6 Model Predictions

As mentioned in the previous sections, the AERMOD was performing well for daily PM10 and particulate Uranium concentrations; so further, we extended our work to carry out predictions using AERMOD View for hourly, monthly, seasonal and annual concentrations of PM10, PM2.5, U, SO2 and NOX, in & around Tummalapalle uranium mining at all the receptors for the year 2011. A total of 969 receptors were selected within the 32 km radius of Tummalapalle mine taking boiler stack as reference point.

Hourly, Monthly, seasonal & annual concentrations were predicted (PM10, PM2.5, U, NOX, SO2) and obtained results were presented in the following sections. Even though concentrations were all the receptors, the data was presented for discrete receptors for the better understanding. For ease of reading and to understand the data, only PM10 concentrations were explained elaborately, whereas remaining pollutant concentrations were briefly explained as results followed similar trends.

Further, the estimations were also made for mitigated for the existing 3000 TPD. In addition pollutant concentrations for proposed 4500 TPD were also predicted. Here mitigated and unmitigated were also discussed. Prediction of pollutant concentrations for extra plant capacity of 4500 TPD along with 3000 TPD were made considering mitigation and non-mitigation cases.

AERMOD View Predicted Average Concentrations (Cp) PM10

The predicted hourly, daily, monthly, seasonal and annual concentrations were examined to study the pollutant trends. The pollutant concentration distributions for PM10 are explained in detail for hourly and daily time periods, and for the remaining pollutants brief description was presented.

PM10

Hourly dispersion of PM10 dispersion for 2011 was presented in the section 6.1.1.1 Daily pollutant dispersion for all the five pollutants was discussed in 6.1.1.2.

Hourly average PM10 concentrations in the modeling area

One hourly and daily prediction of AERMOD View simulations for PM10 on 21st October, was taken as an example to discuss the evolution of pollutant dispersion. PM10 dispersion from sources to the 11 discrete receptors locations was presented. A maximum of 1h concentration of 378μg/m3 was observed near area sources at the receptor (205285/1585074) Figure 6.1. From Figure 6.1 to 6.3, it was observed that, on 21-10-2011, pollutant PM10 dispersion was dependent on meteorological factors like wind speed, MH and temperatures.
Figure Error! No text of specified style in document..1: Predicted maximum hourly concentration of PM10 on 21-10-2011

Figure Error! No text of specified style in document..2: Wind rose on 21-10-2011

The nearest location to the pollutant sources, L-11 showed highest PM10 concentrations along with L7-Mabbuchinthalapalle (333.25µg/m3) (Table 6.1). Predominant wind direction (Figure 6.2) was from South and South-East-East, which was towards locations L-11, L-2, L-7, L-4, and L-8, hence resulted in high PM10 and other pollutants concentrations at these locations respectively.
Abnormally L-7 showed highest concentration, may be due to the presence of 726 m height hilly obstacle and the presence of 55.2 m Monin-Obukhov layer indicating the stable atmosphere (Figure 6.3). Stable atmospheric state usually prevails whilst warm air resulted from daytime earth heating is on top of the cool air and the mixing height is considerably unchanging, consequently resulting in a temperature inversion.

Released air pollutants in the lower atmosphere during temperature inversion get trapped and only strong horizontal winds could make them disperse. Thus maximum pollution levels were witnessed at 2000 LT here. Remaining locations recorded minimal concentrations. From Table 6.1 we can see that, all these maximum concentrations resulted from 1000 LT to 1800 LT, except for L-2 and L-7. On 21st October 2011 the highest 1 hour concentration might have resulted due to available high mixing height owing to moderate wind velocity from 1200 noon to 1730LT also contributed to the elevated concentration levels. For the study duration in 2011, overall maximum 1-hour PM10 concentration in area was predicted to be 2201μg/m3. There are no specified 1-hour ambient air quality standards for concentrations of PM10.

