	66.2	0.0	0.0
10.09.2015	291	29.1	68.9	0.0	0.5
26.09.2015	76	29.9	70.8	0.0	0.0
10.10.2015	1	28.8	62.8	0.0	0.0
19.10.2015	120	26.9	61.8	0.0	0.0
11.11.2015	144	23.9	65.0	0.0	0.0
25.11.2015	94	25.2	63.8	0.0	0.0
10.12.2015	179	23.8	57.7	0.0	0.0
25.12.2015	135	21.0	52.2	0.0	0.0
12.01.2016	91	22.0	53.0	0.0	0.2
27.01.2016	180	25.8	64.0	0.0	1.6
12.02.2016	269	28.4	57.0	0.0	1.3
27.02.2016	94	28.9	60.2	0.0	0.0
12.03.2016	268	32.0	45.6	0.0	0.1
25.03.2016	323	30.6	48.8	0.0	1.3
12.04.2016	118	35.0	31.5	0.0	3.5
27.04.2016	211	36.4	44.9	0.0	3.0
12.05.2016	191	35.1	40.1	0.0	1.1
25.05.2016	67	37.9	30.3	0.0	1.3
08.06.2016	200	28.6	69.7	3.6	1.1
26.06.2016	185	32.2	60.5	5.8	0.0
11.07.2016	225	24.1	82.0	60.4	2.2
25.07.2016	198	28.1	74.5	26.4	0.5
13.08.2016	275	30.1	72.7	0.0	1.6
25.08.2016	191	29.4	73.5	1.2	0.8
10.09.2016	104	29.2	69.6	0.0	5.1
30.09.2016	176	28.8	73.0	11.2	4.8
14.10.2016	192	24.8	66.3	0.0	0.3
26.10.2016	162	25.2	70.2	0.0	1.2
11.11.2016	169	21.7	61.8	0.0	0.4
26.11.2016	127	21.8	62.0	0.0	1.3
12.12.2016	220	23.5	51.4	0.0	1.0
28.12.2016	189	20.7	50.0	0.0	0.7
11.01.2017	171.0	21.7	69.4	2.0	0.1
27.01.2017	201.0	26.5	57.2	2.0	0.9
10.02.2017	122.0	26.1	59.6	2.0	0.3
25.02.2017	194.7	25.8	59.4	1.0	0.0

BPA OC	Predominant wind direction	Avg. Temp	Avg. Humidity	Avg. Rainfall	Avg. Wind speed
Date	(degrees)	(°c)	(%)	(mm)	(m/s)
10.03.2017	320.0	28.9	71.9	2.0	0.4
29.03.2017	183.0	32.2	64.1	0.0	1.0
13.04.2017	284.0	29.7	70.3	0.0	0.2
28.04.2017	204.0	31.6	63.0	0.0	1.0
13.05.2017	269.0	35.0	62.3	1.0	0.5
27.05.2017	154.0	37.8	40.5	2.0	0.1
12.06.2017	178.0	30.5	74.5	1.6	0.6
27.06.2017	149.0	26.0	86.1	2.4	1.0
13.07.2017	123.0	27.0	79.5	0.0	1.4
28.07.2017	148.0	22.0	98.1	2.1	2.5
13.08.2017	122.0	26.2	89.0	2.0	1.5
28.08.2017	88.0	26.8	84.6	1.0	0.7
15.09.2017	228.6	29.9	71.2	1.0	2.9
29.09.2017	112.0	29.8	72.5	1.0	5.4
14.10.2017	140.3	28.6	66.9	0.3	0.8
31.10.2017	355.0	27.3	67.2	0.0	0.3
14.11.2017	155.0	26.3	49.5	1.0	1.7
28.11.2017	165.7	33.9	42.8	1.0	1.7
13.12.2017	228.8	30.2	80.7	0.0	3.5
27.12.2017	64.3	27.8	53.2	0.0	1.4
13.01.2018	119.5	28.8	54.9	1.0	1.1
27.01.2018	97.3	35.5	30.7	1.0	2.3
12.02.2018	128.2	28.7	55.9	1.0	4.2
27.02.2018	141.3	30.3	53.2	0.0	3.0
12.03.2018	160.5	30.8	29.9	1.0	0.2
27.03.2018	186	34.2	26.9	0.0	4.7
12.04.2018	174	32.3	29.4	0.0	3.8
26.04.2018	192	35.9	23.4	0.0	7.1
11.05.2018	166	37.3	24.1	0.0	8.8
26.05.2018	161	35.8	33.5	0.0	0.5
12.06.2018	205	29.4	64.0	0.1	8.8
27.06.2018	222	27.5	72.3	0.0	5.2
12.07.2018	225	26.1	77.3	0.1	8.0
26.07.2018	246	28.7	60.5	0.0	7.1
13.08.2018	247	28.1	70.9	0.1	7.9
27.08.2018	231	25.6	79.1	0.2	2.6
12.09.2018	149	30.4	53.1	0.0	1.3
27.09.2018	173	29.0	66.3	0.0	1.6
12.10.2018	260	27.7	58.2	0.0	2.9
29.10.2018	103	24.5	48.6	0.0	3.0
13.11.2018	196	22.9	47.2	0.0	1.1
27.11.2018	119	21.5	49.8	0.0	1.7
13.12.2018	72	22.4	89.1	2.2	0.6
27.12.2018	306	21.9	63.5	0.0	2.0
11.01.2019	140	19.6	63.4	0.0	2.1
28.01.2019	238	19.7	69.5	0.0	2.9
12.02.2019	156	24.3	63.3	0.0	3.0
27.02.2019	240	27.2	39.6	0.0	3.0
12.03.2019	120	31.9	37.0	0.0	6.9
28.03.2019	147	33.3	32.9	0.0	2.2
12.04.2019	154	33.5	29.8	0.2	9.2
26.04.2019	161	37.8	24.5	0.0	3.7
11.05.2019	203	37.5	21.8	0.0	5.6
27.05.2019	225	40.0	16.3	0.0	3.7
12.06.2019	187	38.4	27.1	0.0	9.0
27.06.2019	216	33.8	46.3	0.0	2.1

BPA OC	Predominant wind direction	Avg. Temp	Avg. Humidity	Avg. Rainfall	Avg. Wind speed
Date	(degrees)	(°c)	(%)	(mm)	(m/s)
11.07.2019	240	28.2	70.9	0.0	4.5
26.07.2019	232	25.7	83.8	0.4	6.0
12.08.2019	197	28.8	68.4	0.0	2.6
28.08.2019	162	29.2	68.3	0.0	1.5
12.09.2019	213	25.4	83.9	0.7	4.7
27.09.2019	168	26.7	76.0	1.4	6.8
12.10.2019	165	28.5	71.0	0.0	0.1
28.10.2019	118	28.2	73.9	0.0	0.0
12.11.2019	103	25.3	65.2	0.0	1.3
27.11.2019	115	23.9	67.7	0.0	0.8
12.12.2019	116	22.4	65.7	0.0	1.2
27.12.2019	230	21.2	70.5	0.0	0.5
11.01.2020	132	19.6	56.3	0.0	1.0
27.01.2020	142	24.3	44.5	0.0	1.5
12.02.2020	219	24.2	55.7	0.0	1.4
27.02.2020	133	24.5	29.3	0.0	1.5
12.03.2020	159	28.5	52.7	0.0	6.7
26.03.2020	145	31.2	37.6	0.0	2.9
11.04.2020	191	33.4	30.7	0.0	3.9
27.04.2020	227	32.6	38.6	0.0	7.2
13.05.2020	206	35.7	29.5	0.0	2.5
27.05.2020	217	38.2	31.0	0.0	4.4
11.06.2020	224	29.8	63.9	0.4	7.8
26.06.2020	217	32.1	50.8	0.0	1.7
11.07.2020	248	29.6	65.8	0.0	1.0
28.07.2020	194	29.5	67.7	2.7	0.8
12.08.2020	224	28.1	67.3	0.1	0.2
27.08.2020	227	26.7	78.0	0.1	0.5
10.09.2020	234	28.5	73.1	0.0	1.0
26.09.2020	239	27.7	78.4	0.0	1.0
12.10.2020	212	27.1	79.3	0.6	0.5
28.10.2020	187	26.6	58.9	0.0	1.0
11.11.2020	135	22.6	52.8	0.0	1.2
25.11.2020	196	22.3	54.8	0.6	0.6
10.12.2020	265	22.5	53.2	0.0	0.5
28.12.2020	245	21.6	53.1	0.0	2.0
11.01.2021	204	24.5	52.4	0.0	0.9
27.01.2021	159	24.6	55.7	0.0	2.5
10.02.2021	171	22.6	28.2	0.0	1.3
25.02.2021	218	27.6	29.8	0.0	1.3
10.03.2021	161	30.3	34.5	0.0	6.0
25.03.2021	164	31.3	24.6	0.0	1.4
10.04.2021	115	32.6	34.2	0.0	9.0
26.04.2021	170	35.2	25.4	0.0	6.3
11.05.2021	149	31.0	49.9	1.2	9.6
26.05.2021	154	35.9	17.9	0.0	9.3
11.06.2021	132	27.5	66.9	0.7	5.9
25.06.2021	132	30.1	53.8	0.0	5.3
10.07.2021	145	30.0	68.8	0.3	2.7
27.07.2021	110	30.5	51.9	0.0	7.5
11.08.2021	150	30.6	56.1	0.0	4.7
26.08.2021	146	28.4	69.3	0.0	3.1
11.09.2021	167	27.4	79.5	0.7	0.2
25.09.2021	235	28.0	75.7	0.4	0.5
11.10.2021	219	28.4	59.8	0.0	1.0
27.10.2021	269	25.5	56.8	0.0	1.1

BPA OC	Predominant wind direction	Avg. Temp	Avg. Humidity	Avg. Rainfall	Avg. Wind speed
Date	(degrees)	(^o c)	(%)	(mm)	(m/s)
11.11.2021	252	24.1	46.7	0.0	1.1
26.11.2021	193	24.8	62.2	0.0	0.5
10.12.2021	152	23.4	64.0	0.0	0.2
30.12.2021	297	21.1	72.1	0.0	1.0
15.01.2022	303	21.0	78.3	0.0	1.7
31.01.2022	234	21.7	41.3	0.0	1.4
10.02.2022	133	25.7	51.5	0.0	2.5
25.02.2022	167	28.2	35.9	0.0	4.3
11.03.2022	195	29.0	32.9	0.0	2.7
26.03.2022	159	32.9	40.0	0.0	6.5

Table 3. PM₁₀ and PM_{2.5} in core and buffer zones of BPA OC

BPA OC	PM ₁₀ (µg/m ³)						PM _{2.5} (µg/m ³)					
	Date	CHP	WS	Khairagura	Sonapur	Bijal	Gampalapall y	CHP	WS	Khairagura	Sonapur	Bijal
02.04.2012	154	151	91	97	79	92	68.7	61.3	47.3	45.8	31.2	41.6
18.04.2012	151	138	86	78	75	74	63.1	58.3	42.6	43.8	35.6	48.3
03.05.2012	182	163	94	92	88	98	73.2	65.7	53.4	61.7	43.2	56.7
19.05.2012	178	172	96	96	85	92	72.5	71.3	56.4	62.6	42.7	51.6
01.06.2012	235	142	79	80	89	98	68.0	45.0	55.0	25.0	37.5	37.5
19.06.2012	212	121	84	81	67	71	55.0	55.0	60.0	35.7	28.6	28.6
12.07.2012	170	107	80	62	53	59	52.7	55.6	50.6	25.4	27.1	31.2
29.07.2012	139	92	72	62	78	64	43.2	48.0	40.9	21.9	28.1	29.3
11.08.2012	100	105	92	76	79	77	58.8	51.8	42.2	23.7	29.1	29.1
28.08.2012	107	109	83	78	64	83	58.1	53.4	47.5	48.1	32.2	41.7
11.09.2012	138	112	81	99	79	98	60.1	56.7	56.2	42.3	24.0	39.0
26.09.2012	146	109	73	95	74	94	67.7	42.2	72.2	40.9	35.3	51.2
12.10.2012	138	111	79	91	79	95	62.7	51.2	54.1	49.4	44.4	51.8
28.10.2012	126	108	76	86	63	80	45.8	41.9	60.5	34.9	29.6	34.9
10.11.2012	128	103	76	79	73	82	46.1	38.7	52.0	28.9	32.6	27.9
27.11.2012	121	99	84	74	75	89	42.2	39.3	55.8	34.9	29.3	36.6
11.12.2012	130	96	85	75	63	84	67.2	42.5	61.8	34.9	21.9	42.8
26.12.2012	121	109	82	87	67	80	57.6	47.2	57.3	34.9	29.3	35.7
10.01.2013	133	115	97	96	79	87	62.4	42.5	48.5	41.9	36.6	42.8
25.01.2013	144	122	84	81	86	92	62.7	49.6	57.3	41.9	36.6	42.8
12.02.2013	114	122	81	79	68	78	51.2	59.2	61.8	38.2	36.3	37.2
25.02.2013	168	153	78	77	79	91	68.4	58.7	67.3	52.4	40.1	42.4
12.03.2013	162	142	83	72	82	93	67.7	57.2	69.8	61.4	44.3	49.4
27.03.2013	167	151	79	80	90	94	73.6	76.2	83.3	66.7	51.6	51.6
10.04.2013	198	147	81	73	94	98	74.3	63.6	93.2	62.4	55.2	54.7
26.04.2013	173	124	80	76	88	79	61.3	57.4	70.2	56.1	48.4	48.6
11.05.2013	173	124	77	70	95	96	69.7	61.5	75.3	58.7	53.4	57.2
27.05.2013	181	133	71	68	92	84	74.3	64.5	84.5	62.4	52.4	60.8
13.06.2013	124	118	64	62	76	66	49.4	44.6	38.2	35.7	39.2	36.4
27.06.2013	129	112	68	65	74	73	45.6	42.4	37.4	35.2	35.7	38.7
10.07.2013	127	116	64	67	73	71	46.7	40.6	31.7	34.6	36.7	37.2
28.07.2013	115	101	60	56	51	64	42.1	39.6	33.1	31.2	27.3	36.1
12.08.2013	112	107	61	58	62	66	40.5	37.6	32.4	29.7	30.5	33.6
27.08.2013	121	116	60	64	61	70	41.6	40.5	30.8	31.7	31.4	36.8
11.09.2013	117	118	67	70	63	69	41.6	42.3	36.4	38.1	31.8	36.7
25.09.2013	143	123	72	81	69	83	54.3	44.3	32.8	38.7	32.7	39.4
10.10.2013	124	103	58	68	54	66	43.5	40.6	28.7	32.4	25.8	30.7
26.10.2013	119	112	63	69	56	64	44.2	41.3	31.4	34.8	27.6	30.9
13.11.2013	126	109	62	71	64	72	44.2	41.8	32.6	38.7	35.7	38.4
27.11.2013	122	124	71	73	70	76	48.7	49.8	40.6	42.6	39.2	41.6
11.12.2013	128	122	74	81	70	83	49.8	46.3	41.6	42.6	42.2	46.8
28.12.2013	142	136	81	92	81	96	53.2	52.3	47.3	51.3	46.6	52.3
10.01.2014	135	131	84	94	83	97	53.2	52.3	46.3	50.4	44.6	53.6
29.01.2014	153	132	92	98	86	97	59.2	54.3	51.3	52.3	47.5	52.1
12.02.2014	148	143	90	96	84	94	61.2	55.3	50.6	52.6	47.1	54.2
25.02.2014	155	138	95	97	88	96	62.3	56.7	51.3	52.3	47.5	52.1

