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# Computer Simulation Modeling of Air Pollution Dispersion in and around Coal Mining Complexes of Multi-Sources

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**ABSTRACT**

In the present paper, the emission rates of SPM and $SO_2$ from various sources and activities of coal washery complexes have been estimated using empirical models, developed on the basis of experimental data. Further, using modified computer aided Gaussian dispersion model, simulation of SPM and $SO_2$ has been carried out in and around the coal washery complexes, which are situated at the banks of Damodar River during summer, as the concentration of air quality will be low in summer season . The isopleths of air quality parameters, SPM and $SO_2$ have been presented to visualize the dispersion pattern of the air pollutants. The presented models will be a pioneer work for the environmental researchers, engineers, policy makers and protection agencies to assess the impact of air quality in an industrial complex where is the combined consequence of multi-industrial pollution sources on the valuable receptors.

***Keywords:*** Pollution dispersion modeling, dispersion coefficients, point source, area source, and line source.

***AMS Subject Classification 2010:*** 68U07,68U20,68W01

## 1. INTRODUCTION

The impacts of *air pollution*, in particular the suspended particulate maters are considerably severe in and around a coal washery complex. The dust is generated significantly due to different operational units such as screening, crushing, loading & unloading, exposed piles and stock yards, thermal dryers and the dropping points of conveyer belts etc. The particulate maters generated during its operations are being transported by wind in downwind direction and disperse both horizontally and vertically. Further the pollutants have an adverse impact on the buildings, plants and other valuable receptors [1]. As a result, the whole eco-system is disturbed and the fertility status of the soil around the coal washery complex is significantly changes with unpleasant impacts [2]. Therefore it is very much warranted to estimate the emission of air quality from different sources of coal washery complexes using suitable statistical approach. Further the air quality in and around coal washery complexes has to be predicted using an appropriate air quality dispersion model, developed for multi-sources like elevated point source, area source, ground level point source and line source taking the terrain elevation factor and the effect of temperature variance into account. Much attention has been paid to develop mathematical models for simulating the suitable flow-sheets on the basis of the characterization the coal received from the nearby mines for preparing coals for the indented use in order to increase the production of coal with intended to meet the fast growing demand of the energy. Unfortunately less focus has been made for simulating the environmental impact due to coal preparation plants. Simulation of environmental scenario in and around coal washery complexes may help the industry in planning and implementing the control strategies for protecting the surrounding from the adverse impact.

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The present research work contributes towards Environmental Management Plan (EMP) through air pollution impact assessment using computer aided mathematical models.

## 2. METHODOLOGY

### Study Domain

A window containing seven coal washery complxes, situated nearby the Damodar River stretch of about 38Km in Dhanbad district of Jharkhand State in India was chosen for the present study. The geographical boundary of the study area is 23°35'00" to 23°45'00" N latitude and 86°15'00" to 86°30'00" E longitude. The study window has been divided into three sub-windows covering the river course have been considered for the present study and the total area of the study windows is about windows is about 50Km.Gaussian Dispersion model is nothing but the normal distributive function of the pollutants along the down wind direction (positive x-axis) and normally distributed along the y-axis having its peak at y=0. The Gaussian plume equations have been presented for various types of sources located at the point represented by the polar coordinate system (θ) where r is the distance of the point from the origin and θ is the angle of line joining the point and the origin with the positive direction of x-axis.

**A. Elevated point source:** For a source elevated a distance H above ground level, the Gaussian plume geometry has been shown in Figure 2 and the plume equation is presented as follows:

$$Cj\,(r,\theta,h) = \frac{Q_j}{2\Pi\hat{u}\,\sigma_y\sigma_z} e^{-\frac{1}{2}\left\{\frac{r\sin^2\theta}{\sigma_y^2}+\left[\frac{(h-H)^2}{\sigma_z^2}+\frac{(h+H)^2}{\sigma_z^2}\right]\right\}} \quad (1)$$

where r = distance from the point to the origin (m)

θ = angle of the line joining the point and the origin with the positive direction of x-axis (degree)

h = height from the surface (m)