Table Error! No text of specified style in document..1: First highest 1 h concentrations of PM10 on 21-10-2011

<table>
<thead>
<tr>
<th>S.No</th>
<th>Discrete receptor Name</th>
<th>UTM X co-ordinate</th>
<th>UTM Y co-ordinate</th>
<th>Base elevation</th>
<th>Hill height</th>
<th>Distance from the mine</th>
<th>PM10(μg/m3)</th>
<th>0-24hour s on</th>
</tr>
</thead>
</table>

Figure Error! No text of specified style in document..3: Hourly variation of Mixing height and wind speed with Temperature on 21-10-2011
<p>| | | | | | | |</p>
<table>
<thead>
<tr>
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<tbody>
<tr>
<td>L11</td>
<td>UCIL-Near Mine</td>
<td>205685.3</td>
<td>1584893</td>
<td>374.31</td>
<td>725</td>
<td>0.53</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>L1</td>
<td>Tummalapalle</td>
<td>203871.2</td>
<td>1585626</td>
<td>354.26</td>
<td>733</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>1800LT</td>
</tr>
<tr>
<td>L6</td>
<td>Rachakunta palle</td>
<td>208346.7</td>
<td>1583429</td>
<td>377.49</td>
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<tr>
<td>L7</td>
<td>Mabbuchintala palle</td>
<td>203727.4</td>
<td>1586739</td>
<td>335.85</td>
<td>726</td>
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<tr>
<td>L5</td>
<td>Bhumaigaripalle</td>
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<td>1100LT</td>
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<tr>
<td>L2</td>
<td>Velpula</td>
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<tr>
<td>L3</td>
<td>Vemula</td>
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<td>L9</td>
<td>V.Kothapalle</td>
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<tr>
<td>L4</td>
<td>Pulivendula</td>
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</tr>
<tr>
<td>L10</td>
<td>Pandula Kunta</td>
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<td>1569471</td>
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<td>920</td>
<td>17.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1100LT</td>
</tr>
</tbody>
</table>
Daily PM10 concentrations at discrete receptors were presented in the Figure 6.4. Only L-11, L-1, L-7 and L-2 showed high concentrations. At L-11, 49.78µg/m³ of PM10 was observed; At L-2, L-8 and L-4 moderate concentrations were observed. At remaining L-6, L-5, L-3, L-9 and L-10 very minute concentrations were obtained. This may be due to the predominant wind direction towards North, North-West-West on that day. PM10 plume was dispersed towards NS also and pollutant cloud mainly covered locations L-1, L-2, L-4, L-11, L-7 and L-8, excluding L-3, L-5, L-6, L-8, L-9 and L-10 (Figures 6.5 and 6.7). The concentration of PM10 at discrete receptors over 24 h periods is less than the Indian air quality standard of 100µg/m³.

![Graph showing PM10 concentrations at various locations](image)

**Figure Error! No text of specified style in document.4:** Predicted daily PM10 concentrations at discrete receptors on 21-10-2011
Daily PM10 concentrations at discrete receptors were presented in the Figure 6.7. Only L-11, L-1, L-7 and L-2 showed high concentrations. Average daily PM10 concentrations for all locations
varied from the detection limit of 0.0204µg/m3 to 378µg/m3, with a geometric mean of 47.2µg/m3 and an arithmetic mean of 9.497µg/m3. In the study area for the modeling period, 24h predictions for PM10 showed that maximum highest 24h concentration of 378µg/m3 at a receptor (204785/1585674) located at a distance (0.5 km) close to area sources due to the presence of downwind effect that created air movement around the mine.

In general, the more distant monitoring stations displayed lower daily PM10 concentrations (0.19 to 0.035µg/m3), and decreased sensitivity to source and wind direction variations; however, the site 9 (L-9), approximately 14.28 km North-South, recorded a higher daily concentration (4.03 µg/m3). Location 11 (UCIL-mine) being the nearest receptor located near mine and location 10 (Pandulakunta) the farthest. In addition, decreasing hourly and daily concentrations were observed for PM10 at all of the 10 community air monitoring stations (L-1 to L-10 are located in villages except L-11).