BPA OC	PM ₁₀ (µg/m ³)						PM _{2.5} (µg/m ³)					
	Date	CHP	WS	Khairagura	Sonapur	Bijal	Gampalalpal	CHP	WS	Khairagura	Sonapur	Bijal
12.03.2014	122	124	81	83	72	78	48.3	45.6	40.6	43.7	32.2	37.5
26.03.2014	162	146	93	98	87	88	70.3	60.8	50.4	49.7	43.8	46.3
11.04.2014	154	151	91	97	79	92	68.7	61.3	47.3	45.8	31.2	41.6
25.04.2014	151	138	86	78	75	74	63.1	58.3	42.6	43.8	35.6	48.3
13.05.2014	182	163	94	82	88	98	73.2	65.7	53.4	61.7	43.2	56.7
28.05.2014	178	172	96	86	85	92	72.5	71.3	56.4	62.6	42.7	51.6
11.06.2014	173	146	89	98	84	93	72.3	67.3	46.7	58.7	42.2	52.3
27.06.2014	156	136	81	92	71	86	64.5	58.6	42.1	54.3	41.8	46.7
12.07.2014	148	122	82	87	71	76	61.4	52.3	41.6	44.8	38.9	41.5
28.07.2014	132	113	74	82	65	79	61.2	52.4	41.2	46.7	36.9	45.8
13.08.2014	157	138	87	94	76	84	62.3	61.2	49.8	51.7	37.6	48.9
28.08.2014	122	111	78	87	75	91	58.9	51.2	39.8	45.3	38.2	46.7
11.09.2014	140	123	77	84	68	75	55.4	54.5	44.3	46.0	33.5	43.5
28.09.2014	151	133	88	97	82	92	60.4	59.4	48.3	56.2	42.6	55.2
14.10.2014	145	127	84	93	79	88	58.6	57.6	46.9	54.5	41.3	53.5
29.10.2014	133	117	78	86	72	81	54.5	53.6	43.6	50.7	38.4	49.8
11.11.2014	166	124	83	91	70	82	67.6	60.8	51.6	54.8	40.7	53.2
26.11.2014	174	130	87	90	73	88	71.0	63.8	54.2	57.5	42.7	55.9
10.12.2014	156	117	78	86	66	77	64.2	57.8	49.0	52.1	38.7	50.5
26.12.2014	134	128	78	85	73	87	52.8	49.1	44.1	45.2	44.7	49.6
10.01.2015	153	132	92	98	86	97	59.2	54.3	48.9	50.4	46.3	44.1
26.01.2015	162	133	91	89	82	83	64.2	55.6	53.6	50.2	45.6	51.2
10.02.2015	148	128	89	95	83	94	56.8	56.4	51.9	52.4	46.1	55.7
26.02.2015	157	129	88	92	81	81	62.3	53.9	52.0	53.4	45.6	49.7
11.03.2015	152	131	91	97	85	96	60.1	59.7	54.9	55.4	48.7	58.9
26.03.2015	167	142	93	92	81	88	71.2	62.8	53.4	54.9	50.8	50.7
11.04.2015	146	126	88	93	82	93	55.0	60.9	56.5	53.9	50.0	52.7
25.04.2015	154	151	91	97	79	92	68.9	61.5	54.9	57.7	31.5	53.9
11.05.2015	152	131	91	97	85	96	60.4	60.0	55.0	55.9	53.5	59.3
25.05.2015	164	141	91	87	85	92	72.7	71.6	56.6	57.2	42.6	51.4
13.06.2015	148	127	87	91	83	94	59.1	58.5	53.6	54.5	51.4	58.0
27.06.2015	128	107	71	73	67	80	57.7	52.1	47.0	44.8	37.7	50.2
13.07.2015	141	122	83	87	79	89	56.3	56.1	51.2	52.2	49.5	55.0
27.07.2015	126	105	70	72	66	79	56.7	51.3	46.3	44.4	37.0	49.4
13.08.2015	123	106	72	76	69	78	48.9	48.6	44.8	45.3	38.7	48.4
26.08.2015	135	104	68	78	66	88	59.3	53.2	47.8	46.1	38.6	51.6
10.09.2015	153	132	92	98	86	97	59.0	54.2	51.5	52.6	47.6	52.1
26.09.2015	160	140	81	84	80	86	61.2	65.9	60.6	55.3	46.1	50.0
10.10.2015	181	192	78	81	82	84	81.3	75.4	66.4	58.4	41.7	49.1
19.10.2015	160	145	81	90	86	92	75.2	72.1	60.4	61.2	48.9	56.8
11.11.2015	157	128	85	95	88	94	67.4	60.5	50.7	69.3	50.7	62.1
25.11.2015	166	166	91	96	89	97	69.1	69.1	50.7	66.4	42.1	57.3
10.12.2015	161	134	94	93	83	91	71.2	69.6	54.2	64.1	45.1	51.1
25.12.2015	165	133	79	93	73	82	74.2	67.1	51.4	54.7	47.5	52.8
12.01.2016	162	137	81	87	81	85	71.2	68.3	54.2	58.6	53.6	56.1
27.01.2016	155	128	74	84	70	70	73.3	63.7	48.1	54.7	47.5	45.0
12.02.2016	158	130	72	83	69	70	73.2	63.8	48.1	51.8	45.5	46.8
27.02.2016	164	140	78	88	74	76	73.6	69.1	53.3	59.1	51.5	52.1
12.03.2016	166	132	66	73	69	72	71.6	65.9	44.8	46.0	45.3	45.6
25.03.2016	160	128	64	81	64	75	73.2	65.0	46.4	55.7	47.1	52.7
12.04.2016	161	128	67	74	66	72	72.2	64.5	45.7	47.8	46.3	50.1
27.04.2016	162	127	63	75	66	70	71.5	63.1	42.3	52.3	42.9	49.8
12.05.2016	161	128	67	74	66	72	72.2	64.5	45.7	47.8	46.3	50.1
25.05.2016	162	130	67	74	66	73	72.8	65.1	45.9	47.8	47.1	51.3
08.06.2016	145	116	53	50	59	62	66.8	63.3	44.7	37.7	44.2	42.2
26.06.2016	135	103	54	47	50	53	58.5	60.0	42.8	45.6	43.6	42.8
11.07.2016	103	85	54	65	46	58	47.4	46.3	37.7	30.6	30.9	42.2
25.07.2016	83	72	60	55	51	60	50.3	53.3	44.7	47.2	47.4	43.5
13.08.2016	111	70	57	52	50	58	54.2	40.9	39.6	40.6	44.8	47.1
25.08.2016	103	88	66	61	67	50	59.5	57.8	40.6	47.5	40.8	39.1
10.09.2016	135	111	62	62	59	68	57.1	58.8	48.6	49.3	47.9	48.7
30.09.2016	115	77	61	55	60	62	56.6	55.3	42.3	45.5	42.7	40.8
14.10.2016	136	108	59	62	57	68	57.1	57.9	47.5	48.3	43.1	47.2
26.10.2016	121	96	64	53	56	66	61.2	58.3	48.7	48.9	52.6	53.1
11.11.2016	142	97	56	66	68	55	75.5	67.6	40.3	53.1	59.5	51.5

BPA OC	PM ₁₀ (µg/m ³)						PM _{2.5} (µg/m ³)					
	Date	CHP	WS	Khairagura	Sonapur	Bijal	Gampalappally	CHP	WS	Khairagura	Sonapur	Bijal
26.11.2016	125	98	52	50	88	61	60.9	64.8	42.7	37.7	52.2	44.5
12.12.2016	162	109	54	52	91	64	61.3	66.3	44.6	39.2	55.9	46.2
28.12.2016	159	118	74	79	89	70	65.2	68.2	48.2	54.3	53.2	52.6
11.01.2017	198	124	76	81	91	69	72.4	66.7	51.1	46.2	54.6	50.2
27.01.2017	204	130	75	88	91	73	84.0	73.9	48.0	48.4	56.2	51.3
10.02.2017	214	130	78	85	94	75	62.4	70.2	42.4	44.6	54.3	52.1
25.02.2017	224	181	82	88	91	78	79.8	73.4	44.9	46.3	52.6	54.4
10.03.2017	218	173	74	81	91	65	77.5	73.9	48.0	46.5	54.1	42.1
29.03.2017	214	184	71	72	93	65	79.1	71.1	44.8	46.7	52.5	49.0
13.04.2017	216	185	77	76	95	70	81.2	74.2	46.8	48.4	54.4	50.4
28.04.2017	214	166	78	78	91	71	77.3	73.9	49.2	55.5	53.2	50.0
13.05.2017	222	176	81	82	93	81	85.1	71.8	50.4	52.0	54.5	48.0
27.05.2017	202	168	78	75	87	72	71.6	71.4	48.8	50.2	49.4	46.0
12.06.2017	195	165	77	77	86	70	70.9	70.9	48.7	49.8	50.1	45.8
27.06.2017	193	168	79	73	88	69	69.7	68.0	48.8	48.9	49.3	44.9
13.07.2017	189	170	76	69	85	67	67.8	64.5	48.1	47.5	47.6	43.7
28.07.2017	185	168	76	64	80	65	65.4	62.1	47.9	45.1	41.2	41.0
13.08.2017	186	169	74	60	76	61	62.8	60.7	47.1	40.8	40.9	38.1
28.08.2017	185	165	75	58	72	56	58.7	58.5	47.3	38.9	39.1	36.7
15.09.2017	183	169	73	52	70	54	52.7	55.6	47.1	34.5	37.1	35.5
29.09.2017	173	184	74	55	68	47	65.2	62.2	46.9	40.9	36.6	31.3
14.10.2017	196	198	75	61	65	55	73.9	80.0	46.7	40.9	35.5	35.8
31.10.2017	196	216	73	79	63	59	75.0	104.5	46.6	50.8	31.6	46.9
14.11.2017	164	173	72	79	62	59	117.4	106.6	46.5	45.4	39.9	44.8
28.11.2017	164	207	71	73	64	58	92.9	101.5	37.8	48.5	48.0	48.9
13.12.2017	190	193	84	77	64	85	96.3	99.2	41.4	46.5	50.4	55.5
27.12.2017	201	192	76	78	65	83	113.0	104.3	40.7	54.5	48.8	49.2
13.01.2018	187	187	84	65	64	69	79.4	83.2	38.3	47.5	47.6	45.4
27.01.2018	181	164	80	62	61	69	72.3	76.1	34.0	43.2	45.5	43.4
12.02.2018	183	162	72	65	60	59	77.1	69.1	46.8	43.2	42.1	40.3
27.02.2018	175	156	65	59	59	52	72.3	67.1	42.5	38.8	40.9	40.3
12.03.2018	173	155	65	64	59	52	68.1	68.6	38.3	43.2	45.4	35.3
27.03.2018	182	161	61	63	58	59	71.8	67.6	46.8	38.8	45.4	50.4
12.04.2018	181	162	62	59	60	53	72.3	68.1	42.5	34.5	40.9	45.4
26.04.2018	171	165	59	65	56	61	71.8	67.6	38.3	38.8	36.4	40.3
11.05.2018	173	166	60	64	61	58	73.4	69.6	38.3	43.2	40.9	35.3
26.05.2018	170	164	54	60	57	60	70.6	68.6	34.0	38.8	36.4	40.3
12.06.2018	168	161	52	57	54	60	73.3	69.1	34.0	34.5	36.4	45.4
27.06.2018	169	159	50	58	57	62	73.4	69.1	34.0	38.8	40.9	45.4
12.07.2018	166	156	49	56	55	59	69.8	66.7	33.0	39.6	36.4	40.0
26.07.2018	171	161	53	59	59	61	72.6	66.7	35.6	40.8	42.0	46.1
13.08.2018	167	157	51	57	56	59	74.4	67.2	35.6	40.0	34.9	41.2
27.08.2018	167	159	55	60	58	62	75.0	66.1	34.9	41.6	40.4	47.0
12.09.2018	170	163	59	64	63	65	70.0	68.8	39.2	44.9	45.3	48.0
27.09.2018	176	163	61	61	65	63	84.3	75.0	44.4	43.2	46.1	41.2
12.10.2018	180	167	67	68	69	60	80.7	69.4	43.6	44.9	50.5	38.9
29.10.2018	175	165	59	64	67	64	76.9	70.0	39.2	43.6	48.6	46.6
13.11.2018	181	168	58	70	66	68	79.3	74.4	34.9	49.5	49.1	45.3
27.11.2018	179	164	63	66	69	70	80.7	70.0	44.4	44.9	49.5	52.9
13.12.2018	181	169	61	69	70	67	81.8	66.1	43.6	48.6	51.9	46.6
27.12.2018	178	159	58	71	68	65	72.4	60.5	33.3	43.6	41.6	34.3
11.01.2019	185	166	62	68	71	69	82.0	67.2	33.0	45.3	46.6	43.6
28.01.2019	180	162	57	62	73	66	78.2	60.0	38.9	43.6	50.0	44.0
12.02.2019	177	170	61	65	71	70	71.2	67.2	39.2	45.7	50.9	46.6
27.02.2019	180	167	65	68	73	69	78.2	66.1	45.7	51.9	50.5	51.4
12.03.2019	183	169	64	64	70	68	81.3	65.5	46.6	44.4	51.4	50.9
28.03.2019	178	171	60	70	72	65	79.3	76.9	40.0	50.9	52.4	45.7
12.04.2019	183	161	59	65	69	70	85.0	62.6	35.3	43.6	51.9	52.4
26.04.2019	191	164	61	68	70	67	91.5	61.0	40.8	49.5	50.0	45.7
11.05.2019	187	168	58	70	72	68	84.3	65.0	34.0	50.5	53.5	44.9
27.05.2019	180	162	62	70	69	69	76.3	65.0	39.6	47.5	51.4	46.6
12.06.2019	184	159	60	67	70	64	85.0	61.0	40.0	45.3	50.0	44.4
27.06.2019	188	156	57	64	67	68	84.2	56.4	35.3	40.8	49.5	50.9
11.07.2019	184	152	60	61	66	65	80.7	61.0	40.0	45.3	47.0	44.4
26.07.2019	190	160	59	66	71	70	89.5	60.0	39.6	44.4	51.4	51.9