Cj = concentration of species j at the point (x, y, z) (g/sec)

Qj = emission rate of the species j (g/sec)

û = average wind speed (m/sec)

H = effective plume height (m)

σy, σz = Gaussian dispersion coefficients for horizontal and vertical directions

Geometry presented in Figure 1 & Figure 2 shows the point where the plume dispersion is assumed to begin the plume centerline of elevated point source. The Gaussian dispersion model for the elevated point source is denoted as $C_e$ for convenient in the present study

Ground-level point source: For a source at ground level with perfect reflection, the Gaussian plume geometry has been shown in Figure.3 and the plume equation is presented as follows:

$$C_j\,(r,\theta,h) = \frac{Q_j}{\Pi\hat{u}\,\sigma_y\,\sigma_z} e^{-\frac{1}{2}\left(\frac{r\sin^2\theta}{\sigma_y^2}+\frac{h^2}{\sigma_z^2}\right)} \quad (2)$$

where r = distance from the point to the origin (m)

θ = angle of the line joining the point and the origin with the positive direction of x-axis (degree)

h = height from the surface (m)

Cj = concentration of species j at the point (r, θ, h) (g/sec)

Qj = emission rate of the species j (g/sec)

û = average wind speed (m/sec)

σy, σz = Gaussian dispersion coefficients for horizontal and vertical directions

The Gaussian dispersion model for the ground level point source is denoted as Cg for convenient in the present study

Line source: For a line source the Gaussian plume geometry has been shown in Figure.4 and the plume equation is presented as follows:

$$C_j(r,\theta,h) = \frac{2Q_j/L}{\sqrt{2\Pi}\hat{u}\,\sigma_z} e^{-\frac{h^2}{2\sigma_z^2}} \quad (3)$$

where r = distance from the point to the origin (m)

θ = angle of the line joining the point and the origin with the positive direction of x-axis (degree)

h = height from the surface (m)

Cj = concentration of species j at the point (x, y, z) (g/sec)

Q = emission rate of the line source per unit length (g/sec)

û = average wing speed (m/sec)

L = Length of the line source (m)

σz = Gaussian dispersion coefficients for vertical directions

The Gaussian dispersion model for the line source is denoted as $C_l$ for convenient in the present study.

**B. Area source:** The area source can be assumed as a finite number of point source by dividing into finite number of grids by taking the grid size as small as possible. Each grid is assumed as a point source. Once the emission of the air pollutants per unit area is computed, the emission from each grid can be calculated, as it is directly proportional to the area of the source falls within the grid considered. Here the location of each grid source is assumed as the center of the grid. The Gaussian dispersion model for the area source is denoted as Ca for convenient in the present study.

**C. Dispersion coefficients:** The present model require information on the values of the dispersion coefficients $\sigma_y$ and $\sigma_z$, and also the variation of these coefficients with atmospheric stability classes, wind speed and downwind distance. An attempt has been made to develop empirical models for the ground level source for different stability classes according to the meteorological condition of the study area on the basic experimental data compiled by Pasquil and Gifford.

**D. Computer-Aided Model**: The air quality dispersion model is obtained for the multi-industrial source complex, hilly terrain and valley. The model has been derived on the basic concept of Gaussian dispersion models discussed above, which was later made more effective by Turner. The sources of the air pollution may be categorized as Ground level point source (G), Elevated point source (E), Area source (A) and Line source (L). The Computer-Aided Gaussian Plume Modeling was carried out using the Pasquill–Gifford coefficients for both horizontal dispersion and vertical dispersion.

**E. Empirical models for estimating emission factors:** The major sources of air pollutants in and around a coal washery complex are coal stockpiles & silos, rotary-breaker & crusher installations, thermal dryers, coal handling & loading areas, conveyer built transfer points, dry-screening operations, dry-cleaning operations, haulage roads and transport roads. Further, the activities concerning the major sources have been identified and listed as follows:(i) Unloading of raw coals, (ii) Loading of clean coals, (iii) Loading of middlings, (iv) Loading of rejects, (v) Transport roads, (vi) Haul road, (vii) Screening plant, (viii) Thermal dryers, (ix) Exposed piles of clean coal, (x) Exposed piles of middlings, (xi) Exposed piles of rejects, (xii) Exposed surface area, (xiii) Rotary crusher and (xiv) Conveyer-belt's dropping points [4].