Particulate Uranium

The maximum 24h particulate U concentration at the discrete receptors in the modeling area was predicted to be 13.41µg/m3 on 29-4-11 (Figures 6.8 and 6.9) and corresponding wind rose is shown in wind rose Figure 6.10.
From this wind rose it can be seen that the wind direction is from South-West, South and North-West-West and the resultant wind direction was towards North-East and North-West and hence the pollutant dispersion in those directions. Because of the presence of mountains on back side of the mine, the resultant wind direction changes. Therefore it transposes the figure 6.8 and 6.9.

Average U daily concentrations in modeling area ranged from 0.00014μg/m3 to 31.41μg/m3 over a year period (Figures 6.11 and 6.12), with mean concentration of 1.37μg/m3 and a geometric mean of 0.134μg/m3.
All predicted particulate U concentrations at receptors were below ambient standards for the annual maximum allowed standard of 0.03μg/m³. Predicted effects of U in the area were determined to be fairly small at L-11, L-1 and L-5 receptors and were nonexistent all other receptors (Figure 6.12). L-11 being the receptor near to mine, the maximum predicted U concentrations were obtained near ventilation shafts and ROM and waste piles.

In the modeling area, major part of the high concentrations predicted were at receptor locations, L-11, L-5, L-1, L-7 and L-9 respectively in the declining order of concentrations with respect to distance from the source. High concentration (9.85μg/m³ and 10μg/m³) were observed at L-5 (Bhumaigaripalle) and L-9-V.Kothapalle on 13th June.

This may be attributed to the fact that, these high concentrations might have resulted due to the seasonal wind directions towards these locations, though the distance from the mine is more.

From the analysis, maximum of daily concentrations of 3μg/m³ were observed up to the receptor L-7, Mabbuchinthalapalle located at a distance of 3.71 km, beyond this radius very nominal concentrations were simulated. There are no established CPCB guidelines for 24h for U, however, as per OSHA (Occupational Safety and Health Administration) the standard is 250μg/m³ TWA (time weight averaged over 8 hour work shift). The 1h concentrations of particulate U were in the range of 0.002 to 37μg/m³ in the modeling area. There are no 1h standards for Uranium.

PM2.5

Average daily PM2.5 concentrations for all locations varied from the detection limit of 0.0005μg/m³ to 43.63μg/m³ (Figure 6.13 and 6.15), with a geometric mean of 0.48μg/m³. In general, the daily PM2.5 concentrations were high only at L-11, L-1, L-5, L-9 and L-4. At L-6, L-2, L-4, L-5, L-7 and L-10, its concentrations were very low. This might be attributed to the predominant wind direction towards North, NS during the study period. Maximum daily concentration of 317μg/m³ was observed in the modeling area (Figure 6.14) on 15-4-2011 nearer to the waste piles. Prediction for PM2.5 demonstrated that maximum highest 1h concentration of 294μg/m³ was observed at a receptor (205735/1585124) located at a distance (0.3 km North-East) in downwind direction from area sources on 12-05-11. Four exceedances were observed for PM2.5 standard violations over the entire year.
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Figure Error! No text of specified style in document. 13: Daily PM2.5 concentrations at discrete receptors:

![Map showing PM2.5 concentrations](image)

Figure Error! No text of specified style in document. 14: Maximum predicted PM2.5 concentrations on 15-4-11

![Graph showing predicted PM2.5 concentrations](image)

Figure Error! No text of specified style in document. 15: Daily PM2.5 concentrations in 2011

Sulfur Dioxide-SO2

Predicted concentrations of SO2 at the discrete receptors are shown in Figures 6.16 to 6.18. Major part of the high concentrations predicted were at receptor locations, L-11,L-5, L-1, L7 and L-9 respectively in the declining amount of concentration with respect to distance from the source.