BPA OC	PM ₁₀ (µg/m ³)						PM _{2.5} (µg/m ³)					
	Date	CHP	WS	Khairagura	Sonapur	Bijal	Gampalapally	CHP	WS	Khairagura	Sonapur	Bijal
12.08.2019	179	154	56	60	65	63	76.3	55.9	34.6	40.8	47.5	44.9
28.08.2019	176	152	50	58	63	65	78.9	52.2	34.9	39.6	46.1	45.3
12.09.2019	169	149	54	55	60	62	72.4	50.4	34.6	34.9	39.6	44.0
27.09.2019	172	151	51	59	61	60	69.0	56.9	32.7	39.2	45.7	40.8
12.10.2019	175	153	56	54	59	61	74.3	57.9	35.3	34.3	35.3	40.8
28.10.2019	171	155	54	57	60	62	71.2	58.4	34.0	35.3	40.8	41.6
12.11.2019	176	153	57	59	64	60	75.6	56.9	38.2	40.0	41.6	39.6
27.11.2019	181	154	54	56	60	59	68.7	56.9	32.7	34.3	40.8	38.9
12.12.2019	186	157	58	60	67	63	85.0	56.4	38.9	39.6	46.1	44.9
27.12.2019	183	154	55	62	65	64	83.5	55.0	34.0	43.6	44.4	41.2
11.01.2020	187	157	57	63	63	62	85.0	62.6	34.3	39.2	40.0	43.6
27.01.2020	184	155	53	59	61	63	83.5	58.4	33.3	34.9	44.4	41.2
12.02.2020	187	158	55	54	63	60	85.0	55.9	34.6	29.4	40.4	40.8
27.02.2020	183	161	57	58	66	65	83.5	56.9	38.2	39.2	44.0	44.4
12.03.2020	190	164	53	56	67	64	87.2	63.1	33.3	32.7	46.1	43.6
26.03.2020	182	159	49	57	63	61	78.2	55.5	28.8	33.3	44.0	40.4
11.04.2020	135	136	41	51	56	54	45.8	40.0	22.2	32.7	34.3	33.0
27.04.2020	140	134	39	49	53	50	42.5	41.0	22.2	28.0	33.3	34.0
13.05.2020	150	138	42	43	50	49	50.8	40.0	22.6	27.5	28.6	33.0
27.05.2020	180	151	47	55	61	58	76.3	51.3	27.3	33.0	41.6	34.9
11.06.2020	176	153	46	52	57	56	75.0	50.0	27.5	32.7	38.9	32.7
26.06.2020	179	157	44	50	60	57	77.6	51.3	27.3	29.4	40.4	34.9
11.07.2020	175	155	42	48	57	54	75.0	52.2	22.6	28.3	35.3	33.6
28.07.2020	176	152	40	45	53	49	77.6	51.3	21.8	27.3	34.0	29.7
12.08.2020	182	160	45	50	58	53	83.5	57.4	23.5	32.7	38.2	34.3
27.08.2020	175	154	40	46	52	47	75.0	55.9	21.6	27.3	33.6	29.4
10.09.2020	181	163	44	51	59	55	79.3	62.1	23.1	29.4	40.0	34.6
26.09.2020	178	159	41	48	53	51	77.6	56.4	21.8	28.8	33.3	32.7
12.10.2020	175	156	36	45	49	48	73.7	55.5	17.0	23.1	28.8	27.3
28.10.2020	171	151	33	41	47	46	69.0	51.3	16.5	22.2	27.8	23.3
11.11.2020	176	158	38	44	50	49	71.8	57.4	17.0	22.9	29.1	27.5
25.11.2020	172	153	36	40	48	47	69.4	56.4	16.8	21.8	28.6	26.8
10.12.2020	177	157	40	45	52	51	73.0	58.4	22.2	23.3	34.6	32.7
28.12.2020	171	152	37	42	49	46	72.4	52.6	17.3	22.2	28.0	27.3
11.01.2021	175	156	39	46	50	49	73.7	56.4	17.5	26.8	28.8	28.0
27.01.2021	167	150	34	41	47	44	65.0	52.6	16.8	22.4	26.5	23.1
10.02.2021	170	154	37	43	49	47	66.7	55.0	16.4	21.8	28.6	28.3
25.02.2021	173	159	40	45	52	48	71.2	59.0	17.6	22.9	31.6	28.6
10.03.2021	178	163	43	49	53	52	73.7	61.5	22.4	23.5	32.1	31.3
25.03.2021	181	168	46	52	57	56	77.6	66.1	23.1	28.8	32.7	29.4
10.04.2021	185	171	50	56	60	59	75.6	69.4	23.3	28.0	33.6	33.3
26.04.2021	189	175	53	59	63	62	76.9	68.3	23.5	28.8	32.7	33.6
11.05.2021	184	172	57	63	68	65	75.0	69.4	23.8	32.1	33.3	32.7
26.05.2021	170	163	48	53	54	52	66.7	60.5	22.0	28.3	30.5	28.6
11.06.2021	177	170	52	57	62	60	73.0	66.7	23.5	29.1	34.6	32.4
25.06.2021	181	174	56	60	65	63	78.2	70.0	26.8	32.7	35.3	34.6
10.07.2021	175	169	50	54	58	55	71.8	66.1	22.6	27.5	29.1	28.8
27.07.2021	179	172	53	58	62	61	75.0	70.6	23.1	28.6	29.7	32.1
11.08.2021	170	167	49	53	56	54	71.8	65.0	22.4	23.5	27.0	27.5
26.08.2021	173	170	51	56	59	58	70.6	66.1	22.2	23.3	28.8	28.6
11.09.2021	165	162	45	46	50	48	67.2	60.0	21.8	22.6	27.3	27.8
25.09.2021	168	167	49	50	52	52	65.0	61.5	22.6	23.5	28.3	28.0
11.10.2021	164	170	47	52	54	55	65.5	63.7	23.1	26.8	28.8	28.3
27.10.2021	162	174	50	55	51	51	62.1	66.1	23.3	27.3	28.0	23.8
11.11.2021	165	176	53	57	54	59	62.6	65.5	23.5	28.6	27.5	27.8
26.11.2021	172	180	56	61	57	63	65.0	70.0	27.0	29.4	28.8	32.1
10.12.2021	169	172	52	56	54	59	63.1	67.2	23.8	27.8	27.0	30.0
30.12.2021	158	167	46	51	50	52	59.5	60.0	22.0	26.3	26.1	26.8
15.01.2022	164	170	57	58	54	56	65.0	65.5	23.5	27.8	28.0	28.3
31.01.2022	169	173	54	60	57	59	66.1	70.6	23.3	29.1	28.3	28.8
10.02.2022	166	168	51	57	55	56	62.1	65.0	23.1	28.3	27.8	27.5
25.02.2022	168	171	55	59	52	58	67.8	70.0	23.8	28.8	27.3	28.0
11.03.2022	172	174	50	61	56	55	69.4	71.2	26.3	32.7	28.3	27.0
26.03.2022	175	178	54	62	59	59	73.0	69.4	23.1	29.7	27.5	28.0

Appendix VII

Table 1. KHG OC Mine parameters

KHG OC	Production (Coal+OB)	Area contributing to pollution	Max. Quarry depth	Max. Dump height	Lead distance
Date	(t)	(Ha)	(m)	(m)	(km)
02.04.2012	102,934	300.8	55.0	55.0	5.5
18.04.2012	117,639	300.9	55.1	55.0	5.5
03.05.2012	88,474	300.9	55.2	55.0	5.6
19.05.2012	94,372	301.0	55.4	55.0	5.7
01.06.2012	52,496	301.1	55.5	55.0	5.7
19.06.2012	59,996	301.2	55.6	55.0	5.8
12.07.2012	17,112	301.3	55.7	55.0	5.8
29.07.2012	18,252	301.3	55.8	55.0	5.9
11.08.2012	19,567	301.4	56.0	55.0	6.0
28.08.2012	20,872	301.5	56.1	55.0	6.0
11.09.2012	23,589	301.6	56.2	55.0	6.1
26.09.2012	26,959	301.7	56.3	55.0	6.1
12.10.2012	51,049	301.7	56.4	55.0	6.2
28.10.2012	54,452	301.8	56.6	55.0	6.3
10.11.2012	59,051	301.9	56.7	55.0	6.3
27.11.2012	67,486	302.0	56.8	55.0	6.4
11.12.2012	85,764	302.1	56.9	55.0	6.4
26.12.2012	91,481	302.1	57.0	55.0	6.5
10.01.2013	84,131	302.2	57.2	55.0	6.6
25.01.2013	89,740	302.3	57.3	55.0	6.6
12.02.2013	80,864	302.4	57.4	55.0	6.7
25.02.2013	80,864	302.5	57.5	55.0	6.7
12.03.2013	63,472	302.5	57.6	55.0	6.8
27.03.2013	67,703	302.6	57.8	55.0	6.9
10.04.2013	60,167	302.8	58.0	55.0	6.92
26.04.2013	68,763	303.7	58.5	55.2	6.9
11.05.2013	37,435	304.7	59.0	55.4	6.9
27.05.2013	39,930	305.7	59.4	55.6	6.8
13.06.2013	27,255	306.7	59.9	55.8	6.8
27.06.2013	31,149	307.7	60.4	56.0	6.8
10.07.2013	19,903	308.6	60.9	56.2	6.7
28.07.2013	21,229	309.6	61.4	56.4	6.7
12.08.2013	18,001	310.6	61.8	56.6	6.7
27.08.2013	19,201	311.6	62.3	56.8	6.7
11.09.2013	68,644	312.5	62.8	57.0	6.6
25.09.2013	78,450	313.5	63.3	57.2	6.6
10.10.2013	95,988	314.5	63.8	57.4	6.6
26.10.2013	102,387	315.5	64.2	57.6	6.5
13.11.2013	164,191	316.4	64.7	57.8	6.5
27.11.2013	187,647	317.4	65.2	58.0	6.5
11.12.2013	271,290	318.4	65.7	58.2	6.5
28.12.2013	289,376	319.4	66.2	58.4	6.4
10.01.2014	203,311	320.3	66.6	58.6	6.4
29.01.2014	216,865	321.3	67.1	58.8	6.4
12.02.2014	213,843	322.3	67.6	59.0	6.3
25.02.2014	213,843	323.3	68.1	59.2	6.3
12.03.2014	177,253	324.2	68.6	59.4	6.3
26.03.2014	189,070	325.2	69.0	59.6	6.3
11.04.2014	179,242	327.2	70.0	60.0	6.2
25.04.2014	204,848	328.0	70.0	60.2	6.2
13.05.2014	194,759	328.8	70.0	60.5	6.1
28.05.2014	207,743	329.6	70.0	60.7	6.1
11.06.2014	174,761	330.5	70.0	61.0	6.1