**F. Air quality prediction:** The air quality dispersion model for the prediction of air quality in and around the coal washery has been carried out with the aid of a super computer. The study window was divided into finite number of grids. The center of each grid is assumed to be the location of different sources that falls in the respective grids. However, the kind of each source, source height from the ground, their respective emission rates will be duly considered for the prediction of air quality whereas the wind speed and climate condition is assumed as the same. But when the altitude of the topography varies in the downwind direction, the temperature also varies. In such a situation, the program predicts the temperature using the model and the influence of the temperature on air quality has been duly incorporated in the model. Surface plan of the industry showing the locations of various operational units like coal stack yard, screening section, primary crusher, secondary crusher, chuts or drop-points of conveyor belts, exposed piles, thermal dryers, exposed surface containing coal dusts etc was prepared. The study area was divided into grid size of 100mX100m in order to mark the area occupied by the various operational units and other sources of air pollutants. The weighted average of wind speeds (km/hr) taking the percentage of hours prevailed with the ranges classified as 1.6-5, 5-10, 10-15 and 15-20 km/hr as the weightages in the different prevailing directions were calculated using the wind-rose diagrams of summer and winter seasons. The emission rates of SPM and $SO_2$ from the identified major sources were estimated using the empirical emission models. The concentration of air pollutants will be diluted in the atmosphere and it will be reduced significantly due to the inversion effect when the temperature is very high. The concentration of air quality may be high during morning, evening and night hours than noon hours in and around the coal washery complexes. Therefore the prediction of air quality in the prevailing directions with the respective average wind speed was predicted with the interval of 25m in both longitudinal (X-axis) and latitudinal (x-axis) distances for summer and winter seasons to evaluate the present model. In order to assess the optimized impact the maximum values of the SPM and $SO_2$ concentrations at the each grid were assessed using spreadsheet (Microsoft excel) and the isopleths of the concentration of the air quality parameters were plotted using the software "SURFER". The isopleths of the SPM and $SO_2$ for summer season have been presented in Figures 5 to 6.

## 3. RESULTS AND DISCUSSION

Empirical emission formulae on various sources of air pollutants in order to estimate the emission rates of various significant sources have been developed based on the experimental data generated from various field studies. These emission formulae have been evaluated through statistical analysis. The estimated empirical coefficients are based on the experiments conducted in the field. If more experiments would be conducted and the results would be used for estimating the unknown empirical coefficients, exponents and constants, the percentage of error may be minimized and the accuracy of the prediction may be brought through the empirical models. However, it has been observed that $\pm$6.1% of error occurs in the predicted emission rates of suspended solid matters (SPM) with reference to the field data and $\pm$5.23% in the emission of sulfur dioxide ($SO_2$) from all identified major sources. The predicted SPM and $SO_2$ concentrations in summer at Mahuda coal washery complex are 423 µg/m$^3$ and 37.5 µg/m$^3$ respectively, which falls in the interval, constituted with minimum and maximum values of field experimental data, viz., 402 - 457.3 µg/m$^3$; 30 - 40.32 µg/m$^3$ respectively.

The predicted SPM and $SO_2$ concentrations in summer at Munidih coal washery complex are 392 ?g/m3 and 69.3 µg/m3 respectively which falls in the interval constituted with minimum and maximum values of field experimental data, viz., 375 - 426 µg/m3; 45 - 75.4 µg/m3 respectively. Similarly, for other coal washery complexes, the predicted and field experimental data were compared and it was found that the predicted air qualities through modeling and simulation are very close to the data obtained in the laboratory by analyzing the ambient air samples. It has been found that 5 - 10% error occurs in the predicted air quality. Therefore, the present model can be used as a tool to visualize the impact of coal washeries on the surrounding.