At all receptors, maximum concentration of 67.18μg/m3 was predicted at a receptor near the boiler stack and lower concentration was obtained at L-10, Pandulakunta. Average SO2 concentrations in area ranged from 0.00014μg/m3 to 43.63μg/m3 over a year period, with mean concentration of 2.527μg/m3 and a geometric mean of 3.23μg/m3 (Figure 6.17).

In the modeling area, all predicted one hour SO2 concentrations were below ambient standards for the 1-hour maximum desirable standard of 197μg/m3. At individual grid receptors in the modeling area, rare exceedances of the 24-hour standard were observed. The maximum 24-hour SO2 concentration in the chosen area was predicted to be 28μg/m3. This is below the established CPCB guidelines of 80μg/m3. Predicted 24h concentrations above 80μg/m3 are experienced only once in a while (~2% of the time).
The predicted maximum 24-hour SO2 concentrations at all other receptor locations were below the respective air quality standards of 80μg/m³ (24-hour) and 197μg/m³ (1-hour).

Oxides of Nitrogen-NOx
Major amount of the high concentrations predicted were at receptor locations, L-11, L-5, L-7 and L-9 respectively in the decreasing order of concentration with respect to distance from the source (Figure 6.19). Maximum concentration of 26.26μg/m³ was observed on 13-06-2011.

The maximum 1-hour NOx concentration in the Tummalapalle mine area was predicted to be 126μg/m³. This is well below the established NAAQS Maximum Acceptable guideline of 188μg/m³ for 1-hour concentrations of NOx. Predicted modeling results from the study at all receptors, found that in general, average NOX concentrations in area ranged from 0.0006μg/m³ to 29.17μg/m³ over a year period, with mean concentration of 19.79μg/m³ and a geometric mean of 0.16μg/m³. Maximum concentration of 29.17μg/m³ was predicted at a receptor near the mine and lower concentration was obtained at L-4, Pulivendula.

Portions of mining area nearer to the haul roads and boiler stack experienced these higher values. Remaining locations showed lesser 1h maximum values. In other words, the CPCB and NAAQS guidelines were exceeded less than 0.001% of the modeling time in the region. This is well below the established CPCB Maximum Acceptable guideline of 80μg/m³.

![Daily NOx concentrations at discrete receptors in 2011](image)

Figure Error! No text of specified style in document. 19: Daily NOx concentrations at discrete receptors in 2011

In summary, the AERMOD View hourly and daily assessment of effects of the Tummalapalle Project on surroundings suggested that, there were occasional exceedances but overall the pollution is under control and area can be deemed good. Marginal high concentrations were observed at all receptors outside 2-3 km radius of the mining site, considerable but normal concentration were obtained within 5 km radius and very small concentrations were observed beyond this 5 km. Whatever exceedances were predicted, all were within the mine facility and occurred only twice outside this area.
Monthly Concentrations

The analysis of month wise pollutant concentrations revealed that, in January, February, November and December the pollutant concentrations were high. This may be attributed to the fact that, lower temperatures result in stable atmospheric conditions and consequent higher accumulation of pollutant concentrations. The concentrations simulated in the month of August were low. Hourly wind speed was greater than the 5 m/s and even reached 9.3 m/s during August, due to the effect of monsoon and consequent low depression weather conditions may disperse the pollutants away. Overall, winter months pollutant concentration were high and summer months simulated relatively lower concentrations. All selected pollutant monthly concentrations for January are depicted in Figure 6.20. Similarly Figures 6.21 to 6.22 show monthly pollutant dispersions for PM10 (February) and NOx (April).

For Uranium all month concentrations were presented in Figure 6.23. From the figure, it can be seen that, except for L-11 and sometimes L-5, all remaining U monthly concentrations were very small.