KHG OC	Production (Coal+OB)	Area contributing to pollution	Max. Quarry depth	Max. Dump height	Lead distance
Date	(t)	(Ha)	(m)	(m)	(km)
27.06.2014	199,726	331.3	70.0	61.2	6.1
12.07.2014	175,996	332.1	70.0	61.4	6.0
28.07.2014	187,729	332.9	70.0	61.7	6.0
13.08.2014	80,277	333.7	70.0	61.9	6.0
28.08.2014	85,628	334.6	70.0	62.2	5.9
11.09.2014	98,352	335.4	70.0	62.4	5.9
28.09.2014	112,402	336.2	70.0	62.6	5.9
14.10.2014	189,242	337.0	70.0	62.9	5.9
29.10.2014	201,858	337.8	70.0	63.1	5.8
11.11.2014	216,278	338.7	70.0	63.4	5.8
26.11.2014	247,175	339.5	70.0	63.6	5.8
10.12.2014	71,293	340.3	70.0	63.8	5.8
26.12.2014	76,046	341.1	70.0	64.1	5.7
10.01.2015	180,372	341.9	70.0	64.3	5.7
26.01.2015	192,396	342.8	70.0	64.6	5.7
10.02.2015	88,888	343.6	70.0	64.8	5.6
26.02.2015	88,888	344.4	70.0	65.0	5.6
11.03.2015	137,647	345.2	70.0	65.3	5.6
26.03.2015	146,823	346.0	70.0	65.5	5.6
11.04.2015	162,454	347.7	70.0	66.0	5.5
25.04.2015	185,661	351.7	70.7	66.7	5.5
11.05.2015	170,702	355.6	71.4	67.4	5.5
25.05.2015	182,083	359.6	72.0	68.0	5.5
13.06.2015	107,022	363.6	72.7	68.7	5.5
27.06.2015	122,311	367.6	73.4	69.4	5.4
13.07.2015	96,516	371.6	74.1	70.1	5.4
27.07.2015	102,950	375.5	74.8	70.8	5.4
13.08.2015	67,414	379.5	75.4	71.4	5.4
26.08.2015	71,908	383.5	76.1	72.1	5.4
10.09.2015	111,796	387.5	76.8	72.8	5.4
26.09.2015	127,767	391.5	77.5	73.5	5.4
10.10.2015	192,025	395.4	78.2	74.2	5.4
19.10.2015	204,826	399.4	78.8	74.8	5.3
11.11.2015	192,297	403.4	79.5	75.5	5.3
25.11.2015	219,768	407.4	80.2	76.2	5.3
10.12.2015	194,204	411.4	80.9	76.9	5.3
25.12.2015	207,151	415.3	81.6	77.6	5.3
12.01.2016	185,166	419.3	82.2	78.2	5.3
27.01.2016	197,511	423.3	82.9	78.9	5.3
12.02.2016	188,508	427.3	83.6	79.6	5.3
27.02.2016	201,973	431.3	84.3	80.3	5.2
12.03.2016	144,267	435.2	85.0	81.0	5.2
25.03.2016	153,885	439.2	85.6	81.6	5.2
12.04.2016	139,876	447.2	87.0	83.0	5.19
27.04.2016	159,858	446.9	87.1	83.6	5.1
12.05.2016	175,252	446.6	87.2	84.1	5.1
25.05.2016	186,935	446.4	87.4	84.7	5.0
08.06.2016	107,991	446.1	87.5	85.2	5.0
26.06.2016	123,419	445.8	87.6	85.8	5.0
11.07.2016	18,645	445.6	87.7	86.4	4.9
25.07.2016	19,888	445.3	87.8	86.9	4.9
13.08.2016	52,095	445.0	88.0	87.5	4.8
25.08.2016	55,568	444.8	88.1	88.0	4.8
10.09.2016	28,731	444.5	88.2	88.6	4.7
30.09.2016	32,835	444.2	88.3	89.2	4.7
14.10.2016	49,341	444.0	88.4	89.7	4.6
26.10.2016	52,631	443.7	88.6	90.3	4.6

KHG OC	Production (Coal+OB)	Area contributing to pollution	Max. Quarry depth	Max. Dump height	Lead distance
Date	(t)	(Ha)	(m)	(m)	(km)
11.11.2016	164,940	443.4	88.7	90.8	4.5
26.11.2016	188,503	443.2	88.8	91.4	4.5
12.12.2016	186,726	442.9	88.9	92.0	4.4
28.12.2016	199,174	442.6	89.0	92.5	4.4
11.01.2017	209,710	442.3	89.2	93.1	4.3
27.01.2017	223,691	442.1	89.3	93.6	4.3
10.02.2017	149,087	441.8	89.4	94.2	4.2
25.02.2017	149,087	441.5	89.5	94.8	4.2
10.03.2017	130,356	441.3	89.6	95.3	4.1
29.03.2017	139,046	441.0	89.8	95.9	4.1
13.04.2017	172,180	440.5	90.0	97.0	4.0
28.04.2017	196,777	441.0	91.0	97.0	4.0
13.05.2017	199,918	441.6	91.9	97.0	4.0
27.05.2017	213,246	442.2	92.9	97.0	4.0
12.06.2017	135,757	442.8	93.8	97.0	4.0
27.06.2017	155,150	443.4	94.8	97.0	3.9
13.07.2017	129,027	443.9	95.8	97.0	3.9
28.07.2017	137,629	444.5	96.7	97.0	3.9
13.08.2017	84,084	445.1	97.7	97.0	3.9
28.08.2017	89,689	445.7	98.6	97.0	3.9
15.09.2017	115,210	446.2	99.6	97.0	3.9
29.09.2017	131,669	446.8	100.5	97.0	3.9
14.10.2017	146,088	447.4	101.5	97.0	3.9
31.10.2017	155,827	448.0	102.5	97.0	3.8
14.11.2017	197,061	448.6	103.4	97.0	3.8
28.11.2017	225,213	449.1	104.4	97.0	3.8
13.12.2017	190,008	449.7	105.3	97.0	3.8
27.12.2017	202,675	450.3	106.3	97.0	3.8
13.01.2018	199,498	450.9	107.3	97.0	3.8
27.01.2018	212,798	451.4	108.2	97.0	3.8
12.02.2018	192,498	452.0	109.2	97.0	3.8
27.02.2018	192,498	452.6	110.1	97.0	3.7
12.03.2018	181,198	453.2	111.1	97.0	3.7
27.03.2018	193,278	453.7	112.0	97.0	3.7
12.04.2018	189,777	454.9	113.0	97.0	3.7
26.04.2018	216,888	455.2	113.1	97.1	3.7
11.05.2018	146,935	455.4	113.2	97.2	3.7
26.05.2018	156,730	455.7	113.2	97.4	3.7
12.06.2018	97,742	455.9	113.3	97.5	3.7
27.06.2018	111,705	456.2	113.4	97.6	3.7
12.07.2018	61,253	456.5	113.5	97.7	3.6
26.07.2018	65,336	456.7	113.6	97.8	3.6
13.08.2018	42,830	457.0	113.6	98.0	3.6
27.08.2018	45,686	457.2	113.7	98.1	3.6
12.09.2018	119,071	457.5	113.8	98.2	3.6
27.09.2018	136,081	457.7	113.9	98.3	3.6
12.10.2018	193,668	458.0	114.0	98.4	3.6
29.10.2018	206,580	458.3	114.0	98.6	3.6
13.11.2018	207,679	458.5	114.1	98.7	3.6
27.11.2018	237,348	458.8	114.2	98.8	3.6
13.12.2018	175,698	459.0	114.3	98.9	3.6
27.12.2018	187,411	459.3	114.4	99.0	3.6
11.01.2019	188,072	459.6	114.4	99.2	3.5
28.01.2019	200,610	459.8	114.5	99.3	3.5
12.02.2019	228,426	460.1	114.6	99.4	3.5
27.02.2019	228,426	460.3	114.7	99.5	3.5
12.03.2019	227,151	460.6	114.8	99.6	3.5

KHG OC	Production (Coal+OB)	Area contributing to pollution	Max. Quarry depth	Max. Dump height	Lead distance
Date	(t)	(Ha)	(m)	(m)	(km)
28.03.2019	242,295	460.8	114.8	99.8	3.5
12.04.2019	209,201	461.4	115.0	100.0	3.49
26.04.2019	239,087	460.9	115.8	100.7	3.5
11.05.2019	177,299	460.4	116.6	101.4	3.5
27.05.2019	189,119	459.9	117.4	102.2	3.5
12.06.2019	98,167	459.4	118.2	102.9	3.5
27.06.2019	112,191	458.9	119.0	103.6	3.5
11.07.2019	65,951	458.4	119.8	104.3	3.5
26.07.2019	70,348	457.9	120.6	105.0	3.5
12.08.2019	38,690	457.4	121.4	105.8	3.5
28.08.2019	41,269	456.9	122.2	106.5	3.5
12.09.2019	59,653	456.5	123.0	107.2	3.5
27.09.2019	68,175	456.0	123.8	107.9	3.5
12.10.2019	6,159	455.5	124.6	108.6	3.5
28.10.2019	6,570	455.0	125.4	109.4	3.4
12.11.2019	8,991	454.5	126.2	110.1	3.4
27.11.2019	10,276	454.0	127.0	110.8	3.4
12.12.2019	239,011	453.5	127.8	111.5	3.4
27.12.2019	254,945	453.0	128.6	112.2	3.4
11.01.2020	216,148	452.5	129.4	113.0	3.4
27.01.2020	230,558	452.0	130.2	113.7	3.4
12.02.2020	230,635	451.5	131.0	114.4	3.4
27.02.2020	247,109	451.1	131.8	115.1	3.4
12.03.2020	137,466	450.6	132.6	115.8	3.4
26.03.2020	146,630	450.1	133.4	116.6	3.4
11.04.2020	47,575	449.1	135.0	118.0	3.41
27.04.2020	54,371	446.5	135.5	118.1	3.4
13.05.2020	45,867	443.8	136.0	118.2	3.3
27.05.2020	48,925	441.2	136.6	118.2	3.2
11.06.2020	86,849	438.5	137.1	118.3	3.2
26.06.2020	99,256	435.9	137.6	118.4	3.1
11.07.2020	31,059	433.3	138.1	118.5	3.1
28.07.2020	33,130	430.6	138.6	118.6	3.0
12.08.2020	26,552	428.0	139.2	118.6	3.0
27.08.2020	28,322	425.4	139.7	118.7	2.9
10.09.2020	48,137	422.7	140.2	118.8	2.8
26.09.2020	55,013	420.1	140.7	118.9	2.8
12.10.2020	93,887	417.5	141.2	119.0	2.7
28.10.2020	100,146	414.8	141.8	119.0	2.7
11.11.2020	140,950	412.2	142.3	119.1	2.6
25.11.2020	161,086	409.6	142.8	119.2	2.6
10.12.2020	172,821	406.9	143.3	119.3	2.5
28.12.2020	184,342	404.3	143.8	119.4	2.5
11.01.2021	178,051	401.7	144.4	119.4	2.4
27.01.2021	189,921	399.0	144.9	119.5	2.3
10.02.2021	176,698	396.4	145.4	119.6	2.3
25.02.2021	176,698	393.8	145.9	119.7	2.2
10.03.2021	152,411	391.1	146.4	119.8	2.2
25.03.2021	162,572	388.5	147.0	119.8	2.1
10.04.2021	145,170	383.2	148.0	120.0	2.0
26.04.2021	165,908	383.2	148.0	120.0	2.0
11.05.2021	143,840	383.2	148.0	120.0	2.0
26.05.2021	153,429	383.2	148.0	120.0	2.0
11.06.2021	78,341	383.2	148.0	120.0	2.0
25.06.2021	89,533	383.2	148.0	120.0	1.9
10.07.2021	52,479	383.2	148.0	120.0	1.9
27.07.2021	55,978	383.2	148.0	120.0	1.9

KHG OC	Production (Coal+OB)	Area contributing to pollution	Max. Quarry depth	Max. Dump height	Lead distance
Date	(t)	(Ha)	(m)	(m)	(km)
11.08.2021	73,076	383.2	148.0	120.0	1.9
26.08.2021	77,948	383.2	148.0	120.0	1.9
11.09.2021	41,855	383.2	148.0	120.0	1.9
25.09.2021	47,835	383.2	148.0	120.0	1.9
11.10.2021	209,820	383.2	148.0	120.0	1.9
27.10.2021	223,808	383.2	148.0	120.0	1.8
11.11.2021	230,968	383.2	148.0	120.0	1.8
26.11.2021	263,963	383.2	148.0	120.0	1.8
10.12.2021	232,229	383.2	148.0	120.0	1.8
30.12.2021	247,711	383.2	148.0	120.0	1.8
15.01.2022	205,321	383.2	148.0	120.0	1.8
31.01.2022	219,009	383.2	148.0	120.0	1.8
10.02.2022	205,009	383.2	148.0	120.0	1.8
25.02.2022	205,009	383.2	148.0	120.0	1.7
11.03.2022	259,569	383.2	148.0	120.0	1.7
26.03.2022	276,874	383.2	148.0	120.0	1.7