It has been observed that SPM is the major source of pollution in and around the coal washery complexes and it has been perceived through the study that the haul roads are the significant sources among all other identified sources. It is necessary to sprinkle water along the haul roads of the washery complexes to suppress the particulate matters of the aerodynamic diameter less than 10μ. It has been found that the crusher points, drop-points of conveyer belts, screening sections are the significant sources in continuously transporting the particulate matters into the atmosphere. Therefore, it is recommended that installation of water sprinkling system in the prevailing wind direction in order to control air pollutants. It has been endorsed that raw piles of raw coals should be packed properly and made more compact using bigger size material on the top to arrest the fine particles so that the wind may not enter inside and take away them into the atmosphere. Similarly, the piles of clean coal, middling and rejects must be stored in such a place where the wind cannot have any influence on them to drive up the fine particulate matters into the atmosphere.

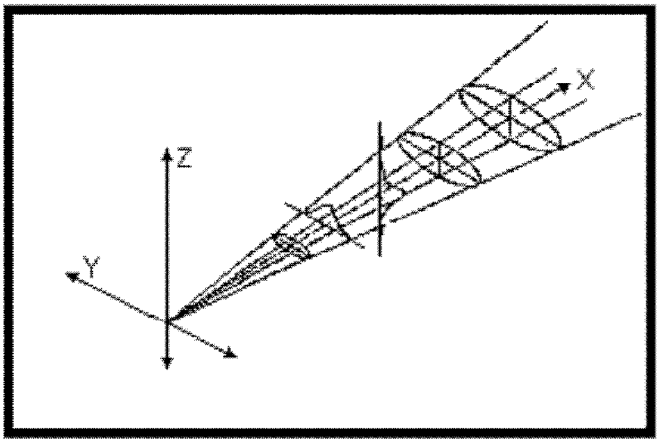



**Figure 1: Control volume of the plume**

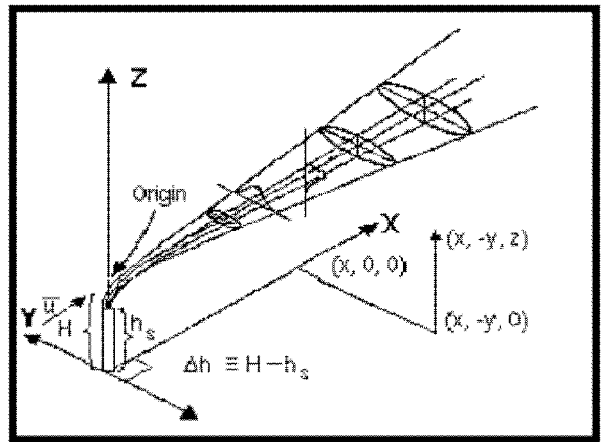



**Figure 2: Plume geometry of elevated point source**

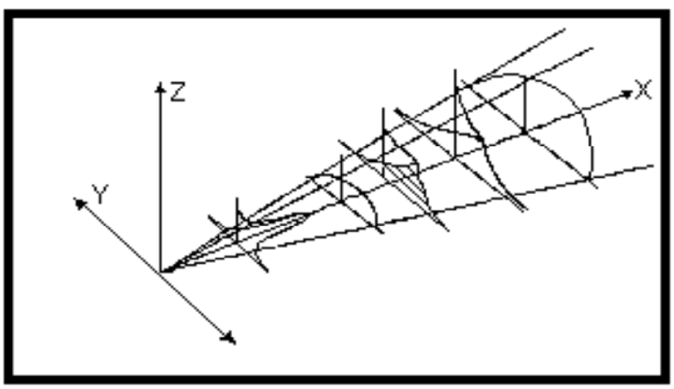



**Figure 3**: **Plume geometry of ground level**

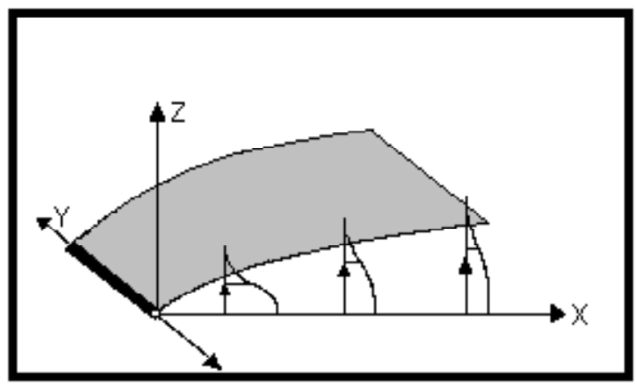



**Figure 4**: **Plume geometry of line source point source**

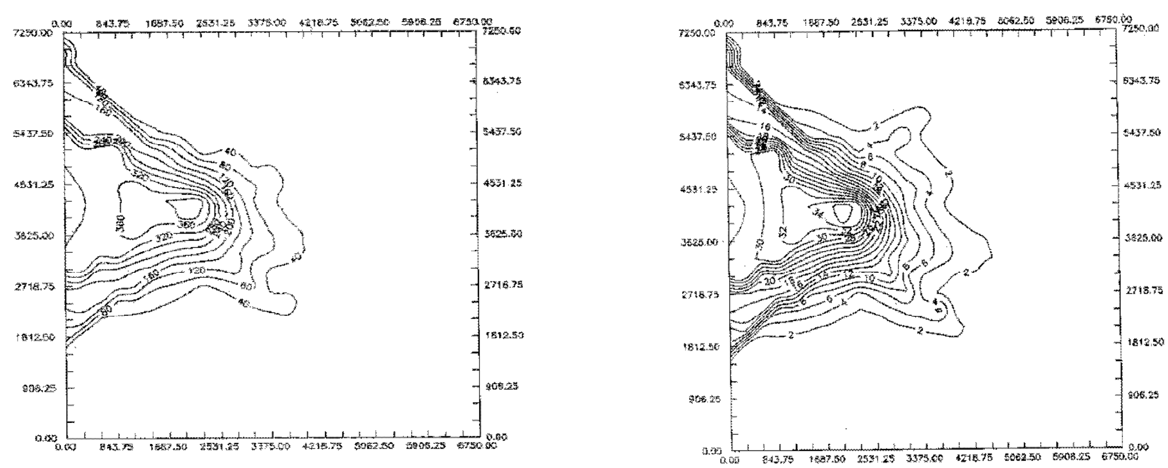


**Figure 5**: **Dispersion of air quality in the Mahuda coal washery complex of the first sub-window of the study area in summer season**