In general months in winter experienced high concentrations whereas, summer witnessed lower concentrations.
Seasonal Concentrations

The study of seasonal pollutant distribution showed that, pollutants followed characteristic shifts in the flow direction among the winter, summer and monsoon months (Figure 5.1a, b and c). During the summer the average wind direction was from the West and South with just about no flow from the North and East. Similarly monsoon and winter had distinct directions. Figure 6.24 shows the seasonal variation of pollutants around the mine at L-11.
Wind field patterns obtained for the winter months showed more frequent flow from the NE, East and SSE, resulting in dense plume over L-7 and L-11, surprisingly L-1 was least affected during winter. VC value was higher for winter implying poor assimilative capacity of atmosphere, hence high concentrations were predicted (Figure 6.24).

In summer, affected area is only L-11-UCIL mine (Figure 6.25). Wind flow was towards North-East, East and North- North-East during the monsoon months with an increase in the North-East flow. L-7-Mabbuchinthalapalle and L-5-Bhumaigaripalle were affected during Monsoon (Figure 6.26). Pollutant dispersion was towards L-11, UCIL mine and L-5, Bhumaigaripalle and slightly over L-9, V. Kothapalle in winter (Figure 6.27 to 6.30).
Figure Error! No text of specified style in document. 25: Pollutant concentrations at discrete receptors during Summer-2011

Figure Error! No text of specified style in document. 26: Pollutant concentrations at discrete receptors during Monsoon-2011

Figure Error! No text of specified style in document. 27: PM10 dispersion during winter 2011

Figure Error! No text of specified style in document. 28: Pollutants dispersion in winter at discrete receptors in 2011
Aside from the very low frequency of winds from the west and south-west directions to Tummalapalle mine, it should be noted that the highest impact from a fixed source like mine, generally becomes obvious under stable meteorological conditions which prevail generally in low temperature days i.e. winter.

Annual Concentrations of Pollutants

Annual plot (Figure 6.31) for mine shows that, all the pollutant concentrations were below the CPCB/NAAQ limits.
Figure Error! No text of specified style in document..32 Annual pollutant concentrations at discrete receptors
Figure 6.32 shows that, only the discrete receptors, UCIL mine (L-11), Tummalapalle (L-1), Mabbuchinthalapalle (L-7) and Bhumaigaripalle (L-5), which are within 5 km radius from the reference point experienced significant concentrations.

Particulate Matter (PM10)

We can clearly understand from the Figures 6.33 and 6.34 that, pollutant dispersion strongly depends on the wind direction due to the South-West-West and Southern prevailing winds which flew towards the area, affect the mine emissions. Pollutant dispersion was due in North-East-East direction (Figures 6.33). As the distance from the reference point increased, very low concentrations were observed within 32 km modeling domain and showed prominent seasonal and diurnal dependence.

Annual averages concentration of PM10 for the year 2011 was 44.8μg/m3 at (205024.44/1585192.16) and this concentration was observed at site 11 near the mine within core zone situated about 450m east of the facility, the predominant source within the study area.

No pollutant cloud was observed over L6-Rachakuntapalle, which is at a distance of 3.73 km from the site. Receptor L1 (Tummalapalle), situated at about 1 km from the site, also experienced a nominal concentration in the range of 0.3 to 1μg/m3.
Figures 6.35 and 6.36 explain the evolution of PM2.5 concentrations along the downwind distance till 4.5 km from the sources. The obtained annual concentration is less than the stipulated CPCB-NAAQS limit of 40μg/m3.
For PM2.5, maximum annual AERMOD View predicted concentration was 39.7μg/m³ and ranged between 0.3 and 33μg/m³ at the receptors with the co-ordinates (205635/1584974). The high levels were observed near to major dust sources namely, ROM, waste piles and haul roads.

Particulate Uranium

Uranium impact was not predicted beyond 4 km, that too only traces were found towards L-5 (Bhumaiagaripalle) which lies in the down wind direction from the mine. As shown on Figure 6.38, annual average Uranium concentrations predicted were reduced quickly from a level of 12.7μg/m³ in close proximity to the mill to 0.003μg/m³ within 2 km of the mine site (Figure 6.37).