Table 2. KHG OC Meteorological data

KHG OC	Predominant wind direction	Avg. Temp	Avg. Humidity	Avg. Rainfall	Avg. Wind speed
Date	(degrees)	(^o c)	(%)	(mm)	(m/s)
02.04.2012	124	38.1	64.1	1.0	5.2
18.04.2012	139	39.2	57.6	0.0	4.3
03.05.2012	83	40.0	62.8	0.0	5.5
19.05.2012	39	39.8	26.5	0.0	3.5
01.06.2012	175	41.9	79.6	1.0	2.2
19.06.2012	147	42.2	65.2	1.1	3.4
12.07.2012	123	40.5	50.9	0.7	5.5
29.07.2012	126	39.7	86.9	2.0	3.5
11.08.2012	174	38.6	83.9	0.0	3.2
28.08.2012	198	35.2	58.4	0.0	2.5
11.09.2012	97	34.7	95.3	0.0	5.0
26.09.2012	217	35.4	91.1	2.0	4.2
12.10.2012	330	34.4	90.6	1.1	2.5
28.10.2012	242	32.6	77.4	1.0	0.1
10.11.2012	224	31.7	70.1	1.0	2.6
27.11.2012	38	28.5	80.5	1.0	3.3
11.12.2012	21	28.8	76.6	0.0	5.0
26.12.2012	113	27.1	61.8	0.0	3.4
10.01.2013	250	25.6	78.0	0.0	3.8
25.01.2013	269	23.1	69.0	1.0	2.8
12.02.2013	46	23.8	74.8	0.0	4.0
25.02.2013	274	25.5	59.4	0.0	5.3
12.03.2013	97	26.5	76.9	0.0	4.9
27.03.2013	174	29.7	67.8	0.0	3.6
10.04.2013	130	31.1	67.5	0.0	6.0
26.04.2013	168	30.4	70.5	1.1	10.3
11.05.2013	193	31.1	63.1	0.0	6.9
27.05.2013	34	32.9	57.5	0.0	7.9
13.06.2013	185	24.3	79.7	0.0	5.7
27.06.2013	26	27.5	71.6	0.0	5.3
10.07.2013	288	30.0	63.7	0.0	3.5
28.07.2013	5	29.2	67.4	0.1	5.6
12.08.2013	282	28.7	70.8	0.0	5.9
27.08.2013	77	25.7	75.8	1.0	3.0
11.09.2013	248	27.7	73.7	0.0	0.4
25.09.2013	245	28.8	67.0	0.4	3.7
10.10.2013	46	27.2	74.2	0.0	2.3

KHG OC	Predominant wind direction	Avg. Temp	Avg. Humidity	Avg. Rainfall	Avg. Wind speed
Date	(degrees)	(°c)	(%)	(mm)	(m/s)
26.10.2013	102	25.0	80.8	0.0	5.1
13.11.2013	167	21.4	61.3	0.0	5.3
27.11.2013	248	25.3	68.5	0.0	5.7
11.12.2013	47	20.3	52.3	0.0	6.3
28.12.2013	130	21.0	62.4	0.0	0.6
10.01.2014	131	23.7	63.7	0.0	6.9
29.01.2014	19	20.8	51.6	0.0	0.1
12.02.2014	229	24.9	55.7	0.0	1.1
25.02.2014	113	26.1	61.2	0.0	1.8
12.03.2014	15	27.4	59.6	0.0	7.0
26.03.2014	188	29.0	57.0	0.0	7.5
11.04.2014	192	31.0	42.7	0.0	0.1
25.04.2014	20	34.2	43.0	0.0	7.0
13.05.2014	206	33.9	45.2	0.0	4.3
28.05.2014	246	36.3	36.7	0.0	6.5
11.06.2014	245	33.4	55.0	0.0	1.0
27.06.2014	262	30.5	57.8	0.0	4.1
12.07.2014	138	28.1	65.3	0.0	6.2
28.07.2014	112	26.8	73.6	3.6	23.9
13.08.2014	22	30.2	60.8	0.0	0.0
28.08.2014	149	28.2	70.7	38.6	8.7
11.09.2014	250	28.9	69.4	0.0	3.4
28.09.2014	245	28.8	63.2	0.0	0.0
14.10.2014	245	27.8	69.0	0.0	23.3
29.10.2014	245	23.4	67.8	0.0	0.0
11.11.2014	15	27.6	66.1	0.0	0.0
26.11.2014	313	23.3	57.2	0.0	0.0
10.12.2014	59	24.6	64.8	0.0	0.0
26.12.2014	320	19.8	52.6	0.0	11.5
10.01.2015	298	17.4	57.0	0.0	2.4
26.01.2015	116	24.0	57.9	0.0	0.4
10.02.2015	245	23.4	59.7	0.0	1.2
26.02.2015	74	28.3	42.2	0.0	0.0
11.03.2015	320	27.5	60.4	0.0	0.0
26.03.2015	104	30.5	50.9	0.0	4.9
11.04.2015	19	31.5	54.7	0.0	0.0
25.04.2015	86	29.9	58.7	0.0	0.0
11.05.2015	61	35.3	41.6	0.0	9.3
25.05.2015	246	37.0	30.5	0.0	4.2
13.06.2015	25	30.9	59.0	3.2	0.0
27.06.2015	198	30.6	60.7	0.0	0.0
13.07.2015	15	32.6	59.2	0.0	3.8
27.07.2015	65	29.3	66.5	0.0	0.0
13.08.2015	227	28.5	74.6	37.4	1.0
26.08.2015	179	29.3	66.2	0.0	0.0
10.09.2015	291	29.1	68.9	0.0	0.5
26.09.2015	76	29.9	70.8	0.0	0.0
10.10.2015	1	28.8	62.8	0.0	0.0
19.10.2015	120	26.9	61.8	0.0	0.0
11.11.2015	144	23.9	65.0	0.0	0.0
25.11.2015	94	25.2	63.8	0.0	0.0
10.12.2015	179	23.8	57.7	0.0	0.0
25.12.2015	135	21.0	52.2	0.0	0.0
12.01.2016	91	22.0	53.0	0.0	0.2
27.01.2016	180	25.8	64.0	0.0	1.6
12.02.2016	269	28.4	57.0	0.0	1.3
27.02.2016	94	28.9	60.2	0.0	0.0
12.03.2016	268	32.0	45.6	0.0	0.1
25.03.2016	323	30.6	48.8	0.0	1.3
12.04.2016	118	35.0	31.5	0.0	3.5
27.04.2016	211	36.4	44.9	0.0	3.0
12.05.2016	191	35.1	40.1	0.0	1.1
25.05.2016	67	37.9	30.3	0.0	1.3
08.06.2016	200	28.6	69.7	3.6	1.1
26.06.2016	185	32.2	60.5	5.8	0.0

KHG OC	Predominant wind direction	Avg. Temp	Avg. Humidity	Avg. Rainfall	Avg. Wind speed
Date	(degrees)	(^o c)	(%)	(mm)	(m/s)
11.07.2016	225	24.1	82.0	60.4	2.2
25.07.2016	198	28.1	74.5	26.4	0.5
13.08.2016	275	30.1	72.7	0.0	1.6
25.08.2016	191	29.4	73.5	1.2	0.8
10.09.2016	104	29.2	69.6	0.0	5.1
30.09.2016	176	28.8	73.0	11.2	4.8
14.10.2016	192	24.8	66.3	0.0	0.3
26.10.2016	162	25.2	70.2	0.0	1.2
11.11.2016	169	21.7	61.8	0.0	0.4
26.11.2016	127	21.8	62.0	0.0	1.3
12.12.2016	220	23.5	51.4	0.0	1.0
28.12.2016	189	20.7	50.0	0.0	0.7
11.01.2017	171.0	21.7	69.4	2.0	0.1
27.01.2017	201.0	26.5	57.2	2.0	0.9
10.02.2017	122.0	26.1	59.6	2.0	0.3
25.02.2017	194.7	25.8	59.4	1.0	0.0
10.03.2017	320.0	28.9	71.9	2.0	0.4
29.03.2017	183.0	32.2	64.1	0.0	1.0
13.04.2017	284.0	29.7	70.3	0.0	0.2
28.04.2017	204.0	31.6	63.0	0.0	1.0
13.05.2017	269.0	35.0	62.3	1.0	0.5
27.05.2017	154.0	37.8	40.5	2.0	0.1
12.06.2017	178.0	30.5	74.5	1.6	0.6
27.06.2017	149.0	26.0	86.1	2.4	1.0
13.07.2017	123.0	27.0	79.5	0.0	1.4
28.07.2017	148.0	22.0	98.1	2.1	2.5
13.08.2017	122.0	26.2	89.0	2.0	1.5
28.08.2017	88.0	26.8	84.6	1.0	0.7
15.09.2017	228.6	29.9	71.2	1.0	2.9
29.09.2017	112.0	29.8	72.5	1.0	5.4
14.10.2017	140.3	28.6	66.9	0.3	0.8
31.10.2017	355.0	27.3	67.2	0.0	0.3
14.11.2017	155.0	26.3	49.5	1.0	1.7
28.11.2017	165.7	33.9	42.8	1.0	1.7
13.12.2017	228.8	30.2	80.7	0.0	3.5
27.12.2017	64.3	27.8	53.2	0.0	1.4
13.01.2018	119.5	28.8	54.9	1.0	1.1
27.01.2018	97.3	35.5	30.7	1.0	2.3
12.02.2018	128.2	28.7	55.9	1.0	4.2
27.02.2018	141.3	30.3	53.2	0.0	3.0
12.03.2018	160.5	30.8	29.9	1.0	0.2
27.03.2018	186	34.2	26.9	0.0	4.7
12.04.2018	174	32.3	29.4	0.0	3.8
26.04.2018	192	35.9	23.4	0.0	7.1
11.05.2018	166	37.3	24.1	0.0	8.8
26.05.2018	161	35.8	33.5	0.0	0.5
12.06.2018	205	29.4	64.0	0.1	8.8
27.06.2018	222	27.5	72.3	0.0	5.2
12.07.2018	225	26.1	77.3	0.1	8.0
26.07.2018	246	28.7	60.5	0.0	7.1
13.08.2018	247	28.1	70.9	0.1	7.9
27.08.2018	231	25.6	79.1	0.2	2.6
12.09.2018	149	30.4	53.1	0.0	1.3
27.09.2018	173	29.0	66.3	0.0	1.6
12.10.2018	260	27.7	58.2	0.0	2.9
29.10.2018	103	24.5	48.6	0.0	3.0
13.11.2018	196	22.9	47.2	0.0	1.1
27.11.2018	119	21.5	49.8	0.0	1.7
13.12.2018	72	22.4	89.1	2.2	0.6
27.12.2018	306	21.9	63.5	0.0	2.0
11.01.2019	140	19.6	63.4	0.0	2.1
28.01.2019	238	19.7	69.5	0.0	2.9
12.02.2019	156	24.3	63.3	0.0	3.0
27.02.2019	240	27.2	39.6	0.0	3.0
12.03.2019	120	31.9	37.0	0.0	6.9

KHG OC	Predominant wind direction	Avg. Temp	Avg. Humidity	Avg. Rainfall	Avg. Wind speed
Date	(degrees)	(^o c)	(%)	(mm)	(m/s)
28.03.2019	147	33.3	32.9	0.0	2.2
12.04.2019	154	33.5	29.8	0.2	9.2
26.04.2019	161	37.8	24.5	0.0	3.7
11.05.2019	203	37.5	21.8	0.0	5.6
27.05.2019	225	40.0	16.3	0.0	3.7
12.06.2019	187	38.4	27.1	0.0	9.0
27.06.2019	216	33.8	46.3	0.0	2.1
11.07.2019	240	28.2	70.9	0.0	4.5
26.07.2019	232	25.7	83.8	0.4	6.0
12.08.2019	197	28.8	68.4	0.0	2.6
28.08.2019	162	29.2	68.3	0.0	1.5
12.09.2019	213	25.4	83.9	0.7	4.7
27.09.2019	168	26.7	76.0	1.4	6.8
12.10.2019	165	28.5	71.0	0.0	0.1
28.10.2019	118	28.2	73.9	0.0	0.0
12.11.2019	103	25.3	65.2	0.0	1.3
27.11.2019	115	23.9	67.7	0.0	0.8
12.12.2019	116	22.4	65.7	0.0	1.2
27.12.2019	230	21.2	70.5	0.0	0.5
11.01.2020	132	19.6	56.3	0.0	1.0
27.01.2020	142	24.3	44.5	0.0	1.5
12.02.2020	219	24.2	55.7	0.0	1.4
27.02.2020	133	24.5	29.3	0.0	1.5
12.03.2020	159	28.5	52.7	0.0	6.7
26.03.2020	145	31.2	37.6	0.0	2.9
11.04.2020	191	33.4	30.7	0.0	3.9
27.04.2020	227	32.6	38.6	0.0	7.2
13.05.2020	206	35.7	29.5	0.0	2.5
27.05.2020	217	38.2	31.0	0.0	4.4
11.06.2020	224	29.8	63.9	0.4	7.8
26.06.2020	217	32.1	50.8	0.0	1.7
11.07.2020	248	29.6	65.8	0.0	1.0
28.07.2020	194	29.5	67.7	2.7	0.8
12.08.2020	224	28.1	67.3	0.1	0.2
27.08.2020	227	26.7	78.0	0.1	0.5
10.09.2020	234	28.5	73.1	0.0	1.0
26.09.2020	239	27.7	78.4	0.0	1.0
12.10.2020	212	27.1	79.3	0.6	0.5
28.10.2020	187	26.6	58.9	0.0	1.0
11.11.2020	135	22.6	52.8	0.0	1.2
25.11.2020	196	22.3	54.8	0.6	0.6
10.12.2020	265	22.5	53.2	0.0	0.5
28.12.2020	245	21.6	53.1	0.0	2.0
11.01.2021	204	24.5	52.4	0.0	0.9
27.01.2021	159	24.6	55.7	0.0	2.5
10.02.2021	171	22.6	28.2	0.0	1.3
25.02.2021	218	27.6	29.8	0.0	1.3
10.03.2021	161	30.3	34.5	0.0	6.0
25.03.2021	164	31.3	24.6	0.0	1.4
10.04.2021	115	32.6	34.2	0.0	9.0
26.04.2021	170	35.2	25.4	0.0	6.3
11.05.2021	149	31.0	49.9	1.2	9.6
26.05.2021	154	35.9	17.9	0.0	9.3
11.06.2021	132	27.5	66.9	0.7	5.9
25.06.2021	132	30.1	53.8	0.0	5.3
10.07.2021	145	30.0	68.8	0.3	2.7
27.07.2021	110	30.5	51.9	0.0	7.5
11.08.2021	150	30.6	56.1	0.0	4.7
26.08.2021	146	28.4	69.3	0.0	3.1
11.09.2021	167	27.4	79.5	0.7	0.2
25.09.2021	235	28.0	75.7	0.4	0.5
11.10.2021	219	28.4	59.8	0.0	1.0
27.10.2021	269	25.5	56.8	0.0	1.1
11.11.2021	252	24.1	46.7	0.0	1.1
26.11.2021	193	24.8	62.2	0.0	0.5