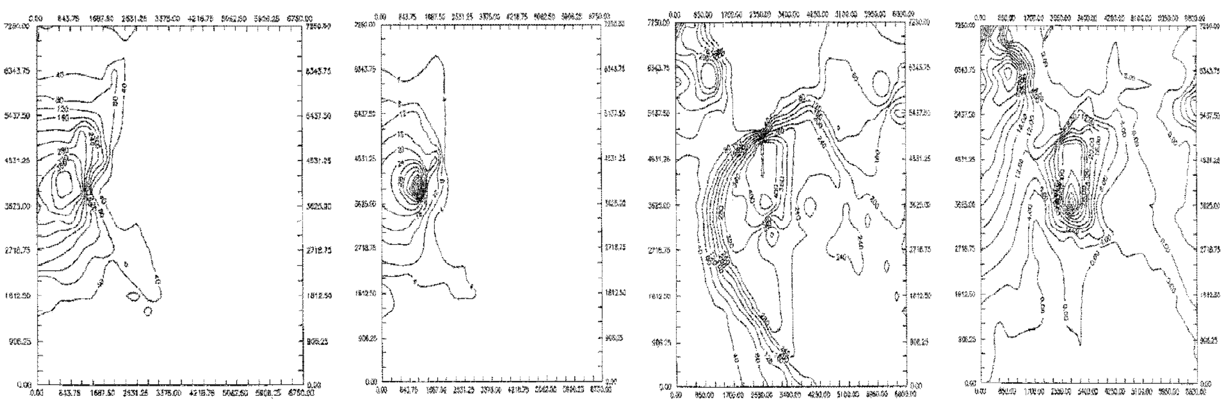
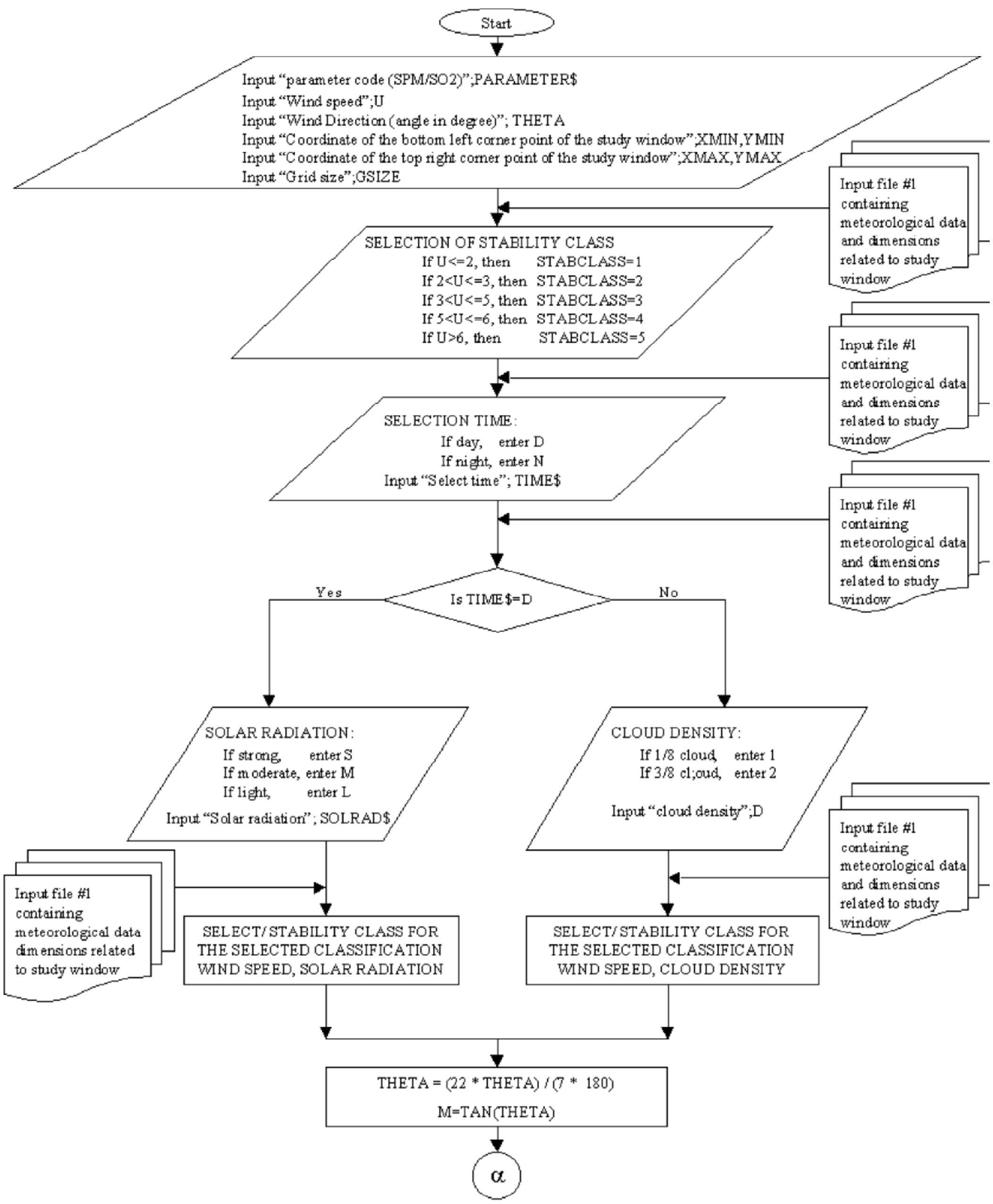
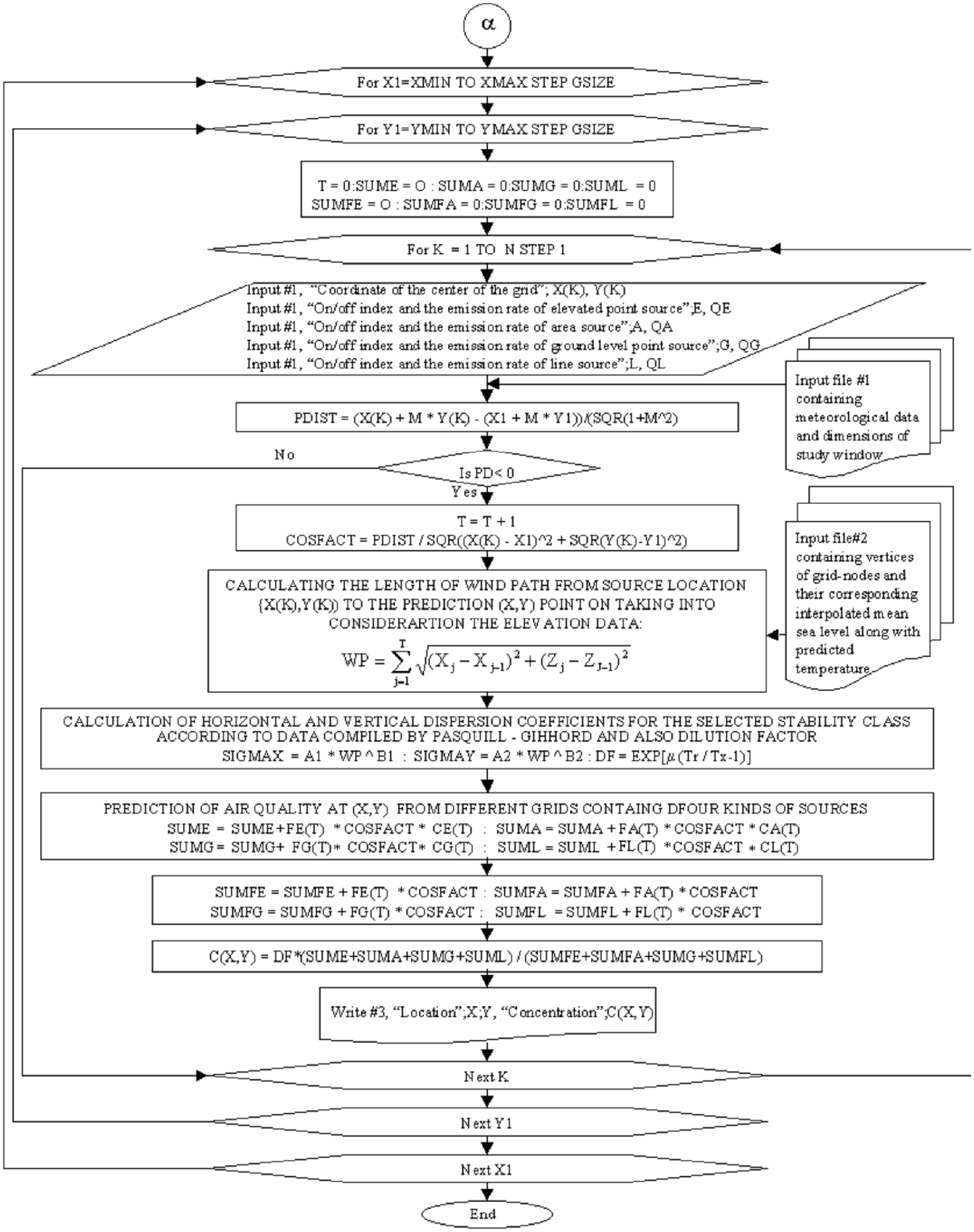


**Figure 6: Dispersion of air quality in the Munidih and Jamadoba Coal Washery complexes of the second & third sub-windows of the study area in summer season.**

## Development of Computer Program for air quality prediction



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## 4. CONCLUSIONS

In this paper, the computer simulation modeling have been developed from the present study which are common to find the solution for environmental problems concerning with air pollution. We have also developed an algorithm for air quality prediction. If the models would be applied in some other areas and subsequently validated, they could be used as universal models.

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