Annual averages concentration of Uranium for the year 2011 was 12.7μg/m³ at (205024.44/1585192.16) and this concentration was observed at Ll-11 near the mine within core zone situated about 670m North-East of the facility.

Nitrogen Dioxide (NOX)

Areas of mine (L-11), Tummalapalle (L-1) and Mabbuchainthalapalle (L-7) region experienced higher maximum concentrations than the Rachakuntapalle (L-6) and Bhumaiagaripalle (L-5), because of the meteorological and topographical conditions (Figure
For L-11, the predicted maximum concentration exceeded the prescribed guideline of 40μg/m³ for annual NOx concentrations, however this happened twice out of 4892 hours in the modeling period. The maximum annual NOx concentration in the modeling domain was predicted to be 23.3μg/m³. This is well below the established Indian pollution board maximum acceptable limit of 40μg/m³ for annual concentrations of NOx.

Figure **Error! No text of specified style in document.**.38: Annual NOx dispersion

Sulfur Dioxide (SO2)

The maximum annual SO2 concentration was observed in the vicinity of mining area was 39.7μg/m³ and occurred at Location-11 with the receptor co-ordinates (205585/1585074) (Figure 6.39).

These values were well below the CPCB-NAAQS limits of 50μg/m³. Minimum concentration of 0.4μg/m³ was obtained far away from the source.

Overall, the main sources of PM10 and PM2.5 seem to be emission contributions from windblown dust, vehicle entrainment on unpaved haul roads, and mining (loading and unloading operations. Auto mobile emissions were sources for SO2 and NOx and particulate Uranium was observed to be resulting partly from mine dust and remaining from the already present back ground Uranium in the atmosphere. Windblown dust from ore piles resulted in the highest ground level concentrations.
Windblown dust typically impacts downwind from the direction where the highest velocity winds occur, with vehicle entrained dust bounded near the road where it is generated from. The highest predicted daily concentrations for all pollutants (PM10, PM2.5, U, SO2 and NOx,) occurred on the days, when neutral atmospheric conditions were predominant, followed by slightly convective or slightly stable conditions. Based on the results of the assessment of possible effects of PM10, Uranium and other pollutant levels present in the atmospheric environment, it was concluded that Tummalapalle Project would not pose any undesirable effects on surroundings.

Comparison of Pollutant Concentrations for Mitigated vs. Unmitigated cases

Control technologies are applied at most of the industry to curb the pollution originating from the processes. Therefore it is necessary to study the effects of air pollution for two cases control technologies (mitigated) and without control technologies (un-mitigated). At mines, to control the emissions and in turn to reduce air pollution, source reduction practices are employed, which include the spraying of water on haul road surfaces and active work areas like storage piles to minimize windblown dust emissions during the summer months. Hence in the present study, it was aimed to predict the pollutant concentrations for mitigated and unmitigated scenarios for the existing mine capacity of 3000 TPD.

The effect of emission control strategies on the air quality in the study area assuming unmitigated case was compared with the existing mitigated case. The annual predicted concentration at different locations in and around the mine for mitigated and un-mitigated was obtained from AERMOD View.

A comparison was made for the highest annual predicted concentrations with mitigated control technology measures like water sprinkling with unmitigated annual concentrations for PM10 respectively for the year 2011 (Figures 6.40 and 6.41, respectively).
Comparison revealed that pollutant concentrations for unmitigated cases are more and it can be seen that debarring a few locations, dust concentration was below the NAAQS limit of 60μg/m³. This suggested, resulting pollution from mining activities is minimal and circumstantial confined to 5 km radius from the mine, and at these specific polluted areas, there is a need for strict mitigation measures to be followed. It was also noted that the model predictions were not affected by the source reduction practices due to harsh weather conditions with high temperatures.