KHG OC	Predominant wind direction	Avg. Temp	Avg. Humidity	Avg. Rainfall	Avg. Wind speed
Date	(degrees)	(^o c)	(%)	(mm)	(m/s)
10.12.2021	152	23.4	64.0	0.0	0.2
30.12.2021	297	21.1	72.1	0.0	1.0
15.01.2022	303	21.0	78.3	0.0	1.7
31.01.2022	234	21.7	41.3	0.0	1.4
10.02.2022	133	25.7	51.5	0.0	2.5
25.02.2022	167	28.2	35.9	0.0	4.3
11.03.2022	195	29.0	32.9	0.0	2.7
26.03.2022	159	32.9	40.0	0.0	6.5

Table 3. PM₁₀ and PM_{2.5} in core and buffer zones of KHG OC

KHG OC	PM ₁₀ (µg/m ³)						PM _{2.5} (µg/m ³)					
	Date	CHP	WS	Goverguda	Ullipitta	Chopdi	Ontimamidi	CHP	WS	Goverguda	Ullipitta	Chopdi
02.04.2012	182	159	89	90	86	69	70.2	48.1	42.4	41.6	44.6	41.1
18.04.2012	180	148	86	87	87	68	78.1	46.0	45.1	40.1	43.7	42.3
03.05.2012	179	139	78	85	82	66	60.4	44.6	41.6	41.4	41.8	41.7
19.05.2012	177	140	80	82	79	65	59.7	47.3	39.4	42.0	42.5	41.0
01.06.2012	179	142	82	78	76	64	55.0	45.0	31.2	43.7	43.7	40.1
19.06.2012	164	121	70	76	75	57	60.0	55.0	28.6	21.4	35.7	21.4
12.07.2012	150	107	56	87	97	53	50.6	55.6	29.3	28.2	43.9	35.3
29.07.2012	120	92	67	79	93	66	40.9	48.0	35.3	28.1	36.1	28.2
11.08.2012	92	105	87	79	84	54	42.2	51.8	28.9	31.4	28.7	28.2
28.08.2012	123	109	71	62	85	70	47.5	53.4	42.2	32.8	47.3	28.4
11.09.2012	151	112	99	90	96	73	56.2	56.7	35.3	37.0	34.9	29.1
26.09.2012	143	109	106	90	87	62	72.2	42.2	41.4	35.3	48.8	36.1
12.10.2012	129	111	98	80	91	69	54.1	51.2	43.9	37.0	37.5	27.9
28.10.2012	131	108	82	86	94	60	60.5	41.9	49.4	27.9	43.9	31.8
10.11.2012	136	103	84	71	91	56	52.0	38.7	27.3	20.7	35.7	22.2
27.11.2012	134	99	75	70	90	60	55.8	39.3	35.3	27.9	41.4	15.2
11.12.2012	125	96	83	77	91	57	61.8	42.5	37.0	36.6	42.0	21.2
26.12.2012	120	109	79	68	89	73	57.3	47.2	37.0	29.3	41.8	35.3
10.01.2013	125	115	83	72	87	76	48.5	42.5	44.4	32.9	41.1	38.8
25.01.2013	137	122	95	85	86	68	57.3	49.6	44.4	36.6	41.6	28.2
12.02.2013	122	122	73	86	84	77	61.8	59.2	30.3	40.4	41.0	34.5
25.02.2013	163	153	87	96	85	97	67.3	58.7	43.7	52.3	41.7	51.3
12.03.2013	176	142	86	93	81	107	69.8	57.2	42.7	51.4	40.8	57.9
27.03.2013	205	151	88	95	82	123	83.3	76.2	43.7	68.3	41.1	64.7
10.04.2013	224	147	92	90	78	131	93.2	63.6	46.9	61.6	40.0	72.4
26.04.2013	191	124	86	89	76	116	70.2	57.4	47.2	57.2	39.9	61.4
11.05.2013	198	124	94	83	72	109	75.3	61.5	51.2	58.4	38.4	62.4
27.05.2013	221	133	91	88	74	110	84.5	64.5	50.6	57.2	37.8	61.8
13.06.2013	142	118	68	61	71	70	42.6	44.6	34.3	31.4	37.6	35.8
27.06.2013	148	112	64	72	70	72	47.8	42.4	32.4	34.8	37.5	34.7
10.07.2013	146	116	66	72	69	74	52.4	40.6	31.2	35.6	37.0	37.2
28.07.2013	118	101	61	66	68	59	43.6	39.6	34.3	31.6	36.8	31.1
12.08.2013	114	107	64	60	68	63	42.4	37.6	33.4	29.8	36.6	31.8
27.08.2013	124	116	68	62	69	66	46.7	40.5	34.7	32.7	35.1	33.5
11.09.2013	142	118	68	61	70	68	52.6	42.3	35.9	31.2	42.0	34.4
25.09.2013	164	123	70	66	73	73	56.2	44.3	37.8	32.7	41.4	37.2
10.10.2013	136	103	61	59	79	64	52.6	40.6	32.4	30.4	45.0	30.9
26.10.2013	132	112	67	61	80	59	46.8	41.3	34.2	31.2	46.1	27.8
13.11.2013	142	109	66	63	82	66	54.3	41.8	32.4	32.7	52.8	33.7

KHG OC	PM ₁₀ (µg/m ³)						PM _{2.5} (µg/m ³)					
	Date	CHP	WS	Goverguda	Ullipitta	Chopdi	Ontimamidi	CHP	WS	Goverguda	Ullipitta	Chopdi
27.11.2013	141	124	71	69	83	68	53.4	49.8	36.7	33.8	53.2	33.4
11.12.2013	158	122	78	81	96	80	58.7	46.3	42.6	44.1	56.0	41.2
28.12.2013	173	136	91	93	95	84	61.3	52.3	49.6	43.2	54.1	42.8
10.01.2014	166	131	94	92	91	89	62.2	52.3	51.2	50.7	49.8	41.9
29.01.2014	223	132	94	98	90	86	76.2	54.3	51.7	56.7	48.9	44.6
12.02.2014	234	143	92	97	80	87	78.6	55.3	53.3	52.3	47.0	48.3
25.02.2014	228	138	91	94	78	89	77.8	56.7	51.7	56.7	46.7	44.6
12.03.2014	168	124	87	91	79	82	64.3	45.6	44.9	47.1	45.4	42.6
26.03.2014	234	146	94	97	78	87	80.6	60.8	50.7	54.0	44.6	43.2
11.04.2014	228	151	87	94	76	78	78.5	61.3	43.2	48.3	43.1	34.9
25.04.2014	198	138	80	82	77	71	71.2	58.3	47.2	41.2	44.5	33.6
13.05.2014	244	163	94	89	79	83	81.4	65.7	51.6	57.6	45.0	44.9
28.05.2014	248	172	91	91	78	87	86.4	71.3	53.4	58.5	45.3	45.5
11.06.2014	228	146	81	94	74	79	80.5	67.3	49.7	58.3	44.3	41.9
27.06.2014	224	136	75	91	75	71	71.4	58.6	46.2	57.2	43.9	40.4
12.07.2014	173	122	68	73	77	64	63.4	52.3	34.5	50.6	42.5	34.6
28.07.2014	167	113	64	82	76	66	67.8	52.4	33.4	51.2	41.3	32.2
13.08.2014	234	138	70	97	73	69	77.6	61.2	36.2	51.4	48.6	32.8
28.08.2014	172	111	68	89	75	64	65.8	51.2	32.1	47.3	42.2	31.2
11.09.2014	208	123	62	86	77	61	69.1	54.5	32.2	51.2	50.6	34.2
28.09.2014	225	133	76	92	96	76	83.2	59.4	40.6	63.5	62.4	42.3
14.10.2014	216	127	73	96	92	73	80.7	57.6	39.4	58.3	60.5	41.0
29.10.2014	199	117	67	88	85	67	75.1	53.6	36.6	54.2	56.3	38.2
11.11.2014	221	124	72	88	87	70	75.6	60.8	41.4	50.7	50.9	36.4
26.11.2014	232	130	76	92	91	74	82.6	63.8	43.5	58.9	59.2	40.3
10.12.2014	208	117	68	83	82	66	71.8	57.8	39.3	48.2	48.4	34.6
26.12.2014	166	128	82	88	84	84	62.2	49.1	45.2	46.7	48.3	43.7
10.01.2015	223	132	94	98	83	86	76.2	54.3	47.6	56.7	50.0	44.6
26.01.2015	232	133	87	93	91	88	84.3	55.6	46.2	58.7	50.1	46.8
10.02.2015	206	128	91	95	87	83	78.5	56.4	51.6	56.4	47.3	43.3
26.02.2015	225	129	84	94	90	85	81.8	53.9	44.8	57.1	50.9	45.4
11.03.2015	211	131	93	97	89	85	83.1	59.7	54.6	59.7	50.0	45.8
26.03.2015	236	142	87	94	91	87	87.6	62.8	53.7	58.4	54.2	51.1
11.04.2015	203	126	90	94	86	82	81.2	60.9	51.2	55.2	53.9	47.7
25.04.2015	228	151	87	94	91	78	83.3	61.5	43.0	58.4	48.9	35.2
11.05.2015	211	131	93	97	89	85	83.6	60.0	54.8	60.0	56.6	51.0
25.05.2015	231	141	84	96	91	87	86.5	71.6	53.2	58.6	52.8	45.2
13.06.2015	205	127	79	95	87	83	78.3	58.5	48.7	52.4	54.5	49.8
27.06.2015	182	107	71	83	81	67	71.2	52.1	41.7	49.6	42.1	34.4
13.07.2015	196	122	76	90	83	79	75.3	56.1	46.7	50.4	52.1	47.7
27.07.2015	179	105	70	81	79	66	70.1	51.3	40.7	49.2	41.9	34.3
13.08.2015	170	106	66	79	72	69	65.3	48.6	38.5	43.6	45.8	39.5
26.08.2015	196	104	75	84	87	73	73.2	53.2	43.0	50.9	44.0	35.7
10.09.2015	224	132	94	98	90	86	76.0	54.2	51.9	57.0	48.6	44.4
26.09.2015	212	129	90	92	87	82	75.1	60.4	50.5	51.2	45.9	43.8
10.10.2015	189	145	89	93	89	80	77.7	63.8	48.3	47.9	43.4	43.1
19.10.2015	174	192	88	96	91	81	79.3	75.4	46.5	44.3	42.4	42.3
11.11.2015	237	128	91	88	102	92	107.1	60.5	45.0	45.5	68.6	70.3
25.11.2015	242	166	121	98	107	86	88.2	69.1	61.5	52.3	60.8	38.0
10.12.2015	247	134	125	89	113	90	90.4	69.6	66.8	62.4	62.7	49.3
25.12.2015	244	133	105	86	99	82	88.3	67.1	60.5	56.3	58.4	53.0
12.01.2016	217	137	99	91	88	85	81.7	68.3	62.1	61.8	59.4	56.6
27.01.2016	224	128	94	88	85	88	83.7	63.7	60.0	58.8	56.2	56.6
12.02.2016	221	130	92	87	88	84	83.7	63.8	59.5	53.2	54.7	52.8

KHG OC	PM ₁₀ (µg/m ³)						PM _{2.5} (µg/m ³)					
	Date	CHP	WS	Goverguda	Ullipitta	Chopdi	Ontimamidi	CHP	WS	Goverguda	Ullipitta	Chopdi
27.02.2016	228	140	96	90	84	81	83.6	69.1	61.5	60.2	56.1	55.5
12.03.2016	225	132	90	80	89	82	82.3	65.9	50.7	47.7	49.1	48.5
25.03.2016	219	128	94	81	87	71	81.3	65.0	62.3	56.1	61.5	49.3
12.04.2016	220	128	85	80	87	81	80.2	64.5	53.2	48.7	53.4	49.5
27.04.2016	223	127	91	79	61	79	79.7	63.1	51.7	46.6	42.7	50.8
12.05.2016	220	128	85	80	87	81	80.2	64.5	53.2	48.7	53.4	49.5
25.05.2016	221	130	86	81	88	81	80.9	65.1	54.1	50.6	54.2	50.1
08.06.2016	210	116	72	70	76	76	54.1	63.3	44.7	43.7	49.0	41.2
26.06.2016	175	103	61	56	53	72	54.6	60.0	46.5	45.3	38.7	40.0
11.07.2016	102	85	58	57	64	57	52.8	46.3	34.3	45.9	40.6	32.5
25.07.2016	91	71	54	59	55	45	52.8	53.3	49.0	45.3	48.9	43.7
13.08.2016	130	70	58	54	47	58	52.1	40.9	34.9	48.5	39.4	44.4
25.08.2016	132	88	67	60	68	61	66.8	57.8	43.7	45.6	42.2	43.4
10.09.2016	147	110	61	62	62	62	62.0	58.8	49.4	48.5	41.0	47.5
30.09.2016	141	77	62	55	65	56	62.3	55.3	41.1	43.3	40.1	45.5
14.10.2016	145	108	60	61	61	62	61.2	57.9	40.1	52.8	43.6	36.9
26.10.2016	155	96	56	60	62	64	63.7	58.3	48.2	38.1	41.7	41.8
11.11.2016	141	97	62	65	60	59	72.8	67.6	51.3	53.4	56.8	55.6
26.11.2016	148	98	65	66	58	66	71.6	64.8	44.3	52.2	44.3	37.5
12.12.2016	195	109	69	76	71	65	72.5	66.3	45.4	51.9	44.8	38.6
28.12.2016	216	118	78	87	75	77	80.6	68.2	59.4	53.4	51.6	56.2
11.01.2017	207	124	77	82	71	69	82.7	66.7	54.5	56.7	51.1	51.8
27.01.2017	215	130	88	80	89	87	85.7	73.9	48.2	48.4	55.5	49.6
10.02.2017	212	130	82	78	85	79	81.6	70.2	49.6	50.2	51.2	43.6
25.02.2017	219	181	84	74	89	77	85.8	73.4	47.4	52.2	53.6	48.2
10.03.2017	219	173	73	74	67	72	81.3	73.9	46.1	53.3	47.5	47.6
29.03.2017	209	184	88	78	66	79	79.8	71.1	42.1	44.8	46.4	48.7
13.04.2017	212	185	89	75	80	74	80.6	74.2	50.5	47.1	49.4	50.2
28.04.2017	218	166	84	74	85	69	87.0	73.9	48.2	45.4	50.0	46.1
13.05.2017	244	176	79	84	85	80	90.0	71.8	45.0	51.6	50.8	44.4
27.05.2017	232	168	82	86	78	84	74.4	71.4	48.4	50.6	49.8	48.6
12.06.2017	213	159	79	82	76	81	74.0	68.9	48.0	50.1	49.2	47.9
27.06.2017	215	158	76	79	77	78	69.9	64.6	47.1	51.2	41.8	46.5
13.07.2017	204	139	65	76	69	74	68.7	60.8	46.7	49.8	41.5	45.1
28.07.2017	198	126	63	77	67	75	67.4	59.3	45.8	49.7	38.8	44.8
13.08.2017	174	125	66	68	61	68	61.1	58.2	41.4	48.9	36.9	41.6
28.08.2017	166	137	65	70	57	62	55.6	56.9	38.7	49.0	35.5	38.7
15.09.2017	156	169	67	78	52	51	52.2	55.6	35.0	49.1	34.5	35.2
29.09.2017	165	184	62	81	55	49	56.1	62.2	44.1	48.8	40.9	36.4
14.10.2017	200	198	81	84	61	67	69.1	80.0	48.5	46.3	40.9	50.0
31.10.2017	185	216	80	87	79	67	92.9	104.5	55.9	44.4	50.8	50.0
14.11.2017	179	173	77	88	79	64	94.9	106.6	52.9	42.6	45.4	40.9
28.11.2017	195	207	86	89	73	82	120.9	101.5	52.8	50.1	48.5	43.6
13.12.2017	205	193	87	87	77	79	111.1	99.2	46.9	52.2	46.5	50.5
27.12.2017	191	192	67	85	78	71	102.2	104.3	35.3	49.3	54.5	36.4
13.01.2018	196	187	90	84	65	60	90.0	83.2	51.4	51.1	47.5	43.6
27.01.2018	186	164	87	86	62	57	81.8	76.1	51.4	46.9	43.2	43.6
12.02.2018	181	162	74	75	65	56	72.8	69.1	45.7	51.1	43.2	38.2
27.02.2018	173	156	70	72	59	51	68.6	67.1	45.7	46.9	38.8	32.7
12.03.2018	176	155	73	72	64	51	72.3	68.6	40.0	42.6	43.2	32.7
27.03.2018	182	161	77	72	63	53	72.3	67.6	51.4	46.9	38.8	43.6
12.04.2018	188	162	71	74	59	54	72.8	68.1	45.7	46.9	34.5	38.2
26.04.2018	185	165	75	72	65	47	73.4	67.6	51.4	46.9	38.8	27.3
11.05.2018	176	166	62	65	64	43	75.0	69.6	40.0	42.6	43.2	21.8

KHG OC	PM ₁₀ (µg/m ³)						PM _{2.5} (µg/m ³)					
	Date	CHP	WS	Goverguda	Ullipitta	Chopdi	Ontimamidi	CHP	WS	Goverguda	Ullipitta	Chopdi
26.05.2018	173	164	64	61	60	40	73.4	68.6	45.7	42.6	38.8	21.8
12.06.2018	171	161	61	59	57	38	77.3	69.1	45.7	38.3	34.5	27.3
27.06.2018	170	159	60	60	58	40	75.0	69.1	45.7	46.9	38.8	27.3
12.07.2018	167	156	57	57	56	39	73.2	66.7	41.6	39.7	39.6	28.0
26.07.2018	173	161	62	61	59	41	76.2	66.7	48.2	47.6	40.8	27.8
13.08.2018	169	157	59	59	57	40	74.4	67.2	42.0	40.4	40.0	29.7
27.08.2018	170	159	61	60	60	41	79.3	66.1	47.0	40.8	41.6	29.1
12.09.2018	175	163	69	68	64	44	75.6	68.8	51.4	52.5	44.9	29.7
27.09.2018	172	163	65	64	61	42	79.3	75.0	47.0	44.1	43.2	27.3
12.10.2018	179	167	70	67	68	47	80.0	69.4	50.9	49.1	44.9	27.8
29.10.2018	175	165	68	61	64	46	78.7	70.0	47.5	38.9	43.6	32.7
13.11.2018	170	168	66	65	70	45	75.0	74.4	44.9	43.7	49.5	28.3
27.11.2018	177	164	71	69	66	41	76.9	70.0	49.5	50.1	44.9	23.5
13.12.2018	180	169	67	66	69	43	79.3	66.1	49.1	45.8	48.6	28.8
27.12.2018	183	159	64	59	71	39	75.0	60.5	38.5	29.7	43.6	22.9
11.01.2019	181	166	69	67	68	42	79.3	67.2	45.3	40.0	45.3	22.2
28.01.2019	179	162	66	65	62	39	75.6	60.0	40.8	40.4	43.6	23.1
12.02.2019	178	170	69	60	65	40	76.9	67.2	47.5	41.6	45.7	23.5
27.02.2019	184	167	67	64	68	42	87.9	66.1	46.6	45.8	51.9	23.3
12.03.2019	180	169	64	60	64	44	75.0	65.5	46.1	39.3	44.4	23.8
28.03.2019	186	171	68	65	70	41	91.5	76.9	47.5	46.2	50.9	23.2
12.04.2019	182	161	64	63	65	54	82.7	62.6	46.6	44.9	43.6	34.3
26.04.2019	188	164	70	66	68	51	80.7	61.0	51.9	45.8	49.5	29.4
11.05.2019	191	168	64	68	70	53	89.5	65.0	44.4	45.8	50.5	33.6
27.05.2019	189	162	67	63	70	50	87.2	65.0	45.7	44.1	47.5	28.0
12.06.2019	186	159	63	69	67	52	85.7	61.0	44.0	51.5	45.3	34.9
27.06.2019	184	156	66	67	64	48	83.5	56.4	45.3	44.9	40.8	28.6
11.07.2019	181	152	62	64	61	45	75.6	61.0	44.9	45.8	45.3	23.3
26.07.2019	187	160	67	65	66	51	87.2	60.0	47.0	46.6	44.4	34.3
12.08.2019	177	154	62	61	60	48	73.0	55.9	44.4	38.6	40.8	28.3
28.08.2019	175	152	60	59	58	49	76.9	52.2	44.0	39.7	39.6	29.1
12.09.2019	170	149	64	58	55	47	71.8	50.4	46.6	38.6	34.9	28.6
27.09.2019	168	151	60	54	59	44	67.2	56.9	45.3	34.7	39.2	28.8
12.10.2019	171	153	62	59	54	46	71.2	57.9	41.2	40.0	34.3	27.8
28.10.2019	173	155	59	56	57	45	75.0	58.4	40.8	34.7	35.3	23.3
12.11.2019	177	153	63	60	59	48	76.3	56.9	45.7	39.7	40.0	28.0
27.11.2019	180	154	61	58	56	46	75.6	56.9	40.0	39.3	34.3	28.3
12.12.2019	183	157	66	61	60	50	84.2	56.4	44.4	40.0	39.6	29.1
27.12.2019	181	154	63	58	62	52	82.0	55.0	39.6	40.4	43.6	34.9
11.01.2020	184	157	65	60	63	54	78.2	62.6	44.0	41.2	39.2	33.3
27.01.2020	180	155	62	57	59	50	79.6	58.4	40.0	39.3	34.9	28.8
12.02.2020	182	158	60	59	54	47	77.6	55.9	39.2	39.3	29.4	28.0
27.02.2020	188	161	63	56	58	51	80.7	56.9	45.3	34.3	39.2	28.8
12.03.2020	191	164	65	58	56	50	88.7	63.1	44.4	38.2	32.7	28.3
26.03.2020	186	159	61	53	57	48	75.6	55.5	39.6	34.7	33.3	27.5
11.04.2020	133	136	55	44	51	39	41.7	40.0	34.6	27.8	32.7	23.3
27.04.2020	142	134	51	40	49	35	47.8	41.0	33.3	21.8	28.0	17.0
13.05.2020	149	138	52	44	43	36	45.4	40.0	33.6	28.6	27.5	17.5
27.05.2020	181	151	60	50	55	42	77.6	51.3	40.0	27.6	33.0	22.4
11.06.2020	179	153	58	49	52	41	75.6	50.0	38.9	28.6	32.7	22.0
26.06.2020	182	157	56	49	50	40	78.2	51.3	34.3	28.3	29.4	22.2
11.07.2020	176	155	53	46	48	38	76.3	52.2	34.6	27.3	28.3	17.8
28.07.2020	175	152	50	42	45	39	73.7	51.3	29.4	23.3	27.3	17.6
12.08.2020	181	160	55	47	50	41	81.3	57.4	34.9	28.6	32.7	22.0

KHG OC	PM ₁₀ (µg/m ³)						PM _{2.5} (µg/m ³)					
	Date	CHP	WS	Goverguda	Ullipitta	Chopdi	Ontimamidi	CHP	WS	Goverguda	Ullipitta	Chopdi
27.08.2020	176	154	49	41	46	37	75.6	55.9	28.0	23.3	27.3	21.8
10.09.2020	183	163	48	49	51	42	80.0	62.1	28.3	27.8	29.4	22.4
26.09.2020	180	159	43	45	48	39	77.6	56.4	23.1	23.3	28.8	17.5
12.10.2020	174	156	37	40	45	35	70.6	55.5	17.8	21.6	23.1	16.8
28.10.2020	170	151	34	37	41	32	66.7	51.3	17.1	17.2	22.2	16.2
11.11.2020	173	158	36	41	44	37	70.6	57.4	17.3	22.5	22.9	17.3
25.11.2020	171	153	33	38	40	35	67.8	56.4	17.0	17.5	21.8	16.8
10.12.2020	175	157	38	43	45	39	72.4	58.4	17.6	22.9	23.3	21.0
28.12.2020	170	152	34	40	42	34	70.6	52.6	16.8	21.6	22.2	17.5
11.01.2021	174	156	37	44	46	38	73.0	56.4	16.5	23.3	26.8	17.1
27.01.2021	168	150	35	39	41	33	65.5	52.6	17.0	20.9	22.4	17.3
10.02.2021	171	154	34	42	43	36	69.4	55.0	17.1	22.5	21.8	16.7
25.02.2021	177	159	41	46	45	39	76.9	59.0	21.6	26.6	22.9	17.1
10.03.2021	180	163	45	50	49	41	78.2	61.5	21.8	27.3	23.5	17.6
25.03.2021	183	168	48	54	52	44	82.0	66.1	27.8	28.3	28.8	21.8
10.04.2021	187	171	52	57	56	48	84.3	69.4	28.0	33.1	28.0	22.6
26.04.2021	190	175	52	58	59	51	86.4	68.3	27.8	28.1	28.8	23.1
11.05.2021	195	172	56	61	63	55	85.0	69.4	28.0	29.2	32.1	23.5
26.05.2021	178	163	51	56	53	46	71.2	60.5	26.5	28.1	28.3	22.2
11.06.2021	184	170	53	58	57	48	80.0	66.7	28.5	31.6	29.1	23.3
25.06.2021	189	174	55	61	60	52	81.3	70.0	27.8	33.7	32.7	23.8
10.07.2021	181	169	53	56	54	49	70.6	66.1	22.9	28.9	27.5	22.9
27.07.2021	185	172	50	59	58	46	78.2	70.6	23.5	29.4	28.6	23.3
11.08.2021	177	167	46	55	53	41	71.2	65.0	21.8	27.3	23.5	22.2
26.08.2021	179	170	49	57	56	44	69.4	66.1	21.4	27.8	23.3	22.0
11.09.2021	170	162	42	49	46	38	65.5	60.0	20.9	26.8	22.6	20.7
25.09.2021	174	167	45	54	50	40	68.4	61.5	21.8	28.1	23.5	20.9
11.10.2021	178	170	48	51	52	43	72.4	63.7	22.2	28.3	26.8	22.9
27.10.2021	181	174	47	56	55	46	73.0	66.1	23.1	27.8	27.3	22.6
11.11.2021	183	176	49	59	57	47	75.0	65.5	22.2	28.3	28.6	22.0
26.11.2021	186	180	53	62	61	49	76.3	70.0	24.2	31.6	29.4	22.9
10.12.2021	178	172	61	58	56	46	70.6	67.2	29.4	28.1	27.8	22.4
30.12.2021	166	167	54	53	51	40	64.4	60.0	27.5	27.1	26.3	21.4
15.01.2022	173	170	59	57	58	47	71.2	65.5	29.4	28.1	27.8	22.6
31.01.2022	177	173	61	62	60	49	74.4	70.6	32.1	29.7	29.1	23.3
10.02.2022	173	168	58	59	57	46	71.2	65.0	29.4	28.9	28.3	22.4
25.02.2022	176	171	62	61	59	50	75.0	70.0	30.8	32.2	28.8	23.5
11.03.2022	180	174	60	64	61	53	75.6	71.2	38.8	33.7	32.7	27.5
26.03.2022	184	178	63	66	62	50	76.9	69.4	29.1	32.8	29.7	23.3