Comparison of Pollutant Concentrations for 3000 TPD and Expected 4500 TPD Mining Capacity

During our field visits, it was observed that, Government of India was planning to expand the existing plant capacity of 3000 TPD to 4500 TPD. Air quality model could be used as
an efficient tool for future air quality prediction, along with ambient meteorological observations support and analysis also for emission control strategies design. Therefore AERMOD may be used for the prediction of impending air quality effects.

Hence another objective of present work was to predict the air quality in around the mine for enhanced capacity of 4500 TPD, with the help of ambient meteorological data of the year 2011. It was assumed that emission limit for the Tummalapalle mine would (when increased production of 4500 TPD is in effect) be 125g/s considering the highest possible emission rate, compared with the 2011 actual emissions case (average 85g/s). Same emission sources like boiler stack, stock and waste piles along with automobiles were considered for the estimations. For every hour all emission and meteorological conditions were kept constant and the AERMOD View model was re-run with 2011 meteorology.

Figures 6.42 and 6.43 correspond to isopleths based on 2011 meteorology for 4500TPD mining of ore for PM10 at 24h and 1h. For the average 24h and 1h periods, PM10 concentrations of 143μg/m3 and 222μg/m3 were predicted.

After the 50% increased production rate (4500 TPD case), there was a considerable change of concentrations were apparent compared to the 2011 actual emissions case.
It was observed that, a maximum 1-hour average concentration of 66.7μg/m³ was predicted by the 125 g/s run case for mitigated measures considered and 94.5μg/m³ for unmitigated cumulative run 4500 TPD case for the pollutant PM10.
The maximum annual average concentration of 80.8μg/m³, for mitigated and 479.6μg/m³ for unmitigated cumulative case were obtained. (Figures 6.44 and 6.45) show the 1h and 24h future predictions for Uranium at 4500TPD capacity at the mine and corresponding concentration dispersion patterns are illustrated. It was observed that impact can be seen up to 32.57 km for 1h and for 24h it was 25.07 km. Similarly (Figures 6.47 and 6.48) depict Uranium dispersion with color contour variations for annual emissions of existing mining of 3000 TPD to 4500 TPD enhanced capacity. We can observe the dispersion beyond the modeling area with minute concentration values.
Figures 6.46 and 6.47 explain us the 24h variation in PM2.5 dispersion for the present and enhanced ore production capability of the mine. Figures 6.48 and 6.49 show the difference in SO2 daily dispersion. We can see less green color concentration contours representing low concentrations for 3000 TPD (Figure 6.48) case and less green color contours for the 4500 TPD (Figure 6.49).
Figure Error! No text of specified style in document. 48: 24h dispersion of SO2 concentrations of 3000 TPD

Figure Error! No text of specified style in document. 49: 24h dispersion of SO2 concentrations for 4500 TPD
Similarly, Figures 6.50 and 6.51, demonstrate the annual dispersions for 3000 TPD and 4500 TPD for NOx with concentration color contour variations.

Figure Error! No text of specified style in document..50: Annual dispersion of NOx concentrations for 3000 TPD
From these figures we can observe that, for 3000 TPD, high concentrations (green color contours are present nearer to the mine and the violet color concentrations bearing lower concentrations are far from the mine. In case of 4500 TPD, the green color contours are filling up the area nearer the mine, low concentration was seen beyond the modeling area. Impact was seen up to 70 km with lower concentrations. Considerable concentrations were observed up to 32.6 km. Seasonal variation in pollution dispersion was observed. Tables 6.2 explain the annual dispersions for 3000 TPD and 4500 TPD for all the five selected pollutant concentrations at the different discrete receptors.