Appendix VIII

Silt and Moisture Content of 6 Opencast Coal Mines

Table 1. Silt content of 6 Opencast Coal Mines

Height/Depth	JVR OC	GK OC	RG OC-I	SRP OC	BPA OC	KHG OC
90m	11.24	17.25	23.75	19.43	17.64	16.76
60m	9.38	17.42	30.00	15.00	14.30	13.39
30m	8.45	21.00	27.50	23.75	11.04	10.92
0m	10.14	14.00	13.75	22.50	10.56	9.48
30m(-)	12.52	18.00	11.50	12.50	9.85	9.10
60m(-)	13.48	20.00	10.75	10.00	8.57	8.67
90m(-)	14.54	24.00	10.00	8.75	8.13	8.05
Avg	11.39	18.81	18.18	15.99	11.44	10.91

(-) indicates depth

Table 2. Moisture content of 6 Opencast Coal Mines

Height/Depth	JVR OC	GK OC	RG OC-I	SRP OC	BPA OC	KHG OC
90m	3.51	3.00	4.56	5.89	5.65	6.58
60m	3.87	4.65	4.82	5.56	6.19	6.97
30m	3.90	5.35	5.05	5.75	6.34	6.89
0m	4.05	5.09	5.63	6.12	6.58	7.25
30m(-)	4.06	5.25	5.61	6.09	6.63	7.33
60m(-)	5.96	5.00	5.80	6.39	7.96	7.54
90m(-)	6.24	6.25	6.16	6.42	8.05	7.80
Avg	4.51	4.94	5.38	6.03	6.77	7.19

(-) indicates depth

Appendix IX

Code for development of software. Python code has been used for development of software (PMPOM) used for prediction of PM using RF algorithm.

```
import tkinter as tk
from tkinter import ttk
import pandas as pd
from sklearn.ensemble import RandomForestRegressor
from sklearn.model_selection import train_test_split
import numpy as np
from PIL import ImageTk
selected_mine = ""
def on_select(selection):
    global selected_mine
    selected_mine = selection
def predict_PM(list_x, index):
    list_x_numeric = [float(x) if str(x).replace('.', '', 1).isdigit() else 0.0 for x in list_x]
    xls = pd.ExcelFile(excelfile)
    mydata = pd.read_excel(xls, filename)
    x_train = mydata.iloc[:, :10]
    y_train = mydata.iloc[:, 10 + index]
    x_train, _, y_train, _ = train_test_split(x_train, y_train, test_size=0.05, random_state=50)
    mybagmodel = RandomForestRegressor(criterion='squared_error', max_features='sqrt')
    mybagmodel.fit(x_train, y_train)
    list_x_arr = np.array(list_x_numeric).reshape(1, -1)
    pred = mybagmodel.predict(list_x_arr)
    return pred[0]
def get_output_fields():
    if selected_mine == "BPA OC":
        return ["CHP", "WS", "Khairagpura", "Sonapur", "Bijal", "Gampalapalli"]
    elif selected_mine == "GK OC":
        return ["CHP", "WS", "Sitampet", "Penagadapa", "Tippanapalli", "RDP Colony"]
    elif selected_mine == "JVR OC":
        return ["CHP", "WS", "Kistaram", "Pallewada", "Sathupally", "Venkatapuram"]
    elif selected_mine == "KHG OC":
        return ["CHP", "WS", "Goverguda", "Ullipitta", "Chopri", "Ontimamidi"]
    elif selected_mine == "RG OC":
        return ["CHP", "WS", "Gunjapadugu", "Sector-III", "Julapalli", "Mulakalapalli"]
```

```

else:
    return ["CHP", "WS", "Srirampur", "Ramaraopet", "Indaram", "Sitarampalli"]
def get_values():
    global output_frame
    global filename
    global excelfile
    global selected_mine
    if selected_mine == "Select":
        return
    mining_values = [mining_entry_vars[i].get() if mining_entry_vars[i].get() else 0.0 for i in range(5)]
    meteorological_values = [meteorological_entry_vars[i].get() if meteorological_entry_vars[i].get() else
    None for i in range(5)]
    values = mining_values + meteorological_values
    season = ""
    if radio_var1.get() == 1:
        season = "Sumr"
    elif radio_var1.get() == 2:
        season = "Rain"
    elif radio_var1.get() == 3:
        season = "Wint"
    predict = "PM 2.5" if radio_var2.get() == 1 else "PM 10"
    filename = f"{selected_mine} {predict} {season}"
    excelfile = f"{selected_mine}_for_programming.xlsx"
    output_label.config(text="")
    xls = pd.ExcelFile(excelfile)
    mydata = pd.read_excel(xls, filename)
    avg_meteorological_values = mydata.iloc[:, 5:10].mean().tolist()
    for i, val in enumerate(meteorological_values):
        if val is None:
            meteorological_values[i] = avg_meteorological_values[i]
    values = mining_values + meteorological_values
    output_fields = get_output_fields()
    predictions = [round(predict_PM(values, i), 2) for i in range(len(output_fields))]
    for i, prediction in enumerate(predictions):
        output_entry_vars[i].set(prediction)
    for i, field in enumerate(output_fields):
        label = ttk.Label(output_frame, text=field)
        label.grid(row=i+1, column=0, padx=10, sticky="w")

```

```

if selected_mine != "":
    output_frame.grid(row=1, column=0, columnspan=3, padx=10, pady=10, sticky="nsew")
output = f"Mine: {selected_mine}\n Season: {season}\n Parameter: {predict}\n Excel file: {excelfile}"
output_label.config(text=output)
primary_color = "#3498db"
secondary_color = "#2980b9"
background_color = "#006400" # Define the green color hex code
root = tk.Tk()
root.title("PREDICTION OF PM 10 AND PM 2.5")
root.configure(bg="light green")
screen_width = root.winfo_screenwidth()
screen_height = root.winfo_screenheight()
window_width = int(screen_width * 0.9)
window_height = int(screen_height * 0.9)
x_offset = (screen_width - window_width) // 2
y_offset = (screen_height - window_height) // 2
root.geometry(f'{window_width}x{window_height}+{x_offset}+{y_offset}')
root.configure(bg="light green")
root.grid_rowconfigure(0, weight=1)
root.grid_columnconfigure(0, weight=1)
root.grid_columnconfigure(1, weight=1)
root.grid_columnconfigure(2, weight=1)
style = ttk.Style()
style.configure("Bordered.TFrame", borderwidth=2, relief=tk.SOLID)
main_frame = ttk.Frame(root, style="Green.TFrame")
main_frame.pack(fill=tk.BOTH, expand=True)
input_frame1 = ttk.Frame(main_frame, style="Bordered.TFrame")
input_frame1.grid(row=0, column=0, padx=10, pady=10)
input_frame2 = ttk.Frame(main_frame, style="Bordered.TFrame")
input_frame2.grid(row=0, column=1, padx=10, pady=10)
input_frame3 = ttk.Frame(main_frame, style="Bordered.TFrame")
input_frame3.grid(row=0, column=2, padx=10, pady=10)
output_frame = tk.Frame(main_frame, bg='light green', bd=2, relief=tk.SOLID)
output_frame.grid(row=3, column=0, columnspan=3, padx=10, pady=20, sticky="nsew")
output_frame.grid_remove()
line_label = ttk.Label(input_frame1, text="Select the mine, PM & season ", font=("Arial", 14, "bold"))
line_label.grid(row=0, column=0, pady=0, padx=0, sticky="w")
variable = tk.StringVar(root)

```

```

options = ["Select", "BPA OC", "KHG OC", "SRP OC", "RG OC", "GK OC", "JVR OC"]
variable.set("Select")
dropdown = ttk.OptionMenu(input_frame1, variable, "Select", *options, command=lambda value:
on_select(value))
dropdown.grid(row=1, column=0, pady=5, padx=0, sticky="w")
radio_frame = ttk.Frame(input_frame1)
radio_frame.grid(row=1, column=1, padx=10, pady=10, sticky="w")
radio_var1 = tk.IntVar()
radio_var2 = tk.IntVar()
radio_label2 = ttk.Label(radio_frame, text="Predict :")
radio_label2.grid(row=0, column=0, sticky="w")
radio2_option1 = ttk.Radiobutton(radio_frame, text="PM 2.5", variable=radio_var2, value=1)
radio2_option1.grid(row=1, column=0, sticky="w")
radio2_option2 = ttk.Radiobutton(radio_frame, text="PM 10", variable=radio_var2, value=2)
radio2_option2.grid(row=2, column=0, sticky="w")
radio_label1 = ttk.Label(radio_frame, text="Enter the season :")
radio_label1.grid(row=3, column=0, sticky="w")
radio1_option1 = ttk.Radiobutton(radio_frame, text="Summer", variable=radio_var1, value=1)
radio1_option1.grid(row=4, column=0, sticky="w")
radio1_option2 = ttk.Radiobutton(radio_frame, text="Rainy", variable=radio_var1, value=2)
radio1_option2.grid(row=5, column=0, sticky="w")
radio1_option3 = ttk.Radiobutton(radio_frame, text="Winter", variable=radio_var1, value=3)
radio1_option3.grid(row=6, column=0, sticky="w")
mining_parameters_label = ttk.Label(input_frame2, text="Mining Parameters", font=("Arial", 14,
"bold"))
mining_parameters_label.grid(row=0, column=0, pady=10, padx=10, sticky="w")
mining_titles = [
    "Production (Coal+OB) [in Te/day]",
    "Area contributing to pollution [in hectares]",
    "Max. Quarry depth [in m]",
    "Max. Dump height [in m]",
    "Lead distance [in km]"]
mining_entry_vars = [tk.StringVar() for _ in range(5)]
mining_frame = ttk.Frame(input_frame2)
mining_frame.grid(row=1, column=0, pady=5, padx=10, sticky="w")
for i in range(5):
    title_label = ttk.Label(mining_frame, text=mining_titles[i])
    title_label.grid(row=i, column=0, padx=10, sticky="w")

```

```

entry = ttk.Entry(mining_frame, textvariable=mining_entry_vars[i])
entry.grid(row=i, column=1, sticky="w")
meteorological_parameters_label = ttk.Label(input_frame3, text="Meteorological Parameters",
font=("Arial", 14, "bold"))
meteorological_parameters_label.grid(row=0, column=0, pady=10, padx=10, sticky="w")
meteorological_titles = [
    "Predominant wind direction [in degrees]",
    "Avg Temp [in degree Celsius]",
    "Avg Humidity [in %]",
    "Avg Rainfall [in mm]",
    "Avg Wind speed [in m/s]"]
meteorological_entry_vars = [tk.StringVar() for _ in range(5)]
meteorological_frame = ttk.Frame(input_frame3)
meteorological_frame.grid(row=1, column=0, pady=5, padx=10, sticky="w")
for i in range(5):
    title_label = ttk.Label(meteorological_frame, text=meteorological_titles[i])
    title_label.grid(row=i, column=0, padx=10, sticky="w")
    entry = ttk.Entry(meteorological_frame, textvariable=meteorological_entry_vars[i])
    entry.grid(row=i, column=1, sticky="w")
button_frame = ttk.Frame(main_frame)
button_frame.grid(row=2, column=0, columnspan=3, pady=10)
style = ttk.Style()
style.configure('DarkGreen.TButton', foreground='black', background='#006400')
get_values_button = ttk.Button(button_frame, text="Predict", command=get_values,
style='DarkGreen.TButton')
get_values_button.pack()
output_label = ttk.Label(output_frame, text="Output Values", font=("Arial", 14, "bold"))
output_label.grid(row=0, column=0, pady=10, padx=10, sticky="w")
output_entry_vars = [tk.StringVar() for _ in range(6)]
for i in range(6):
    entry = ttk.Entry(output_frame, textvariable=output_entry_vars[i])
    entry.grid(row=i+1, column=1, padx=10, sticky="w")
root.mainloop()

```


LIST OF PUBLICATIONS

LIST OF PUBLICATIONS BASED ON Ph.D. RESEARCH WORK

1. **Ravi Kiran Podicheti** and Ram Chandar Karra (2022). “Impact of enhanced production from opencast coal mines on ambient particulate emissions”. *Proc. International Conference on geotechnical challenges in Mining, Tunnelling and Underground Infrastructures (ICGMTU)*. Published in Springer series: *lecture Notes in Civil Engineering*. Pp. 551-561. https://doi.org/10.1007/978-981-16-9770-8_36
(Scopus)
2. **Podicheti Ravi Kiran** and Ram Chandar Karra (2024). “Analysis of concentration of ambient particulate matter in the surrounding area of an opencast coal mine using machine learning techniques”. *Journal of Mining and Environment*. <https://doi.org/10.22044/jme.2024.13960.2604>
(Scopus)

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