From Table 6.2, we can see that there is distinguished change in pollutant concentrations at L-11. At remaining discrete receptors no noticeable change in concentrations was observed. After enhanced mine capacity, the area within 3 km from mine experienced large changes in pollutant concentrations with seasonal meteorological dependency. Though the pollutant concentration increase seems less, it increased marginally from 3000 TPD capacity to 4500 TPD. Within 3 km from mine pollutant concentrations increased from 1.5 to 2 times the original concentrations. It was observed that, the density of concentrations increased drastically. In side mine premises the change was obvious from the pollutant isopleths, whereas, outside though the concentrations were high, they were not beyond the CPCB/NAAQ standards.
<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Capacity (TPD)</th>
<th>L-11</th>
<th>L-1</th>
<th>L-6</th>
<th>L-7</th>
<th>L-5</th>
<th>L-2</th>
<th>L-8</th>
<th>L-3</th>
<th>L-9</th>
<th>L-4</th>
<th>L-10</th>
<th>CPCB norms (μg/m3)</th>
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<tr>
<td>PM10(μg/m3)</td>
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<td>17.85</td>
<td>0.47</td>
<td>0.21</td>
<td>0.49</td>
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<td>0.26</td>
<td>0.2</td>
<td>0.09</td>
<td>0.25</td>
<td>0.09</td>
<td>0.009</td>
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<td>4500</td>
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<td>5.64</td>
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<td>0.13</td>
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<td>0.12</td>
<td>0.05</td>
<td>0.2</td>
<td>0.35</td>
<td>0.073</td>
<td>0.06</td>
<td>0.02</td>
<td>0.06</td>
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<td>0.03</td>
<td>0.02</td>
<td>0.001</td>
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</table>

Table Error! No text of specified style in document. 2: Comparison of Annual pollutant concentrations for the current 3000TPD and enhanced 4500 TPD mine capacity.
Control Technologies Suitable for the Mitigation and Control of Mine Emissions

Because of the enhanced mine capacity of 4500 TPD, there would be a reasonable change in mine emissions and consequent pollutant concentrations. So, a dust management plan for the mine, including the assessment of emission control efficiencies required for each significant source is necessary. Preceding identification of suitable pollution abatement measures respective dust control efficiencies, and possible contingency measures should be implemented like, a dust management plan for the mine, including the assessment of emission control efficiencies required for each significant source.

Eliminating/modifying the problematic source or operation/ Amendment of the source operation.

Care should be taken while locating and placing discrete receptors/ HVAS monitors according to seasonal wind rose diagrams.

Continuous water sprinkling on unpaved roads and stock and waste piles.

A suitably devised dust management plan for the mine, together with the review of emission control efficiencies necessary for every considerable source and possible contingency measures;

Care should be taken while locating and placing discrete receptors/ HVAS monitors according to seasonal wind rose diagrams. ROM stock and the Tailings dump walls should be covered (rock glading) up to 1 m from the top & installation of screens and ample vegetation cover be maintained to suppress the erosion.

Sprinkling environment friendly natural and chemical dust suppressants on exposed areas will be good, if water scarcity prevails at the mine area like Pulivendula, which is draught prone area.

Ex :(NaCl), (CaCl2), (MgCl2). Lignin and Asphalt Emulsions, Natural Clays and Plant Oils.

Development of green belt/planting fast growing trees in the down win direction of pollutant sources based on seasonality.

Placing metal mesh on piles. Appropriate and sufficient protection to the workers nearer to the area source is desirable.

Eliminating/modifying the problematic source or operation/ Amendment of the source operation,

Care should be taken while locating and placing discrete receptors/ HVAS monitors according to seasonal wind rose diagrams.

Continuous water sprinkling on unpaved roads and stock and waste piles.

A suitably devised dust management plan for the mine, together with the review of emission control efficiencies necessary for every considerable source and possible contingency measures;

Care should be taken while locating and placing discrete receptors/ HVAS monitors according to seasonal wind rose diagrams. ROM stock and the Tailings dump walls should be covered (rock glading) up to 1 m from the top & installation of screens and ample vegetation cover be maintained to suppress the erosion.
Placing metal mesh on piles. Appropriate and sufficient protection to the workers nearer to the area source is desirable.